Evaluation of a School-Based Intervention Designed to Improve Health-Related Fitness in Adolescent Boys from Schools in Low-Income Communities: The 'Active Teen Leaders Avoiding Screen-time' (ATLAS) Cluster Randomised Controlled Trial

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B Teaching / B Health and Physical Education (Hons)

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Statement of Originality

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university of other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's digital repository, subject to the provisions of the Copyright Act 1968.

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Jordan J. P. Smith Date: 04/02/15

Thesis by Publication

I hereby certify that this thesis is in the form of a series of published papers of which I am a joint author. I have included as part of my thesis a written statement from each co-author, endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications.

……………………………………………...

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Conflict of Interest

The ATLAS cluster randomised controlled trial was funded by an Australian Research Council Discovery Grant (DP120100611). This sponsor had no involvement in the research process, including the drafting of this thesis or the manuscripts contained herein. This trial has been registered with the Australian and New Zealand Clinical Trials Registry (ACTRN 12612000978864). Jordan Smith was supported by a University of Newcastle postgraduate scholarship.

Publications and Presentations Arising from this Thesis

This thesis is comprised of six research papers, all of which have been published in peer-reviewed journals. As seen below, I was the lead author on four of the included papers and appear as a co-author on the remaining two papers.

Manuscripts published in peer-reviewed journals

1. **Smith JJ**, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sports Medicine*. 2014; 44(9), 1209-1223.

2. Lubans DR, **Smith JJ**, Harries SK, Barnett L, Faigenbaum AD. Development, test-retest reliability and construct validity of the Resistance Training Skills Battery. *Journal of Strength and Conditioning Research*. 2014; 28(5): 1373-1380.

3. **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: An obesity prevention intervention for adolescent boys from schools in low-income communities. *Contemporary Clinical Trials*. 2014; 37(1): 106-119.

4. **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescent boys in low-income communities. *Pediatrics*. 2014; 134(3): e723-e731.

5. Lubans DR, **Smith J**, Skinner G, Morgan PJ. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Frontiers in Public Health*. 2014; 2(42): 1-11.

6. **Smith JJ**, Morgan PJ, Plotnikoff RC, Stodden D, Lubans DR. Mediating effects of resistance training skill competency on health-related fitness and physical activity: The ATLAS cluster randomised controlled trial. *Journal of Sports Sciences*. 2015. (In press).

Conference abstracts: Published in conference proceedings or peer-reviewed journals

The following conference abstracts encompass two national and two international conferences. As shown below, I personally presented at three of the four conferences. Each of these presentations aligns with the research included within this thesis.

1. **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Improving the health-related fitness and movement skills of adolescent boys from low-income communities: The ATLAS cluster RCT. *Oral presentation at the National Physical Activity Conference.* Canberra, Australia; October 15-18, 2014.

2. Lubans DR, **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally K, Salmon J, Okely AD, Skinner G. Description and feasibility of a smartphone application to promote physical activity and reduce sedentary behaviour in adolescent boys. *Oral presentation at the annual meeting of the International Society for Behavioral Nutrition and Physical Activity*; San Diego, USA, May 21-24, 2014.

3. **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Increasing physical activity and improving muscular fitness through school sport: Rationale, methods and baseline findings from the ATLAS program for adolescent boys. *Oral presentation at the International Association for Physical Education in Higher Education (AIESEP) world congress*. Auckland, New Zealand; February 10-13, 2014.

4. Babic M, **Smith JJ**, Harries S, Barnett L, Faigenbaum AD, Lubans DR. Development of a resistance training skills test for school-based research and practice. *Poster presentation at the International Association for Physical Education in Higher Education (AIESEP) world congress*. Auckland, New Zealand; February 10-13, 2014.

5. **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Lubans DR. Group randomized controlled trial of the Active Teen Leaders Avoiding Screen-time (ATLAS) obesity prevention intervention for adolescent boys living in low-income communities. *Oral presentation at the Australasian Society for Behavioural Health and Medicine 10th annual scientific conference*. Newcastle, Australia; February 6-8, 2013.

Additional Publications and Presentations Arising from my PhD Candidature

Prior to commencing my PhD, I worked on the Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) group randomised controlled trial; a fundamental movement skills intervention for primary schools in low-income communities. Due to my intellectual and practical contributions, I was invited to contribute as a co-author on a publication relating to this research project. Throughout my candidature I also contributed to a number of additional publications. The following publications are consistent with my research focus. However, they sit aside from the research included within this thesis and were therefore not included. Details of the additional publications and conference presentations to which I contributed are listed below.

Additional publications

1. Barnett L, Reynolds J, Faigenbaum AD, **Smith JJ**, Harries S, Lubans DR. Rater agreement of a test battery designed to assess adolescents' resistance training skill competency. *Journal of Science and Medicine in Sport*. 2015; 18(1): 72-76.

2. Thorne HT, **Smith JJ**, Morgan PJ, Babic MJ, Lubans DR. Video game genre preference, physical activity and screen-time in adolescent boys from schools in low-income communities. *Journal of Adolescence*. 2014; 37(8): 1345-1352.

3. Owen KO, **Smith J**, Lubans DR, Ng JY, Lonsdale C. Self-determined motivation and physical activity in children and adolescents: A systematic review and meta-analysis. *Preventive Medicine*. 2014; 67: 270-279.

4. Lubans DR, Lonsdale C, Plotnikoff RC, **Smith J**, Dally K, Morgan PJ. Development and evaluation of the Motivation to Limit Screen-time Questionnaire (MLSQ) for adolescents. *Preventive Medicine*. 2013; 57(5): 561-566.

5. Lubans DR, Morgan PJ, Weaver K, Callister R, Dewar DL, Costigan SA, Finn TL **Smith J**, Upton L, Plotnikoff RC. Rationale and study protocol for the Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) group randomized controlled trial: A physical activity and fundamental movement skills intervention for primary schools in low-income communities. *BMC Public Health*. 2012; 12(1): 427.

Additional conference presentations

1. Lonsdale C, Owen K, **Smith J**, Lubans DR. Motivation and physical activity in children and adolescents: A systematic review and meta-analysis of evidence from studies framed by self-determination theory. *Poster presentation at the Asics Conference of Science and Medicine in Sport*. Phuket, Thailand; October 22-25, 2013.

2. Lubans DR, Lonsdale C, Morgan PJ, **Smith J**, Dally K, Plotnikoff RC. Instrument development and initial validity for a scale to measure adolescents' motivation to limit their screen time. *Oral presentation at the Australasian Society for Behavioural Health and Medicine 10th annual scientific conference*. Newcastle, Australia; February 6-8, 2013.

3. **Smith JJ**, Morgan PJ, Saunders K, Lubans DR. Improving physical self-perception in adolescent boys from disadvantaged communities: Psychological outcomes from the PALs intervention. *Oral presentation at the 4th International Congress on Physical Activity and Public Health, National Physical Activity Conference*, Sydney, Australia; October 31-November 3, 2012.

4. Weaver K, Lubans D, Morgan P, Callister R, Dewar D, Finn T, **Smith J**, Plotnikoff, R. Rationale and intervention description of the Supporting Children's Outcomes using Rewards, Exercise and Skills physical activity intervention. *Poster presentation at the 4th International Congress on Physical Activity and Public Health, National Physical Activity Conference,* Sydney, Australia; October 31-November 3, 2012.

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List of Abbreviations

ASAQ	Adolescent Sedentary Activity Questionnaire
ATLAS	Active Teen Leaders Avoiding Screen-time
BMI	Body Mass Index
CI	Confidence Intervals
cm	Centimetres
CONSORT	Consolidated Standards of Reporting Trials
CRF	Cardiorespiratory Fitness
CVD	Cardiovascular Disease
DEC	Department of Education and Communities
ICC	Intra-class Correlation Coefficient
kg	Kilogram
m	Metre
MF	Muscular Fitness
MVPA	Moderate-to-Vigorous Physical Activity
N	Number
NSW	New South Wales
p	Probability (statistical significance level)
PE	Physical Education
RCT	Randomised Controlled Trial
RT	Resistance Training
RTSB	Resistance Training Skills Battery

RTSQ	Resistance Training Skill Quotient
SCT	Social Cognitive Theory
SD	Standard Deviation
SDT	Self-Determination Theory
SEIFA	Socio-Economic Indexes for Areas
SES	Socioeconomic Status
SPANS	Schools Physical Activity and Nutrition Survey
STROBE	Strengthening Reporting of Observational Studies in Epidemiology
SSB	Sugar-Sweetened Beverages
WC	Waist Circumference
WHO	World Health Organisation

Operational Definitions

Term	Definition
Adolescent	In this thesis, the term adolescent (or adolescence) refers to a young person during the period from the onset of puberty through to the age of legal adulthood. Although puberty may begin earlier, this term will typically be used to describe a young person in secondary school (aged 11 to 18 years).
Body composition	Body composition refers to the relative contribution of different body tissues to total body mass, for example the percentage of body mass comprised of adipose or 'fat' tissue. Within this thesis, the terms 'overweight' and 'obese' - derived from body mass index (i.e., Weight [kg] / Height $[m]^2$) - will be used to indicate a sub-optimal body composition (i.e., a high body fat percentage) (1).
Cardiorespiratory fitness	Cardiorespiratory fitness, also known as cardiovascular endurance, aerobic fitness and maximal aerobic power, refers to the capacity of the cardiovascular and respiratory systems to sustain prolonged bouts of physical activity (2, 3).
Child	In this thesis, the term child refers to a young person aged 5-11 years and will typically be used to describe a young person in primary school.
Health-related fitness	Health-related fitness refers to the components of physical fitness with recognised links to health. The health-related fitness components are body composition, cardiorespiratory endurance, muscular strength, muscular endurance, and flexibility (2).
Muscular fitness	Muscular fitness refers to the capacity of the musculoskeletal system to generate force maximally (i.e., muscular strength), and quickly (i.e., muscular power), or to perform repeated contractions under sub-maximal load (i.e., local muscular endurance) (2, 4).
Physical activity	Physical activity refers to any bodily movement produced by skeletal muscles which results in an increase in energy expenditure beyond that of resting levels (2).
Resistance training	Resistance training (RT) refers to a specialised method of conditioning, using a variety of resistive loads, aimed at achieving improvements in muscular fitness, health, and sports performance (5).
School sport	In this thesis, school sport refers to the period of the school week allocated to compulsory physical activity. In Australian public schools, time for organised sport is provided on a mandatory basis to junior school students. School sport may occur in a variety of formats (6), but also occurs in addition to regular physical education (PE) lessons.

Screen-time	Screen-time refers to the use of small screen devices, such as television, DVDs, personal computers and laptops, video gaming consoles and hand-held gaming devices, smartphones, and tablets for the purposes of entertainment. This term does not include screen use for the purposes of education.
Sugar-sweetened beverages	The term sugar-sweetened beverages (SSBs) refers to carbonated soft drinks (i.e., soda), cordials, refined fruit juices, flavoured milk, sports drinks and caffeinated energy drinks.

Thesis Abstract

Background

Growing concerns over obesity, physical inactivity, and worsening levels of physical fitness among youth have led to a proliferation of school-based intervention studies in recent years. School-based programs aimed at increasing physical activity and fitness, and preventing obesity have demonstrated promise, but results have been inconsistent and short-term. While there is evidence to suggest that previous programs have been less effective for adolescents, there are also relatively few interventions that have been evaluated among this group. Furthermore, many previous interventions have been limited by poor methodological quality. Based on the limited success of previous programs, it has been suggested that future interventions should be directed at specific sub-groups of the population (e.g., males or females). Indeed, there are clear sex differences in regards to key health behaviours (e.g., physical activity, recreational screen-time, and sugar-sweetened beverage [SSB] consumption), suggesting that intervention approaches should be differentiated for boys and girls. It has also been recommended that interventions be evaluated among those most at risk of future ill-health. Youth living in low-income communities are disproportionately affected by poor health outcomes. Consequently, there is a strong rationale for targeted intervention approaches among this population. Finally, considering the recognised links between physical fitness and health outcomes, attempts to engage youth through innovative and theoretically driven physical activity and fitness programs are warranted.

Objectives

This thesis-by-publication presents a series of studies, which aim to address a number of gaps within the current evidence base. The principal focus of this thesis is the development and evaluation of the ATLAS *(Active Teen Leaders Avoiding Screen-time)* cluster randomised controlled trial (RCT), a school-based program aimed at improving health-related fitness and key health behaviours among adolescent males attending schools in low-income communities. Given emerging evidence of the importance of muscular fitness and movement skill competence for achieving and maintaining good health, this thesis also presents a series of studies aimed at investigating key secondary aims related to these topics. Considering the chronology of the research included within this thesis, and the importance of these studies for providing context to the Primary aim, *Secondary aims 1 and 2* are presented first. The *Primary aim* of this thesis and the remaining secondary aims are then presented, as listed in the order below.

Secondary aim 1: To systematically review the evidence base regarding the health-benefits of muscular fitness for children and adolescents.

A systematic literature search of six electronic databases was conducted. Cross-sectional, longitudinal and experimental studies that quantitatively examined the association between muscular fitness and health outcomes among youth populations were included. In total, 110 studies encompassing six health outcomes were included in the review. Meta-analyses were conducted to determine the pooled effect size if at least three studies reported standardised coefficients. Included studies generally demonstrated moderate to low risk of bias. Strong evidence was found for an inverse association between muscular fitness and total and central adiposity, and cardiovascular disease and metabolic risk factors. Strong evidence was also found for a positive association between muscular fitness and bone health and self-esteem. The evidence for an association between muscular fitness and musculoskeletal pain and cognitive ability was inconsistent or uncertain.

Secondary aim 2: To develop and evaluate a test battery for assessing adolescents' resistance training (RT) movement skill competency.

The aim of this study was to describe the development and assess test-retest reliability and construct validity of the Resistance Training Skills Battery (RTSB) for adolescents. The RTSB provides an assessment of resistance training skill competency and includes six exercises (i.e., body-weight squat, push-up, lunge, suspended row, standing overhead press and front support with chest touches). A convenience sample of adolescents completed the RTSB on two occasions separated by seven days. Participants also completed the handgrip strength, timed push-up and standing long jump tests to assess the construct validity of the RTSB. The RTSB can reliably rank participants in regards to their resistance training competency and has the necessary sensitivity to detect small changes in resistance training skill proficiency. Finally, the RTSB was found to be an independent predictor of muscular fitness, providing preliminary evidence for construct validity.

Primary aim: To evaluate the effects of the ATLAS cluster RCT on health-related fitness and RT movement skill competency among adolescent boys attending schools in low-income communities.

The primary aim of this thesis investigated whether participants randomised to the ATLAS intervention group demonstrated more favourable changes in body composition, muscular fitness and RT movement skill competency, compared with a control group. The ATLAS intervention was evaluated using a cluster RCT in 14 secondary schools located in low-income communities of New South Wales, Australia. In total, 361 adolescent boys were assessed at baseline and were randomised at the school level to the intervention or control group. The boys were reassessed 8 months later, following the conclusion of the program. Analyses followed intention-to-treat principles. There were no significant intervention effects for body composition (i.e., body mass index [BMI], waist circumference, or percent body fat), or for maximal strength (i.e., hand grip dynamometry). However, compared to boys in the control condition, intervention boys demonstrated greater muscular endurance (i.e., push-up repetitions) and RT skill competency at 8-month follow-up.

Secondary aim 3: To evaluate the effectiveness of the ATLAS intervention on adolescent boys' physical activity, screen-time, and sugar-sweetened beverage consumption.

The ATLAS intervention also aimed to address a number of key weight-related behaviours. At 8-month follow-up, adolescent boys randomised to the intervention condition reported less recreational screen-time and SSB consumption, compared with boys in the control group. No significant intervention effects were found for accelerometer-assessed total physical activity (i.e., counts per minute) or moderate-to-vigorous physical activity. Compliance with physical activity monitoring was poor.

Secondary aim 4: To describe the development and implementation of a smartphone application designed to promote physical activity and reduce screen-time among adolescent boys.

The ATLAS smartphone app was developed to complement the ATLAS intervention and replace paper-based resources. The app was used for physical activity monitoring, goal setting, and assessment of RT technique. Further, the app provided tailored motivational messages throughout the intervention period. Participants completed process evaluation questionnaires and focus groups, which included questions on the acceptability and usage of the ATLAS app. Seventy percent of boys in the intervention group reported having access to a smartphone or tablet device. Focus group findings suggested that boys' engagement with the smartphone app was limited. Barriers to the implementation and evaluation of the app included limited access to smartphone devices, technical problems with the push notifications, lack of access to usage data and the challenges of maintaining participants' interest in using the app.

Secondary aim 5: To examine the potential mediating effects of RT movement skill competency on health-related fitness and physical activity.

RT movement skill development was a key component of the ATLAS intervention. Three separate multi-level mediation models were analysed to investigate the potential mediating effects of RT skill competency on boys' body composition, muscular fitness and physical activity using a product-of-coefficients test. Analyses followed the intention-to-treat principle. Improvements in RT skill competency significantly mediated the effect of the intervention on percent body fat and muscular fitness. No significant mediated effects were found for physical activity.

Statement of Contribution

As the sole PhD student working on the ATLAS cluster RCT, I was closely involved in the design, implementation and evaluation of the study. Further, I liaised closely with the study project manager to manage the host of logistical and administrative tasks required to successfully complete the project. A summary of my contribution to this study is provided below.

Program development

In close collaboration with my supervisors, I was involved in the design and development of a number of components of the ATLAS intervention. Specifically, I was responsible for the development of the project logo and the design of the smartphone application and website used within the program. In addition, I worked with my supervisors to design the components and structure of the school-based physical activity sessions and the two professional learning workshops for teachers. Finally, I was personally responsible for the development of a number of program resources, including the teacher handbook, a screen-time blog page for parents, circuit cards used during the school physical activity sessions, and the parental newsletters.

Ethics approval

I was involved in the drafting of the Principal, teacher, and student/parent information and consent letters. Further, I was personally responsible for drafting and submission of the University (H-2012-0162) and Department of Education and Communities (2012121) ethics applications and ethics variations.

Study measures

I worked in collaboration with my supervisors to decide on the eligibility screening criteria and outcome measures used in the ATLAS study. In addition, I was closely involved in the design and evaluation of a number of measures that were developed for use in this study. Specifically, I contributed to the design and evaluation of the: (i) Resistance Training Skills Battery (RTSB) for adolescents; and (ii) Motivation to Limit Screen-time Questionnaire (MLSQ). These measures have since been published in the peer-reviewed literature (7-9).

Recruitment

I was personally responsible for the identification and recruitment of eligible schools and students. I compiled the list of schools that satisfied our eligibility criteria and contacted the principals at each of these schools to request their involvement in the study. Where necessary, I met with the school Principal and/or Head Teacher of the Physical Education department to discuss the study. Prior to the commencement of the program, I attended each of the study schools to deliver the eligibility screening questionnaire to all male students in the targeted year group. I personally processed all of the eligibility screening data and compiled the lists of eligible students for each school. In addition, I liaised with the cooperating teachers at the study schools to deliver information sessions to eligible students and to distribute and collect student consent forms.

Data collection, entry and management

During my PhD candidature, I was personally responsible for the development and maintenance of the database for the ATLAS study. Prior to the data collection period, I led a comprehensive training session for the research team to ensure that all assessors understood the assessment protocols. In cooperation with the project manager, I was involved in the organisation of the data collection periods, which were conducted at each of the study schools. In addition, I attended each of the study schools to assist the research team with the collection of baseline and follow-up data. Following data collection, I was responsible for entering, cleaning and de-identifying all data. I performed rigorous data checking procedures to ensure the accuracy of collected data.

Program implementation

I was involved in a number of key aspects of the intervention delivery. First, I was personally involved in the delivery of the two professional learning workshops for teachers, which involved both theoretical and practical activities. In addition, I attended each of the study schools to deliver the researcher-led seminars for students. These interactive seminars were conducted at the start of the program to inform study participants of the key aims and features of the intervention. The first physical activity session at each study school was delivered by a member of the research team, for the purposes of modelling the correct delivery of these sessions. While being observed by a participating teacher, I personally delivered the first physical activity session at a number of intervention schools. Finally, I was personally involved in conducting the observations of the school physical activity sessions. These observations were conducted to assess intervention fidelity and to provide constructive feedback to teachers regarding the session structure and their compliance with the SAAFE teaching principles, which were made familiar to teachers during the professional learning workshops.

Data analysis

With assistance from my primary supervisor, I completed all of the data analysis within the publications in which I am listed as first author (excluding the power calculation in Chapter 5). This included inter-rater reliability analysis and meta-analysis (Chapter 3), scale reliability analysis (Chapter 5), linear mixed model analysis (Chapter 6), and multi-level mediation analysis (Chapter 8).

Presentation of study results and awards

During my PhD candidature I presented study findings at two international and two national conferences. Most recently, my abstract was shortlisted for the ‘Best new investigator’ award at the ‘Be Active’ National Physical Activity conference held in Canberra, Australia in October 2014. I was also a University finalist in the 2012 ‘3 minute thesis’ public speaking competition, having placed first and second at the School of Education and Faculty of Education and Arts levels, respectively. In addition, I was awarded first place in the 2012 Faculty of Education and Arts poster competition (early candidature division).

CHAPTER 1: INTRODUCTION

1.1 Overview

This chapter begins by providing a general overview of the role of physical activity for population health and a brief discussion of the impact of school-based physical activity/fitness interventions. Specifically, this section provides an overview of the rationale for school-based intervention approaches to improve physical activity and fitness and prevent obesity, and outlines the main limitations of previous intervention research. In addition, a rationale for the provision of muscle-strengthening physical activities, such as resistance training (RT), within school-based interventions is provided. In the next section, the potential importance of RT movement skill proficiency is discussed and current measurement issues are outlined. Finally, the chapter provides an overview of the Physical Activity Leaders (PALs) pilot study. The PALs study informed the development of the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) study, on which this thesis is based.

1.2 Background and Context

1.2.1 Physical inactivity: A significant public health challenge

Since the seminal work of Morris and colleagues (10), research into the health benefits of physical activity has provided overwhelming evidence supporting 'movement' as an integral component of healthy living (11). In addition to the recognised physiological health benefits, physical activity has also been found to be important for promoting positive psychosocial health (11). Further, physical activity participation is central to the development of adequate cardiorespiratory fitness (CRF), muscular fitness and a healthy body composition (12), all of which are linked to chronic disease risk (13). Despite these benefits, many people fail to accrue the amount of physical activity needed to maintain good health (14), resulting in what has been termed a 'pandemic' of inactivity (15). Physical inactivity is now one of the leading causes of premature death worldwide, accounting for approximately 5.3 million deaths annually (16). Although traditionally considered to be an issue only for industrialised Western societies, recent data show that the health impacts of physical inactivity have become increasingly prevalent within developing nations (17-20). Clearly, physical inactivity represents one of the most significant public health challenges facing societies worldwide.

Presently, there is a clear gap between the volume and intensity of physical activity typically achieved by young people, and that demanded by their physiology for optimal health. For example, global estimates suggest that only one in five adolescents meet current physical activity guidelines (14). In light of this, it is not surprising that approximately 25% of western youth are now classified as overweight or obese (21). The economic and human cost of chronic disease emphasises the need for preventive interventions, particularly during periods in which health behaviours may still be malleable. Physical activity levels decline substantially during adolescence (22). However, this is also a period in which many lifelong health-related behaviours are being established (23). Consequently, adolescence can be considered a ‘critical period’ for establishing sustainable health behaviours, and is thus an important target period for health promotion efforts (24).

1.2.2 The school setting for preventive health interventions

1.2.2.1 Why schools?

Schools have been identified as important settings for health promotion as they possess trained staff, facilities, equipment, and most importantly have access to the target population for a substantial portion of the day (25). Further, the existing systems and infrastructure within these settings may enable broader implementation and dissemination of successful trials, which is critically important from a population health perspective (26). Growing concerns over youth obesity and inactivity have led to a proliferation of school-based intervention studies in recent years, albeit predominantly within primary/elementary schools (27). Despite the popularity of school-based approaches, the findings of previous research have been limited by a number of methodological shortcomings, including inadequate study designs (e.g., uncontrolled trials), small sample sizes, invalid and/or unreliable outcome measures, and short-term follow-up assessments (28, 29). For example, despite screening studies based on aspects of methodological quality (i.e., randomised study design, all attending children invited, and minimum 12-week program), the most recent Cochrane review of school-based physical activity programs found the majority of included studies demonstrated at least a moderate risk of bias (29). While there have been significant advances within the field in recent years (29), our understanding of the most feasible, efficacious and cost-effective intervention approaches is still developing. There remains a clear need for well-designed, high-quality trials with extended follow-up periods to determine the efficacy of school-based approaches for promoting physical activity and improving related health outcomes, particularly among adolescents (26).

1.2.2.2 A case for gender targeting

Previous school-based obesity prevention interventions have demonstrated promise but results have been, at best, mixed. Although evidence is limited (26, 29), it has been suggested that previous programs have been more effective for females compared with males (28). Indeed, a number of school-based interventions have found sex to be a moderator of intervention effects (30-32). The reasons for these gender differences are unclear. However, there is evidence to suggest that the determinants of physical activity differ between sexes (33), and population surveys clearly show significant sex differences in other important weight-related behaviours among youth (e.g., recreational screen-time, sugar-sweetened beverage [SSB] consumption) (34, 35). Consequently, it may be that previous programs have failed to recognise and address these unique gender differences. It is surprising that few school-based interventions appear to have addressed the needs and preferences of boys and girls within their programs. For example, the most recent Cochrane review of child and adolescent obesity prevention interventions located just four interventions targeting individual sexes (26), only one of which specifically targeted adolescent males (36). Considering the limited effectiveness of previous obesity prevention interventions among adolescents (26), and the lack of evidence regarding the effectiveness of single-sex programs (particularly for males), there appears to be a case for evaluating gender-targeted intervention approaches. Indeed, the testing of "various gender-specific strategies within the school setting" (p. 24) was recommended in a recent review of school-based physical activity programs (29). High quality trials investigating the efficacy of gender-targeted approaches are clearly warranted.

1.2.2.3 Targeting muscular fitness

RT refers to a specialised method of training, using a variety of resistive loads, intended to improve health, muscular fitness and sports performance (5). Although the traditional view of RT may be the use of free weights or machines in a gym setting, RT also includes the use of elastic resistance bands, medicine balls, sand bags, or an individual's own body weight (37). Further, RT (particularly bodyweight RT) can be completed almost anywhere. Despite early calls for youth to avoid RT, accumulating evidence over the past few decades has clearly demonstrated that supervised and developmentally appropriate RT programs are a safe and effective way to improve health, fitness and sports performance (38-40). Interestingly, despite early concerns that youth participation in RT may lead to injury, evidence now suggests that a preparatory RT program may actually be protective against the risk of sports-related injury among young people (40). In addition, RT has been found to be an effective exercise modality for the prevention and treatment of youth obesity

(41, 42), and has shown favourable short-term effects on musculoskeletal and cardiovascular health (43-45). In fact, combined aerobic and resistance training has been shown to be more effective for improving body composition among obese adolescents than aerobic training alone (46). Finally, RT may aid in the development of sports-related motor skills (i.e., jumping, running and throwing) (47), enabling more successful experiences in a range of other physical activity contexts. Clearly, there is strong support within the research literature for the promotion of RT among children and adolescents.

The effectiveness of school-based interventions for increasing physical activity and fitness, and preventing obesity is discussed in greater detail in Chapter 2. However, to provide context to this thesis and to highlight its unique focus, the following rationale is provided. Most previous school-based physical activity programs have focused on delivering aerobic physical activities, or have directly targeted improvements in CRF (29). Although the long-term impact of these interventions remains unclear (48), there is sufficient evidence to conclude that school-based approaches can improve physical activity behaviour and CRF (29, 49). Clear evidence for the beneficial effects of CRF (3, 13) supports the continued inclusion of aerobic physical activities within youth physical activity and fitness programs. However, in recent years research examining the role of 'muscular fitness' in the aetiology of disease has become more prominent within the physical activity and public health literature (50, 51). As described by Warburton and colleagues (51), there has been "a shift in focus in research related to the health benefits of activities that tax the musculoskeletal system" (p. 805). Indeed, muscular fitness has emerged as an important and unique contributor to health status for both adults (52) and youth (53). Notably, a systematic review of prospective studies among youth reported strong evidence of an inverse association between improvements in muscular fitness and changes in overall adiposity (13). Therefore, in addition to aerobic activities, there is a strong rationale for the promotion of activities designed specifically to develop muscular fitness among young people.

Despite the recognised benefits of muscular fitness, very few school-based interventions have focused on the delivery of muscle-strengthening physical activities such as RT (29). As a result, there is a dearth of evidence regarding the feasibility, acceptability, and effectiveness of this type of exercise for improving health when delivered in the school setting. RT may be an appealing activity particularly for adolescent males, as concepts of strength and muscularity may be highly salient among this group (54). Furthermore, this type of exercise may be an attractive physical activity option for overweight and obese youth who often struggle physically with aerobic activities (55). In fact, owing to greater fat-free mass and hence typically higher absolute strength (56), RT may be one of the few physical activities in which overweight and obese youth can outperform their leaner peers (55). This is an important point in light of the poorer physical self-concept typically displayed by overweight and obese youth (57), and the potential impact of these negative self-perceptions on physical activity participation (58). Participation in RT may enable overweight and obese youth to improve their self-efficacy (55), thus promoting lifelong engagement in physical activity. Considering that obesity tracks from youth into adulthood (59), and that overweight and obese youth are at higher risk of a range of deleterious health outcomes (60), finding health-enhancing activities to engage this group is particularly important.

1.2.3 Resistance training movement skill competency

A large body of empirical evidence has demonstrated the importance of fundamental movement skill (FMS) competency (i.e., locomotor, stability, and object control skills) for physical activity participation and related health outcomes (61). Conversely, the associations between RT movement skill competency and psychosocial, health and fitness outcomes are currently unknown. It is recommended RT programs for novice trainers begin gradually, with the initial focus on developing correct movement technique (62). This recommendation is based on concerns for safety, as training progressions may result in injury if exercise technique is poor. Recently published international guidelines for youth RT clearly state “it is vital that the fundamentals of technical competency are prioritised at all times” (p. 6), and that programs should “employ a range of exercises which are designed to…enhance overall fundamental motor skill competency” (p. 6) (37). However, despite the recognised importance of basic movement skill competency for this mode of exercise, there is limited information within the extant literature on what constitutes ‘skilled’ performance. Furthermore, there is currently no test battery for quantifying proficiency in RT skills among school-aged youth.

The closest example of a RT movement skill test is the Functional Movement Screen (63, 64), an instrument designed primarily for use with athletic populations. The Functional Movement Screen assesses stability and mobility skills, with the view that early screening can identify and prompt correction of biomechanical deficits which may impair sports performance and lead to injury (63, 64). Although this instrument does quantify movement skill competency, the included exercises may not accurately reflect the range of skills considered to form the foundation for more complex RT movements. Consequently, the Functional Movement Screen may be an inadequate proxy for RT movement skill competency. From a research perspective, a valid and reliable assessment tool for quantifying RT skill competency would help to elucidate the potential associations between movement skill development and health-related outcomes. For practitioners, such an instrument could be used to evaluate the efficacy of school- and community-based RT programs, and could enable the provision of valuable process-based feedback, which may aid in the progression of novice trainers. Considering the limited experience most youth are likely to have had with RT, and that perceptions of competence are a key driver of motivation (65, 66), developing proficiency in RT movement skills may remove a considerable barrier to participation and facilitate autonomous forms of motivation for this activity.

1.2.4 The Physical Activity Leaders (PALs) pilot study

1.2.4.1 Study description

The PALs pilot study was a multi-component school-based program designed to improve health-related fitness, health behaviours, and psychological wellbeing among low-active adolescent boys attending schools in economically disadvantaged communities (67). PALs was the pilot study preceding the ATLAS cluster randomised controlled trial (RCT), on which this thesis is based. The PALs intervention was developed in reference to Bandura's Social Cognitive Theory (SCT) (68), and involved teacher-delivered school sport sessions (i.e., elastic tubing RT, exercise circuits, and boxing-style fitness activities), interactive researcher-led seminars, lunch-time physical activity mentoring sessions, physical activity and nutrition handbooks, and pedometers for physical activity monitoring. The PALs intervention was evaluated using a cluster RCT in four low-income secondary schools in the state of New South Wales (NSW), Australia. One hundred adolescent boys (n = 50 intervention, n = 50 control), that were either not participating in organised sport or were considered by their physical education (PE) teachers to be disengaged in PE lessons, participated in the program. The PALs intervention was delivered over 10 weeks and assessments occurred at baseline, three months (immediately post-intervention) and six months (follow-up).

1.2.4.2 Key findings

This program resulted in statistically significant intervention effects for BMI, BMI z-score, and body fat percentage (Cohen's d = 0.5 to 0.7), and small non-significant effects for muscular fitness (i.e., push-ups and sit-ups) (Cohen's d = 0.2 to 0.3) (67). Additionally, there were beneficial effects on psychological outcomes including physical self-perceptions (i.e., physical self-worth and perceived physical condition), RT self-efficacy, and the use of physical activity behavioural strategies (69). There were no significant intervention effects for pedometer measured physical activity or for fruit, vegetable or water intake. However, intervention boys did report a significant reduction in their consumption of SSBs (67).

1.2.4.3 Lessons learned from the PALs school-based intervention

PALs demonstrated that a program targeting ‘at risk’ adolescent boys in the school setting can have a positive impact on important markers of health and wellbeing. The strength of the effects for body composition suggested that RT is an effective exercise modality for improving this particular health outcome. Considering the focus on RT, the lack of statistically significant intervention effects for muscular fitness measures was surprising. However, there was a trend in favour of intervention boys, and failure to reach the threshold for significance may have been due to a lack of statistical power. Furthermore, the seven-stage sit-up test may lack sufficient sensitivity to detect small but meaningful changes in abdominal muscular strength. Further testing with a larger sample size and more appropriate outcome measures may help to further determine the effectiveness of this approach for improving boys’ muscular fitness.

The findings for RT self-efficacy suggest that a school-based RT program can positively influence adolescent boys’ confidence to participate in RT, which may have implications for long-term participation. Self-efficacy is a consistently supported correlate of physical activity behaviour across all ages (70). Therefore, improvements in RT self-efficacy may facilitate ongoing participation in this lifelong activity. However, it is unknown whether intervention boys in the PALs study improved their actual RT movement skill competency, or to what extent the development of movement skills may have facilitated improvements in study outcomes.

The null findings for most dietary outcomes in PALs may reflect the level of control adolescents have over many of their dietary choices. For example, the influence of parents on their children’s dietary choices (i.e., through food purchasing and meal preparation) may mean adolescents have little opportunity to improve their fruit and vegetable intake, regardless of their desire for change. Conversely, adolescents would be expected to have more control over their intake of discretionary foods and drinks such as SSBs. This argument is supported by the significant intervention effect for SSB intake. School-based approaches targeting individuals may have more of an impact on the consumption of discretionary foods, whereas improving other aspects of adolescents’ diets may require more intensive family-based interventions that also target parents. Dietary targets within school-based interventions should focus on those that can be realistically expected to change.

The approach used in PALs is potentially scalable, as the program was largely delivered during school hours by existing school personnel. Importantly, the equipment used in the PALs program (e.g., elastic band resistance devices, skipping ropes, and boxing gloves) was portable and therefore the program could be conducted in a range of locations within the school. Consequently, there was no need for a dedicated space with large amounts of fixed equipment to conduct the program. Space and equipment may be considerable logistical and financial barriers for the implementation of RT within schools (71), particularly during scheduled school sport when space is often limited. This program has demonstrated a feasible approach for the delivery of school-based RT. However, additional detailed process evaluation is needed to elucidate the practicality of this approach for broader implementation and dissemination. Furthermore, there is scope to test the effectiveness of this type of intervention on additional weight-related behaviours such as recreational screen-time. PALs was successful in achieving improvements in the primary outcomes (i.e., BMI and BMI *z*-score) and a range of important secondary outcomes. However, being a pilot study, the sample size was relatively small and the results were short-term. Further investigation on a larger scale with longer follow-up is therefore warranted.

1.3 Research Aims

1.3.1 Primary aim

The primary aim of this thesis is to evaluate the effects of the ATLAS cluster RCT on health-related fitness and resistance training (RT) movement skill competency among adolescent boys attending schools in low-income communities (Chapters 5 and 6).

1.3.1.1 Primary hypothesis

The primary hypothesis of this thesis is that, following the delivery of the ATLAS intervention, adolescent boys randomised to the intervention group will demonstrate favourable changes in: (1) body composition; (2) muscular fitness; and (3) RT movement skill competency, compared with a control group participating in usual practice.

1.3.2 Secondary aims

Secondary aims of this thesis are to:

1. Systematically review the evidence base regarding the health-benefits of muscular fitness for children and adolescents (Chapter 3);
2. Develop and evaluate a test battery for assessing adolescents' RT movement skill competency (Chapter 4);
3. Evaluate the effectiveness of the ATLAS intervention on adolescent boys' physical activity, screen-time, and sugar-sweetened beverage consumption (Chapters 5 and 6);
4. Describe the development and implementation of a smartphone application designed to promote physical activity and reduce screen-time among adolescent boys (Chapter 7); and
5. Examine the potential mediating effects of RT movement skill competency on health-related fitness and physical activity (Chapter 8).

1.4 Thesis Structure

1.4.1 Overview

This thesis begins with a summary of literature. Following this is a series of six interrelated research papers, five of which have been published or accepted for publication in peer-reviewed journals. The remaining paper is currently under review in a peer-reviewed journal. For more detailed information, see below. An overview of each chapter is now provided.

1.4.2 Literature review

Chapter 2 presents a review of the literature regarding weight-related behaviours and health-related fitness among adolescents, which is divided into three main sections. First, literature concerning the health benefits, prevalence and trends, and correlates of physical activity, screen-time, and SSB consumption among youth is reviewed. In the second section, a rationale for interventions targeting health-related fitness among adolescents from low-income communities is provided. Specifically, evidence on the determinants and consequences of poor health-related fitness during youth is reviewed. Further, the prevalence and global trends regarding these health outcomes are discussed. Evidence from school-based physical activity and obesity prevention interventions is reviewed, the limitations of past intervention research are outlined and opportunities for future investigations are identified. Finally, theories of behaviour change, more specifically Self-Determination Theory and Social Cognitive Theory, are discussed.

1.4.3 The health benefits of muscular fitness for children and adolescents

In Chapter 2, it is noted that a comprehensive review of studies investigating the associations between muscular fitness and health outcomes among youth populations has not yet been conducted. To address this, Chapter 3 presents the results of a systematic review and meta-analysis of studies examining the health benefits of muscular fitness during childhood and adolescence (*Secondary aim 1*). The study methodology, including the search strategy, eligibility criteria, data extraction procedure, and risk of bias assessment is described in detail. Furthermore, the findings of the review and meta-analyses are provided and recommendations for future research are outlined. This study has been published in the peer-reviewed journal *Sports Medicine*.

Citation: **Smith JJ**, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sports Medicine*. 2014; 44(9), 1209-1223.

1.4.4 Evaluation of a test battery designed to assess adolescents' resistance training movement skill competency

Previously, it was noted that a valid and reliable instrument for measuring RT movement skills has not yet been developed. To address this gap, Chapter 4 presents the development and evaluation of a test battery for assessing adolescents' proficiency in RT movement skills (*Secondary aim 2*). The Resistance Training Skills Battery (RTSB) provides an objective and quantitative assessment of RT skill competency by evaluating the performance of six foundational RT movements (i.e., squat, lunge, push-up, overhead press, front support with chest touches and suspended row). The process for developing the RTSB is described in detail and results for the test-retest reliability and construct validity of the RTSB among a sample of adolescents are provided. The results of this study have been published in the peer-reviewed *Journal of Strength and Conditioning Research*.

Citation: Lubans DR, **Smith JJ**, Harries SK, Barnett L, Faigenbaum AD. Development, test-retest reliability and construct validity of the Resistance Training Skills Battery. *Journal of Strength and Conditioning Research*. 2014; 28(5): 1373-1380.

1.4.5 Study protocol for the ATLAS cluster RCT

Chapter 5 presents the rationale and study protocol for the ATLAS cluster RCT. ATLAS is an 8-month multi-component, school-based program designed to improve the health and wellbeing of economically disadvantaged adolescent males considered 'at-risk' of obesity. This chapter describes the rationale for the study, the theoretical basis of the program, and the selected intervention components. Furthermore, extensive detail regarding the study design, recruitment, power calculation, randomisation procedure, and chosen outcome measures is provided. This paper has been published in the peer-reviewed journal *Contemporary Clinical Trials*.

Citation: **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: An obesity prevention intervention for adolescent boys from schools in low-income communities. *Contemporary Clinical Trials*. 2014; 37(1): 106-119.

1.4.6 Evaluation of the ATLAS cluster RCT for adolescent boys from low-income communities

Chapter 6 details the main study findings of the ATLAS intervention (*Primary aim and Secondary aim 3*). ATLAS was evaluated using a two-arm cluster RCT, with eligible boys allocated at the school-level to either the ATLAS intervention group or a wait-list control group participating in usual practice. The effects of the intervention on body composition (BMI, waist circumference, percent body fat), muscular fitness (push-ups and hand grip strength), and weight-related behaviours (physical activity, screen-time and SSB consumption) are described. In addition, the results of secondary sub-group analyses are provided. This study has been published in the peer-reviewed journal *Pediatrics*.

Citation: **Smith JJ**, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescent boys in low-income communities. *Pediatrics*. 2014; 134(3): e723-e731.

1.4.7 Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys

Chapter 7 details the development and implementation of the ATLAS smartphone application ('app'), which was developed to support the delivery of the ATLAS school-based intervention (*Secondary aim 4*). The ATLAS smartphone app was used by study participants for physical activity monitoring, goal setting, and assessment of RT technique. Further, the app provided tailored motivational messages throughout the intervention period. Participants completed process evaluation questionnaires and focus groups, which included questions on the acceptability and usage of the ATLAS app. Barriers and challenges encountered in the development, implementation and evaluation of the app are described in detail. This paper has been published in the peer-reviewed journal *Frontiers in Public Health*.

Citation: Lubans DR, **Smith JJ**, Skinner G, Morgan PJ. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Frontiers in Public Health*. 2014;2:1-11.

1.4.8 Examining resistance training skill competency as a potential mediator of adolescent boys' health-related fitness and physical activity

Chapter 8 presents the results of a study examining the mediating effects of RT skill competency on health-related fitness and physical activity among adolescent boys participating in the ATLAS intervention (*Secondary aim 5)*. Three hypothesised mediation models were analysed to determine whether improvements in RT skill competency mediated the effect of the intervention on these study outcomes. Secondary analyses were conducted for boys initially classified as overweight or obese to explore potential mediating effects specifically among this 'at risk' sub-group. This paper is published in the peer-reviewed journal *Journal of Sports Sciences*.

Citation: **Smith JJ**, Morgan PJ, Plotnikoff RC, Stodden D, Lubans DR. Mediating effects of resistance training skill competency on health-related fitness and physical activity: The ATLAS cluster randomised controlled trial. *Journal of Sports Sciences*. 2015 (In press).

1.4.9 Ethics

Ethics approval for the study outlined in section 1.4.4 was obtained from the University of Newcastle Human Research Ethics Committee (H-2012-0162) and the Diocese of Maitland-Newcastle Catholic Schools Office. Ethics approval for the study described in sections 1.4.5, 1.4.6, 1.4.7 and 1.4.8 was obtained from the Human Research Ethics Committees of the University of Newcastle (H-2012-0162) and the New South Wales (NSW) Department of Education and Communities (2012121).

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

As shown in Figure 2.1, this chapter is divided into three main sections. First, the benefits of physical activity and the consequences of excessive recreational screen-time and sugar-sweetened beverage (SSB) consumption will be discussed. Furthermore, correlates of each of these behaviours drawn from the adolescent literature will be presented. In the second section, literature on the health consequences, determinants, trends and prevalence of poor health-related fitness among youth will be reviewed. Previous school-based intervention research will be critiqued and opportunities for future research will then be outlined. Finally, this chapter will provide an overview of health behaviour theories and more specifically, the utility of Self-Determination Theory (SDT) and Social Cognitive Theory (SCT) for guiding intervention research.

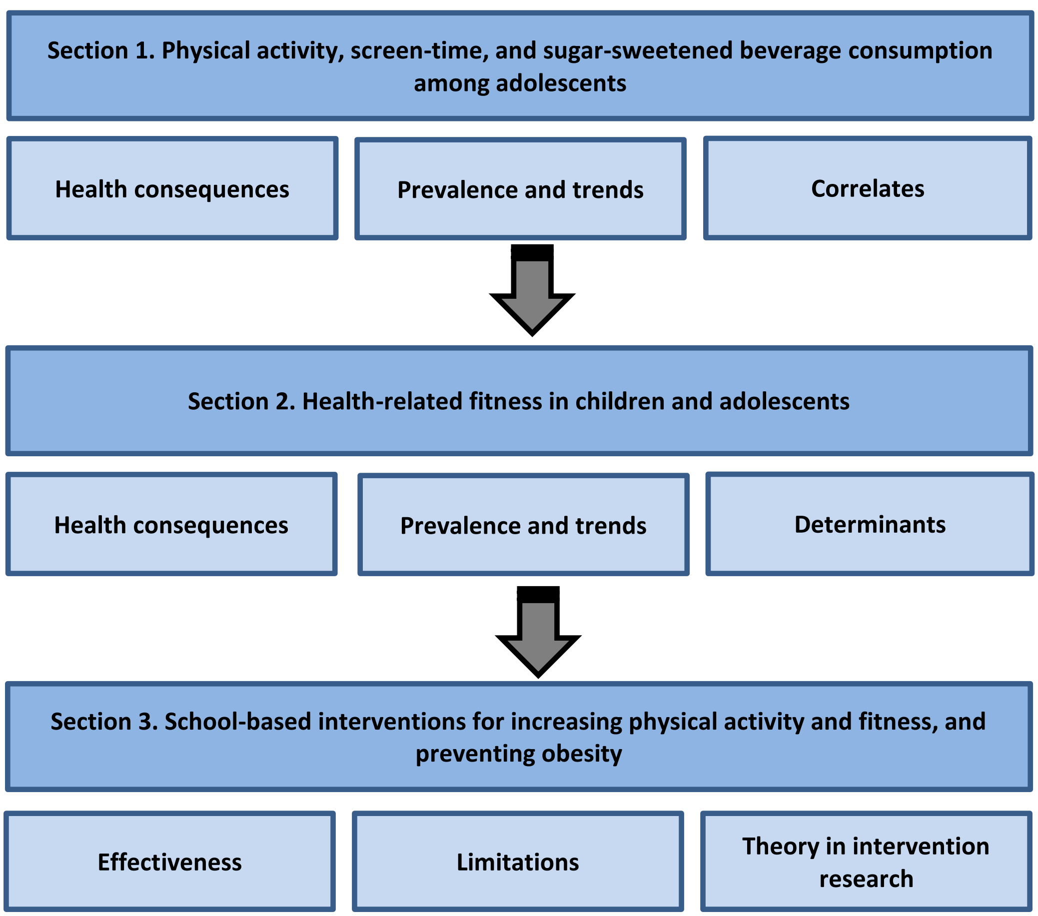

Figure 2.1 Schematic diagram of literature review

2.2 Adolescent health behaviours: Physical activity, screen-time and sugar-sweetened beverage consumption

2.2.1 Health consequences

2.2.1.1 Physical activity

Physical activity is associated with a host of physiological and psychosocial benefits in young people (72). Research shows that habitual physical activity during childhood and adolescence is protective against risk factors for cardiovascular disease (CVD) and Type II Diabetes (73-76), and is predictive of CVD risk markers in adulthood (77, 78). In addition, there is clear evidence of the importance of physical activity for preventing unhealthy weight gain (79), with the strongest associations found for activities of vigorous intensity (80-82). Prospective studies indicate that physical activity during adolescence is a poor predictor of adult adiposity (83), suggesting that the beneficial effects of physical activity are more immediate than long-term. While this may be true for adiposity, a large body of research has demonstrated the powerful and lasting influence of physical activity during childhood and adolescence on lifelong skeletal health (72). Impact and weight bearing activities in particular have been shown to increase bone mineral accrual in young people (84), which can result in reduced risk of fractures both during youth (85) and into adulthood (86). Participation in osteogenic activities around the pubertal growth spurt may be particularly important (87), as up to 35% of peak bone mineral density is achieved during this brief period (84). Intervention studies have demonstrated the value of resistance- and jumping-based physical activities for youth bone development (88), supporting the inclusion of 'muscle and bone strengthening' physical activities within current youth physical activity guidelines (89). Youth physical activity guidelines from four western countries and the World Health Organisation (WHO) can be seen in Table 2.1.

In addition to the physiological benefits, a growing body of evidence is demonstrating the importance of physical activity for positive psychological health (90). Although high quality evidence is sparse, research suggests that physical activity may reduce the risk of anxiety and depression, and may also aid in the treatment of these disorders (91, 92). Exercise trials in young people have also been found to result in short-term improvements in self-esteem (93), highlighting the importance of physical activity for psychological wellbeing. In addition, research has found positive effects of physical activity on cognitive functioning and academic achievement (90, 94), perhaps mediated through functional changes in the brain (95). Of the range of potential benefits of physical activity, these are perhaps the most poorly understood. Yet, improvements in these outcomes may have the greatest impact on lifelong health and flourishing. Mental health issues are thought to affect as many as one in five children and adolescents globally (96), and neuropsychiatric disorders currently account for the greatest proportion of disease burden among adolescents (97). These findings alone provide a strong rationale for promoting health-enhancing physical activity during childhood and adolescence.

2.2.1.2 Screen-time

Operationally defined, recreational screen-time refers to the use of small screen devices including television, DVD players, personal computers and laptops, video game consoles and hand-held gaming devices, smartphones, and tablets for the purposes of entertainment. The current generation of children and adolescents have unprecedented access to a wide range of electronic devices, resulting in ubiquitous consumption of screen media during leisure time (98). Current guidelines recommend that adolescents limit their recreational screen-time to less than two hours per day (89). However, most Australian adolescents exceed this recommendation (34). In recent years, increased research interest in this area has resulted in a large body of literature examining the potential consequences of screen-use for child and adolescent health (99). Excessive screen-time has been identified as an independent risk factor for deleterious health outcomes in adults, including increased risk of cardiovascular morbidity (100), Type II Diabetes, metabolic syndrome, some cancers and premature mortality (99). Among children and adolescents, excessive screen-time has been associated with high adiposity, CVD risk factors, low cardiorespiratory fitness (CRF), poor self-esteem, antisocial behaviour, and poor academic performance (99). Additionally, there is emerging evidence that excessive screen-time may increase the risk of mental health problems (101) and reduce health-related quality of life (102). Screen-time has also been found to track from youth to adulthood (103), and may have lasting consequences for adult health (104).

Table 2.1 International physical activity guidelines for children and adolescents

Country	Guidelines for quantity and intensity of PA		Guidelines for type of PA	
	Total PA	**Vigorous PA**	**Aerobic PA**	**Muscle and bone strengthening PA**
Australia (89)	≥ 60 mins/day MVPA (up to several hours)	Include some	Include a variety	≥ 3 days/week
U.S.A (105)	≥ 60 mins/day MVPA	≥ 3 days/week	Most of total MVPA	≥ 3 days/week (as part of total MVPA)
Canada (106)	≥ 60 mins/day MVPA	≥ 3 days/week	-	≥ 3 days/week
U.K (107)	≥ 60 mins/day MVPA (up to several hours)	≥ 3 days/week	-	Include as part of vigorous PA
WHO (108)	≥ 60 mins/day MVPA	≥ 3 days/week	Most of total MVPA	Include as part of vigorous PA

Abbreviations. **MVPA** = moderate-to-vigorous physical activity; **PA** = physical activity; **U.K** = United Kingdom; **U.S.A** = United States of America; **WHO** = World Health Organisation.

2.2.1.3 Sugar-sweetened beverage consumption

SSB's, (i.e., carbonated soft drinks/soda's, energy drinks, cordials, and refined fruit juices) are considered to be one of the largest sources of added sugar within the typical western diet (109). Adult studies have clearly demonstrated the deleterious effects of high SSB consumption for a number of health outcomes (110). Specifically, there is strong evidence that regular SSB consumption is causally associated with overweight and obesity, the metabolic syndrome, Type II Diabetes, and CVD (110). These associations are thought to be mediated by the effects of SSB intake on unhealthy weight gain, insulin resistance, inflammation, hypertension, visceral adiposity and artherogenic dyslipidemia (110). Among children and adolescents, extensive evidence supports SSBs as a contributor to unhealthy weight gain (109). Further, experimental studies have demonstrated the utility of reducing SSB intake as an obesity prevention strategy (111, 112). However, maintaining low levels of SSB intake among youth following the conclusion of intervention programs may be problematic (113).

2.2.2 Prevalence and trends

2.2.2.1 Physical activity

Physical activity levels decline sharply during adolescence (114), and approximately 80% of adolescents worldwide (aged 13-15 years) fail to accrue the amount of physical activity necessary to achieve health benefits (14). Prevalence estimates for Australian adolescents are similar, with approximately 15% of 12-17 year olds meeting the minimum 60 minutes per day of moderate-to-vigorous physical activity (MVPA) required to satisfy current recommendations (34). These data show clear sex-differences with 22% of male adolescents meeting current recommendations, compared with only 8% of females. Although males are consistently more active than females, overall physical activity levels remain low for both sexes (34). For example, the recently published Active Healthy Kids Australia physical activity report card awarded Australian youth a D minus for overall physical activity levels (115), the second lowest score in an international comparison of 15 nations (116). Importantly, overall physical activity levels among Australian youth remain poor despite relatively high rates of sports participation, a favourable climate, and supportive built environments (115). In fact, in the same 15 nation comparison, Australia rated second highest for youth involvement in organised sports (B-), and highest for community and the built environment (A-) (116). These ratings provide an interesting insight into the settings and contexts in which youth physical activity levels are most greatly influenced.

It is commonly thought there has been a secular decline in child and adolescent physical activity, particularly in western nations (117). However, limited high-quality trend data are available to support this claim (118). Indeed, the most recent review of global trends in youth physical activity concluded that "there is little evidence for the popular view that children's and adolescents' PA is in general decline" (p. 7) (117). Methodological limitations regarding physical activity measurement make firm conclusions challenging. However, there is evidence that physical activity levels within specific contexts have declined significantly over the past few decades (118). Specifically, studies have shown global declines in active transportation (i.e., walking and cycling) and physical education-based physical activity (118). As objective measures of physical activity (e.g., accelerometers, pedometers) have only become widely used in recent years, there is little population-level trend data available from studies using these measures. However, studies are beginning to emerge, and reductions in objectively measured physical activity have been reported among Czech (119) and Canadian (120) adolescents. Although based on self-report, Australian population survey data also show a decline in physical activity levels in recent years for both boys and girls (121). According to the New South Wales (NSW) Schools Physical Activity and Nutrition Survey (SPANS), the prevalence of meeting 60 minutes or more of MVPA per day declined by 1.7% per annum between 2004 and 2010, and the decline was greater for males than for females (121).

2.2.2.2 Screen-time

Screen-based recreation is one of the most popular leisure-activities for the current generation of young people (98), accounting for up to half of total sedentary time (121, 122). Television/DVD viewing remains the most popular form of screen entertainment, accounting for between half and three quarters of total screen-time (123). However, with the recent phenomenon of media-multitasking, up to a quarter of this time may be spent using multiple screen-devices concurrently (98). Prevalence statistics for screen-media use differ depending on the country, assessment methodology and sampling protocols. However, population surveys worldwide show that the majority of western adolescents fail to meet internationally recognised guidelines for screen media use (i.e., < 2 hours per day) (35). In Australia, close to 85% of adolescent males exceed current screen-time recommendations (34). Average screen viewing time among adolescent males is between two and half to three hours per day (123). However, there is considerable inter-individual variation in screen-time, and approximately one in ten young males spends close to seven hours per day using screens (124). Levels of screen-time appear to increase with age, such that adolescents spend significantly more time using screens than younger children (34, 98, 121). In addition, there is some evidence that screen-time peaks during early adolescence (125). Finally, Australian data show those from low-income communities are significantly less likely than their higher-income peers to meet screen-time recommendations (34, 121), suggesting a need for targeted intervention approaches among this group.

While there is general speculation that recreational screen use among western youth has increased in recent decades, the evidence for this argument is somewhat mixed. A population survey of 8-18 year olds in the United States found significant increases in the use of almost all small screen devices, and total screen-time, between 2004 and 2009 (98). Alternatively, survey data among German (126) and Australian (121) youth show relatively stable levels of screen-time within the first decade of the new millennium. In addition, Norwegian data suggest there was a reduction in recreational screen-time among 6^{th} and 7^{th} grade students between 2001 and 2008 (127). Dramatic increases in leisure-time computer use among U.S adolescents between 1999 and 2004 have been reported (128). However, this may not necessarily reflect an increase in total screen-time, as computer use may have displaced other screen-based activities such as television viewing or video gaming. Surprisingly, there is evidence showing that total time spent engaged with 'mass media' among youth has remained relatively stable since the 1950's, suggesting there may be a ceiling on how much time young people can dedicate to sedentary recreational pursuits (129). There are a number of measurement limitations which make firm conclusions regarding screen-time trends among youth challenging (129). However, while convincing evidence of a large secular increase in child and adolescent screen-time remains elusive, it is clear that the prevalence of excessive screen-time (i.e., > 2 hours per day) among the current generation of young people remains high (34). In light of the potential health consequences of high levels of screen-time (99), continued efforts to curb excessive screen use among children and adolescents are warranted.

2.2.2.3 Sugar-sweetened beverage consumption

As previously described, the consumption of SSBs is a large and growing problem in western nations (109, 130). Although declines in heavy SSB intake have been reported among U.S adolescents, these same data have shown a tripling in heavy consumption of sports and energy drinks, up to 12% in 2008 (131). According to data from the Health Behaviour in School-aged Children (HBSC) study (35), the majority of the 39 countries surveyed report prevalence of 'daily' SSB consumption among adolescents in excess of 25%. Currently, 18% of adolescent males in Australia report consuming 1-2 cups of SSBs per day (34). In the HBSC report, it was found that males, older youth, and those from lower socioeconomic strata were significantly more likely to consume SSBs daily, compared with their counterparts (35). Australian data mirror these findings, with particularly strong associations found for sex and socioeconomic status (SES) (34). For example, Australian adolescent males are almost twice as likely as females to report daily consumption of SSBs, whereas low-SES youth are almost 1.5 times as likely compared with their high-SES peers (34). In the case of sex, these associations appear to strengthen with age. For example, in another representative survey of Australian youth, regular consumption of SSBs (i.e., ≥ 2 per week) increased steadily across all year groups for both sexes, but the sex differences only became statistically significant from grade eight onwards (121).

2.2.3 Correlates of physical activity, screen-time, and SSB consumption

In the field of health behaviour, correlational research aims to identify personal, social and environmental factors associated with a given behaviour (e.g., physical activity) (132). The cross-sectional nature of correlational research prevents conclusions on causality. However, this research is important for generating hypotheses which can be tested using longitudinal and experimental study designs (132). Consistently supported correlates of physical activity, screen-time, and SSB consumption from systematic reviews of the child and adolescent literature are listed in Tables 2.2-2.4, respectively. Within each of these tables the direction of the association is provided.

2.2.3.1 Physical activity

In recent years, there have been a number of reviews exploring correlates and determinants of physical activity behaviour among children and adolescents (133-138). Consequently, reviews of reviews are available (70, 139), providing a comprehensive evaluation of the evidence-base to date. As shown in Table 2.2, there is evidence for a range of demographic, physiological, psychosocial, behavioural, and environmental correlates of adolescent physical activity. In a recent review, Bauman and colleagues did not report an association between parental educational level or family income and adolescent physical activity (70). However, parental education and income have been found to be positively associated with physical activity in previous reviews (133, 140). Interestingly, there has been inconsistent evidence of an association between anthropometric factors (e.g., BMI) and physical activity (70). However, in a review of studies using objectively measured physical activity, close to 80% of studies reported an inverse association between adiposity and physical activity (79), suggesting that these factors are indeed related. Perceived competence was found to be a consistent correlate in the review by Bauman and colleagues (70). This association is further supported by the findings of a recent systematic review and meta-analysis of the relationship between physical activity and perceived competence (58). In this review, the pooled effect size for the association between perceived competence and physical activity was *r* = .33, and stronger associations were found for adolescents compared with younger children (58). There was little 'consistent' evidence reported for environmental correlates of physical activity, perhaps due to the heterogeneity in outcome and exposure measures between studies (141). However, there is emerging evidence supporting a number of environmental correlates, as reported in the most recent reviews (141, 142).

Table 2.2 Correlates of physical activity behaviour

Type of correlate	Correlates	Direction
Demographic	Age	-
	Sex (male)	+
	Ethnicity (Caucasian)	+
	Parental education	+
	Family income	+
Physiological	Genetics	+
	Adiposity	-
	Movement skill proficiency	+
Psychological	Perceived competence	+
	Self-efficacy	+
	Body image	+
	Motivation	+
	Perceived barriers to activity	-
	Attitudes toward physical activity	+
	Perceived behavioural control	+
Behavioural	Participation in PE and school sport	+
	Sedentary behaviours	-
	Time spent outside	+
Socio-environmental	Parental and friend support for physical activity	+
	Local crime	-
	Land-use mix (e.g., distance to schools/shops/facilities)	-
	Residential density	+
	Positive exercise culture	+

Note. + = positive association; - = inverse association

2.2.3.2 Screen-time

A number of reviews of correlates of sedentary behaviour have emerged in recent years (99, 143-148). However, comparisons of findings between reviews are challenging as many include the results of studies examining various sedentary behaviours, rather than just screen-time specifically. Further, some reviews are focused on particular populations (e.g., adolescent girls, young children) (149-151) or specific outcomes (e.g., cardio-metabolic risk, dietary intake) (145, 152). A summary of the correlates of screen-time in young people based on a key systematic review (148) and a review of reviews (99) is provided in Table 2.3.

Table 2.3 Correlates of screen-time in young people

Type of correlate	Correlates	Direction
Demographic	Age	+
	Sex (male)	+
	Ethnicity (non-Caucasian)	+
	Socioeconomic status	-
	Parental education	-
Physiological	Cardiorespiratory fitness	-
	Adiposity	+
Psychological	Self-esteem	-
	Academic achievement	-
Behavioural	Antisocial behaviour	+
Socio-environmental	Parental screen-time	+
	Access to televisions/computers	+
	TV in bedroom	+
	Family rules/limitations on child's screen-time	-

Note. + = positive association; - = inverse association

2.2.3.3 Sugar-sweetened beverage consumption

To date, much of the research literature concerning SSB intake has focused on the associations between SSB consumption and health outcomes such as obesity (153, 154). Conversely, there is limited evidence from systematic reviews regarding demographic, behavioural, psychological or environmental correlates of SSB consumption among youth. However, evidence from individual studies suggests a number of potential correlates across each of these levels (155-159). Correlates of SSB consumption appearing within the child and adolescent literature are listed in Table 2.4.

Table 2.4 Correlates of SSB consumption

Type of correlate	Correlates	Direction
Demographic	Age	+
	Sex (male)	+
	Ethnicity (non-Caucasian)	+
	Socioeconomic status	-
Physiological	Adiposity	+
Psychological	Academic achievement	-
	Attitudes/preferences	+
Behavioural	Poor dietary choices	+
	Physical activity	-
	Screen-time	+
	Sleep time	-
	Cigarette smoking	+
Environmental	Accessibility/availability of SSBs at school and home	+
	School rules regarding SSBs	-
	Strength of school district policies regarding SSBs	-
	Family and friend modelling	+

Note. + = positive association; - = inverse association

2.3 Health-related fitness in children and adolescents

In addition to the health behaviours previously mentioned, components of physical fitness during childhood and adolescence are strong markers of current and future health (3, 13, 160). 'Physical fitness' refers to the functional status of most, if not all, of the body's physiologic systems and their ability to facilitate physical activity (3). The specific components of physical fitness found to be important for health (i.e., health-related fitness) are body composition, muscular strength, muscular endurance, cardiorespiratory fitness (CRF), and flexibility. A list of operational definitions for these fitness components can be found on page xxii. Although flexibility is considered a component of health-related fitness, it is not a focus of this thesis and is therefore not discussed in the following section. Research relating to body composition (i.e., overweight and obesity), muscular fitness, and CRF among youth populations is presented below.

2.3.1 Health consequences

2.3.1.1 Overweight and obesity

Overweight and obesity during youth is associated with a range of short- and long-term health consequences (60). There is strong evidence that obesity during youth tracks into adulthood, such that obese youth are likely to become obese adults (59). Consequently, much of the concern regarding youth obesity has centred on its potential influence on future health status. Indeed, many of the 'lifestyle-related' diseases commonly diagnosed during adulthood have their genesis in youth (161, 162). Furthermore, these diseases have been linked to youth weight status (60, 163). Unhealthy weight gain during childhood and adolescence may predispose individuals to an increased risk of cardiovascular disease (CVD), Type II Diabetes and premature death (164). However, the most immediate, but perhaps no less damaging, consequences of youth obesity are psychosocial (60). Evidence suggests obese youth demonstrate lower self-esteem than their normal weight peers and are more likely to experience concern for body image, which can persist into adulthood (165). In addition, a recent review found that obese youth are more likely to experience internalising disorders, attention deficit hyperactive disorder, sleep problems, and poor health-related quality of life (166). The social consequences of obesity are also quite severe. Obese youth are often the target of systematic discrimination by peers (165), and weight prejudice may contribute to poorer educational and economic outcomes throughout adulthood (60). Clearly, there is a strong rationale for addressing overweight and obesity during youth. Efforts to shift the health trajectory of those most 'at risk' may result in substantial population health benefits (167).

2.3.1.2 Muscular fitness

Research into the benefits of health-related fitness components has traditionally focused on the importance of CRF (168, 169). Recently, investigators have begun to examine the associations between muscular fitness and health outcomes (50). Among adults, poor muscular fitness has been identified as a significant predictor of metabolic syndrome (170), coronary heart disease (171) and premature mortality (52, 172). Importantly, recent studies have shown that some of the protective effects of muscular fitness are independent of CRF (52, 172), suggesting a unique contribution of muscular fitness to health status. In light of these findings, research has started to focus on the potential benefits of muscular fitness for youth populations, demonstrating links with an array of health outcomes (3). Cross-sectional studies have found associations between muscular fitness and metabolic risk (173-175), adiposity (56, 176, 177), skeletal health (178, 179), psychological wellbeing (180), and academic ability (181). In addition, prospective studies have shown reductions in adiposity (13) and CVD risk factors (53) with improvements in muscular fitness over time. Notably, a large prospective cohort study of young Swedish males found that those in the highest decile of muscular strength during adolescence had a significantly reduced risk of all-cause and CVD mortality in later life (160). Interestingly, the same study also showed a reduced risk of psychiatric diagnosis and mortality due to suicide with higher levels of muscular strength (160).

Widespread recognition of the health-enhancing benefits of muscular fitness has led to the inclusion of ‘muscle and bone strengthening’ activities within U.S (105), Canadian (106), U.K (107), and more recently, Australian (89) youth physical activity guidelines. Further, this recommendation is also included in the WHO’s global guidelines for youth physical activity (108). The number of studies demonstrating links between muscular fitness and health among youth provide support to this recommendation. However, to date, no systematic review of the literature has evaluated the potential benefits associated with muscular fitness during youth. Although reviews on this topic have been conducted (3, 13), they have been either narrative in nature, focused on the benefits of health-related fitness more broadly, or limited to prospective studies examining specific health-outcomes. Clearly, the lack of a comprehensive and systematic evaluation of the range of health-benefits of muscular fitness for children and adolescents is a notable gap in the extant literature.

2.3.1.3 Cardiorespiratory fitness

As mentioned previously, much of the existing research on the associations between fitness and health has focused on CRF. Indeed, decades of research have demonstrated the powerful influence of CRF on health status (168, 182-184). Among adults, CRF is independently associated with incident diabetes, hypertension and metabolic syndrome (185). Furthermore, evidence suggests that low CRF is a stronger predictor of all-cause and cardiovascular mortality risk than high BMI (186), and is also more strongly linked with cardiovascular risk factors than physical activity (187, 188). Importantly, the protective effects of adequate CRF have been found to be present during youth, with associations for insulin sensitivity (189) and clustered metabolic risk (188, 190, 191) reported in studies of children and adolescents. Recent reviews have confirmed the protective effects of CRF on youth adiposity and CVD risk factors (3, 13). In addition, a number of studies have reported associations between CRF and mental health outcomes (192, 193) and academic/cognitive performance (194, 195). The breadth of outcomes showing associations with CRF highlights the importance of this particular fitness component for child and adolescent health and wellbeing.

2.3.2 Prevalence and trends

2.3.2.1 Paediatric obesity

The past three to four decades has seen a dramatic rise in the global prevalence of obesity (196). According to recent data, rates of child and adolescent obesity worldwide have increased by 47% since 1980. Remarkably, countries such as the United States, England and Australia have experienced at least a doubling in the prevalence of youth overweight and obesity during this time (196). The rise in youth obesity prevalence has coincided with large increases in abdominal adiposity (197-199). Comprehensive data suggest the prevalence of abdominal obesity among U.S children and adolescents has increased by as much as 69% since 1988 (197); a worrying trend considering the health implications of excess fat deposition in this particular region of the body (200).

The most recent estimates suggest that one in four young people living in developed countries are overweight or obese (21), with higher rates observed among those of low SES (201). The Australian context echoes these global findings, with approximately 25% of adolescents considered overweight or obese (121, 202), and similar disparities observed between socioeconomic classes (121). While the overall rate of increase in obesity levels seems to have plateaued in some western countries, the same trend has not been observed among those from low-income backgrounds (203-205). Not only has this disparity not improved (206), evidence suggests that it may actually be widening (203-205). For example, beginning around the mid-2000's, there has been a growing gap in obesity prevalence between U.S adolescents of high and low SES (204). Similarly, Stamatakis and colleagues (205) found that the recent stabilisation of youth obesity rates in England was not shared by those within lower SES groups. When calculating the expected incidence of youth obesity in England by 2015, it was reported that the existing gap between SES groups would likely widen, and interestingly, would widen to a greater extent for males compared with females (207).

In 2006, Norton and colleagues predicted the prevalence of youth obesity in Australia would reach adult levels (i.e., 60%) within 30 years (208). Encouragingly, more recent data suggest this is unlikely to be the case (209). However, assuming a 'business as usual' approach, there appears to be no reason why this could not occur among youth in the lowest SES groups, reinforcing the rationale for targeted intervention approaches among this population. Furthermore, as the prevalence of overweight and obesity among Australian males is higher than females in both adolescents (121) and adults (210), young males from low-income backgrounds can be considered particularly vulnerable to the development of obesity and its comorbidities.

2.3.2.2 Muscular fitness

While decades of data for obesity prevalence are available, global trend data for levels of muscular fitness are far less comprehensive. Of the data that do exist, comparisons between nations and groups are challenging due to the considerable heterogeneity in assessment methodology, sampling protocols, and time periods being examined. Of additional concern is the questionable validity of many field-based muscular fitness tests (211). For example, Woods et al. (212) found that a number of commonly used field-tests for assessing muscular fitness, were better predictors of body fat percentage than criterion measures of muscular strength and muscular endurance. Due to these concerns, and emerging evidence of the health benefits of muscular fitness (3), the validity and reliability of existing fitness tests has begun to receive increased scrutiny. Recent systematic reviews have determined that handgrip dynamometry and the standing broad jump test have the most empirical support as valid (211) and reliable (213) field-tests of upper and lower body muscular fitness, respectively. However, among the small number of studies examining secular trends in muscular performance, many also report findings based on the results of less valid and reliable tests (214-217).Therefore, interpretation of these findings must be approached with caution.

Evidence of a secular decline in muscular performance among youth is somewhat mixed. In a notable review in 2007, Tomkinson (218) found that 'anaerobic performance' among youth worldwide has remained relatively stable since the late 1950's. However, it must be noted that only studies examining changes in power- (i.e., jumping) and speed-based (i.e., sprinting) fitness tests were included in this review. Further, these data also showed a trend toward declining performance in more recent decades, particularly among youth from developed nations (218). Data from other sources (and using different tests) appear to support a general decline in muscular fitness among children and adolescents. For example, significant declines in muscular performance have been observed among European (216, 217, 219-221), Canadian (222), New Zealand (214), and Japanese (223) youth. The paucity of high quality surveillance data makes it difficult to determine whether similar changes have occurred in Australia. In line with international findings (218), the available evidence suggests that jump- and sprint-test performance among Australian youth has remained relatively stable since 1960 (224). However, it is difficult to conclude whether these findings are 'test-dependent', or indeed a true reflection of temporal trends in muscular fitness more broadly among Australian youth. Regardless, the potential health benefits associated with acquiring a high level of muscular fitness (3, 13) warrant a continued focus on the promotion of muscle-strengthening activities among youth populations, particularly for those that are insufficiently active.

2.3.2.3 Cardiorespiratory fitness

In contrast to the muscular fitness literature, there is clear evidence of a global secular decline in child and adolescent CRF (225). In an analysis of over 25 million fitness test results across 27 different countries between 1958 and 2000, Tomkinson and colleagues reported that there has been a precipitous decline in paediatric aerobic fitness performance beginning around the 1970s and accelerating thereafter (225). Averaged across countries and the study time period, the annual decline was found to be 0.36%. Further, this change was found to be consistent across age, sex, and geographical groups, suggesting a truly global phenomenon. However, declines in performance were found to be more pronounced for boys (-0.40% p.a.) compared with girls (-0.31% p.a.) (225). A similar trend was reported among Australasian youth, with average annual declines in aerobic fitness test performance of 0.24% between 1961 and 2002 (226). Again, boys were more adversely affected, showing double the decline of girls during the same period (-0.32% p.a. vs -0.15% p.a.) (226). As these data show, there is strong support for the claim that today's generation of young people are less aerobically fit than their parents. Considering the strong links between CRF and a range of health outcomes (168, 182-184), this finding may have substantial implications for global health.

2.3.3 Determinants

2.3.3.1 Overweight and obesity

It is widely accepted that overweight and obesity are caused by a chronic energy imbalance, with excess energy stored as adipose tissue (227). Since the onset of the obesity pandemic in the 1980's, numerous and often contrasting studies have been published demonstrating possible causes for the global rise in this public health issue (228-231). Changes to the food system, increased urbanisation, use of motorised transportation, and declines in occupational physical activity have all been identified as primary contributors to the growth in global obesity rates (196, 230). Recent research has identified a number of novel causes for obesity, including deficiencies in the gut microflora, genetic and epigenetic factors, intrauterine exposure to maternal adiposity, and inadequate sleep (232). Further, sociocultural and geographic factors such as SES, ethnicity, and urban versus rural residence have been linked with youth weight status (232, 233). In particular, there is overwhelming evidence in support of low-SES as a major determinant of youth obesity risk (233, 234).

The most well-established determinants of obesity relate directly to energy balance, that being energy intake (i.e., diet) and expenditure (i.e., physical activity). Surprisingly, the evidence supporting excess energy intake as a determinant of youth obesity is not particularly strong (232). A number of studies have found no association between total energy intake and risk of overweight/ high adiposity among youth (235-237). In fact, significantly higher energy intakes have been recorded among leaner, more active youths compared with their overweight peers (236). However, methodological limitations regarding dietary assessment have confounded previous findings, and aspects of diet 'quality' (i.e., refined sugar intake) may be more important than overall energy intake for obesity risk (238). Indeed, there is evidence in the published literature that consumption of dietary fibre and energy-dense nutrient poor foods in particular, are linked to youth obesity (239). Furthermore, there is good evidence that sugar-sweetened beverage (SSB) consumption is causally linked to obesity (109). In a notable experimental study, overweight and obese adolescents provided with non-caloric beverages for one year demonstrated significantly lower BMI compared with controls at 12-month follow-up (112). As would be expected, the effect on BMI was found to be mediated by sugar intake (112), providing support for SSB consumption as a determinant of unhealthy weight gain.

Habitual physical activity has emerged as a major determinant of youth weight status (79). Specifically, levels of moderate- and vigorous-intensity physical activity appear to have a strong protective effect against unhealthy weight gain (72), with vigorous physical activity providing the greatest benefits (80, 240). More recently, investigators have also identified sedentary time as a potential determinant of youth obesity (143). While evidence from the adult literature suggests that sedentary time is associated with adiposity independent of physical activity (241), the evidence for this association among children and adolescents is less convincing. For example, a number of recent, methodologically robust studies have found no 'independent' associations between objective measures of sedentary time and adiposity among youth (74, 81, 242, 243), suggesting that MVPA is more important for obesity risk than sedentariness among this population. However, there is support within the research literature for an association between adiposity and recreational screen-time among youth (244-246). This association may be partly explained by unhealthy dietary behaviours (i.e., consumption of energy-dense snacks and drinks), which often occur in conjunction with extended bouts of recreational screen-time (152, 247). Further, screen-time may interact with other health behaviours, such as sleep to indirectly influence obesity risk (248, 249). In addition to increasing MVPA, the literature provides a sufficient justification for targeting screen-time for the purposes of obesity prevention. Indeed, recent experimental evidence suggests that screen-time may be both a mediator and moderator of intervention effects for adiposity (250).

2.3.3.2 Muscular fitness

Muscular fitness is partly inherited (251, 252), with both the number and type of muscle fibres determined by genes (253). However, environmental exposures including participation in certain physical activities also contribute strongly to the development of muscular fitness (254); albeit that individual responses to physical activity can vary markedly (255). Muscular strength during childhood increases in a linear fashion for both boys and girls until the onset of puberty (37). At this point, strength increases rapidly in a curvilinear fashion for males and is largely associated with increases in body size (37). Sex differences in muscle strength become more apparent during adolescence, with boys consistently outperforming girls due to greater increases in muscle cross-sectional area (37). Importantly, there can be considerable heterogeneity in maturational status among youth of the same chronological age, resulting in considerable between-individual differences in muscular strength within a given age group or school grade (37).

Although there is some recent evidence showing that a high level of ‘vigorous’ physical activity (of any kind) is sufficient for developing muscular fitness during adolescence (254), the ‘type’ of physical activity is generally accepted to be the most important variable for eliciting improvements in muscular performance (12, 37). Regular participation in ‘muscle strengthening’ physical activities has been shown to promote a high level of muscular fitness during youth (12). While the term ‘muscle strengthening’ may appear quite broad, these kinds of physical activities are inherently resistance-based, meaning they require a substantial contribution from the musculoskeletal system and anaerobic energy pathways (11).

2.4 School-based interventions to improve health-related fitness and health behaviours

Due to widespread research interest, there have been numerous systematic reviews evaluating the effectiveness of school-based physical activity programs (26-29, 49, 256, 257). Kriemler and colleagues concluded that school-based interventions, particularly multi-component interventions, are effective at increasing both in-school and leisure-time physical activity (27). However, in their review, there were mixed findings for the effects of school-based programs on CRF (27). The most recent Cochrane review supported and extended these findings, concluding that school-based interventions are an effective approach for improving physical activity *and* CRF (i.e., range across studies = 1.6 to 3.7 mL/kg/min) (29). However, the authors recommended caution in the interpretation of findings, as intervention effects were generally small and many studies demonstrated questionable methodological quality (29). The randomised controlled trial (RCT) is considered the gold standard study design for evaluating interventions (258). However, many previous studies have used inferior designs to evaluate program outcomes. For example, in the same review the updated inclusion criteria (i.e., reflecting the inclusion of studies with higher methodological quality) resulted in a loss of almost half of the studies included in an earlier review, mostly due to inadequate study designs (i.e., uncontrolled trials) (29).

Although school-based programs appear to be effective for improving physical activity and CRF, interventions targeting overweight and obesity have shown, at best, mixed success (28). Previous interventions have demonstrated promise, but findings have been inconsistent and based on short follow-up durations (28). Notably, evidence suggests that previous programs have been more successful for females and younger children (28). For the latter, meta-analyses report small and non-significant effects for BMI in adolescent studies (i.e., mean [95%CI] = -0.09 kg/m^2 [-0.20 to 0.03]), compared with larger and statistically significant effects in studies targeting primary/elementary school-aged children (i.e., mean [95%CI] = -0.15 kg/m^2 [-0.23 to -0.08]) (26). However, it must also be noted that there have been far fewer interventions evaluated among adolescents compared with younger children.

Obesity prevention programs often target weight-related behaviours such as screen-time and SSB intake (28). Notably, a recent experimental study demonstrated that sustained reductions in screen-time partially mediated the effect of the intervention on adiposity, providing support for the continued targeting of this health behaviour (250). As the primary focus of this thesis is on health-related fitness, the effectiveness of school-based interventions on weight-related behaviours will not be discussed extensively. Briefly, there is evidence that interventions have been effective for reducing sedentary behaviours among youth (259). However, post-intervention effects have generally been small and, once again, previous programs appear to have been more effective for younger children (259). In addition, recent interventions have shown significant effects for SSB consumption among adolescents (30, 260, 261), although not universally (262).

A key finding from past reviews is that adolescents are largely underrepresented within the current intervention literature. Regardless of the outcome, the vast majority of intervention studies have targeted primary/elementary school-aged children (26-28). For example, only 15% of obesity prevention interventions (26) and 20% of physical activity and fitness interventions (27) have been conducted with adolescents. In their recommendations for future youth obesity prevention research, Waters and colleagues note that, given the large number of existing studies that have targeted primary school-aged youth, there is little need for further efficacy testing of individually-focused school-based trials among this age group (26). Conversely, the authors note that research gaps regarding the effectiveness of obesity prevention programs among adolescents remain, suggesting the need for continued research among this population (26).

Another salient point is that, despite the recognised benefits of RT (37), there are relatively few interventions that have incorporated this training modality into their programs. Of those that have, findings for body composition and muscular fitness outcomes have generally been positive (42, 55, 263, 264). However, many of these programs have targeted clinical populations such as obese youth (55) and have been delivered by specialist facilitators (e.g., exercise physiologists), raising questions about the generalisability and scalability of this approach. Further, consistent with previous intervention research, these programs have generally been evaluated using small sample sizes and have not included long-term follow-up (42, 264, 265). Surprisingly, there is a clear lack of 'school-based' interventions that have utilised RT. Notably, Lubans and colleagues evaluated two eight-week RT programs (i.e., a free-weights and an elastic-tubing RT program) delivered during school lunch-times, finding significant intervention effects for body composition and muscular fitness among both sexes (266). Conversely, in the Nutrition and Enjoyable Activity for Teen (NEAT) girls RCT, which employed once-weekly exercise sessions during school sport periods and lunch-time sessions for 12-months, no significant effects for body composition or muscular fitness were observed immediately post-program (267). Although, a significant effect for body composition was observed at 24-month follow-up (262). In another female-only study, significant intervention effects were found for body composition and blood pressure after 12 weeks of vigorous aerobic and resistance training (268). However, another trial delivering 18 weeks of RT through school PE reported mixed results, with improvements found for some muscular fitness measures but not for measures of body composition (265). As demonstrated by these examples, there is some support for the effectiveness of school-based RT to improve health outcomes among youth. However, studies are few in number and results have clearly been inconsistent. The delivery of RT within the school setting is an under-researched area within the school-based intervention literature. Considering the scientific consensus on the benefits of RT for youth (37), and the recent inclusion of 'muscle and bone strengthening' physical activities within youth physical activity guidelines (108), school-based RT is a worthwhile area of research enquiry with the potential to have a substantial impact on the health and wellbeing of children and adolescents.

2.5 Explaining adolescent health behaviours using theory

2.5.1 The role of theory in health behaviour research

As previously described, many of the public health issues presently confronting modern society are the result of unfavourable behavioural patterns. However, knowing that there is a link between behaviour and health gives little insight into the reasons why people behave the way they do. It is the role of theory to bridge this gap, by offering a conceptual framework for understanding the fundamental processes governing human actions (269). An advanced understanding of the determinants of behaviour, and their interrelationships, enables the development of effective interventions designed to reorient behavioural patterns towards those that are health-enhancing. Indeed, there is good evidence to suggest that interventions underpinned by theory are more effective than interventions developed without theory (48, 270, 271).

Numerous theories have been developed in an attempt to understand why individuals behave as they do (269). Some health behaviour theories focus solely on individual-level or *intrapersonal* constructs (e.g., beliefs, attitudes, self-efficacy) (272-274). These theories tend to concentrate on the cognitive processes that underlie individual decision making (269). However, individuals do not exist in isolation from other people. Rather, they interact in complex ways with their social and physical environments, resulting in distinct influences on behaviour and health (269). *Interpersonal*, or social cognitive models of health behaviour, are those that recognise the additional influence of social forces and attempt to explain the complex interplay between interpersonal interactions, individual cognitions and behaviour (269). In more recent years, *ecological* models of health behaviour have received increased attention (275). Ecological models extend on social cognitive models by further recognising the organisational, environmental and policy contexts in which individuals and groups exist, and their role in guiding behaviour (275).

Ecological models may have more explanatory power than models including only individual- or interpersonal-level determinants. However, when applying theory to behaviour change interventions, pragmatic concerns such as feasibility and potential efficacy are important considerations. Distal determinants such as the built environment and public health policy may, in many cases, be impractical intervention targets given finite resources and personnel. Conversely, interventions utilising a social cognitive approach may be more achievable, and the impacts on individual behaviour more immediate. Individual (e.g., motivation, perceived competence) and interpersonal factors (e.g., interaction with peers and teachers) contribute significantly to students' affect and behaviour within school physical education (PE) lessons (276, 277). Consequently, a social cognitive approach may be appropriate for guiding school-based intervention research. Two key social cognitive theories of health behaviour, successfully applied to the promotion of physical activity for adolescents (278, 279), are detailed below.

2.5.2 Self-Determination Theory

Deci and Ryan's Self-Determination Theory (SDT) (66) is an organismic dialectical approach, which provides a conceptual framework for understanding human motivation. Motivation can be described as the impetus or inspiration to act (280). According to SDT, there are three innate psychological needs which, if satisfied, will promote self-determined forms of motivation and enhance psychological flourishing (66). Conversely, if these basic needs are thwarted, an individual will be amotivated and their psychological wellbeing adversely impacted. These basic psychological needs are: (i) autonomy – a sense that behaviour is volitional or attributed to personal choice; (ii) competence – a perception of efficacy or mastery in a given task; and (iii) relatedness – a sense of belonging or social connectedness (66). A depiction of the SDT model can be seen in Figure 2.2.

The common view of motivation is that it is a unitary phenomenon (280). In other words, motivation is considered in terms of its quantity or magnitude (i.e., *low to high* or *weak to strong*). For example, individuals often express a desire to 'increase' their motivation for a given behaviour (e.g., exercise). Conversely, the view of motivation posited by SDT is one in which motivation is considered in terms of its 'quality' (see Figure 2.3). SDT categorises motivation as either *intrinsic* (i.e., behaviour performed for its own sake or inherent satisfaction) or *extrinsic* (i.e., behaviour performed to satisfy an external demand); while the term *amotivation* is used to describe a lack of willingness or intention to act. Intrinsic motivation is considered to be the highest quality form of motivation, and is thus expected to be most strongly associated with behaviour.

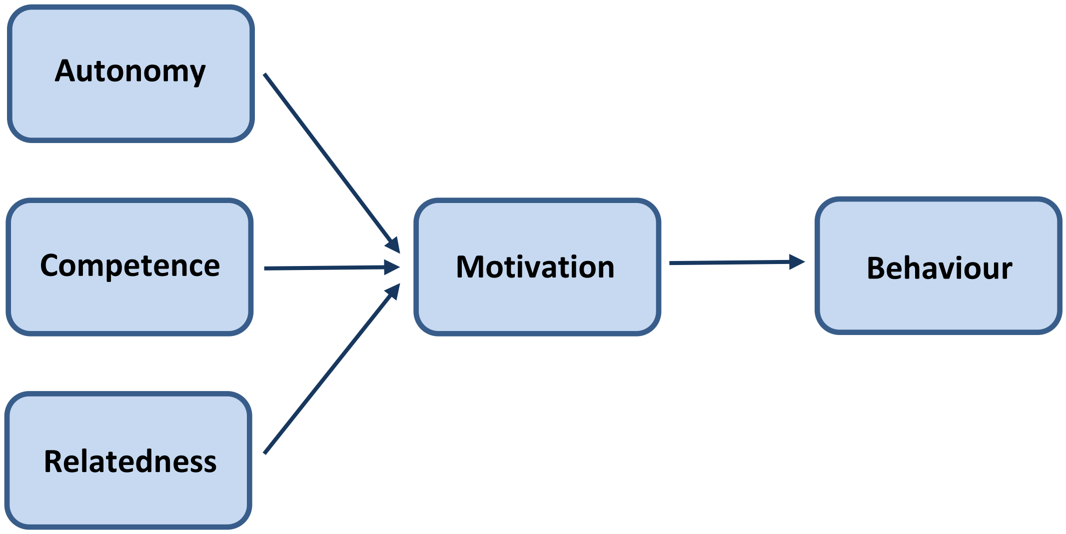

Figure 2.2 Deci and Ryan's Self-Determination Theory model (66)

Extrinsic forms of motivation fall along a continuum of internalisation, that is the degree to which motivation emanates from one's self (280). Although this may sound contradictory, it must be remembered that not all behaviours are intrinsically rewarding. However, the decision to engage in such behaviours may still be 'self-endorsed'. As with intrinsic motivation, *autonomous* forms of extrinsic motivation are associated with an internal perceived locus of causality. Autonomous motivation occurs when: (i) the behaviour is assimilated into an individual's personal value system and aligns with their sense of self (i.e., *integrated regulation*); or (ii) an individual values the outcome of the behaviour or if the behaviour is congruent with personal goals (i.e., *identified regulation*). Although extrinsically motivated, these behavioural regulations still enable one to feel that their behaviour is self-determined.

At the lower end of the extrinsic continuum are *controlled* forms of motivation (280). These behavioural regulations are characterised by an external perceived locus of causality. That is, the reasons for action are determined by external actors (e.g., friend, parent, or teacher) or by personal feelings about them. Controlled reasons for acting may be to: (i) avoid feelings of guilt or shame, or attain ego-enhancements (i.e., *introjected regulation*); or to (ii) obtain a reward or avoid punishment (i.e., *external regulation*). In contrast to autonomous motivation, controlled forms of motivation are of poor quality and are expected to be weakly, and possibly inversely, associated with behaviour.

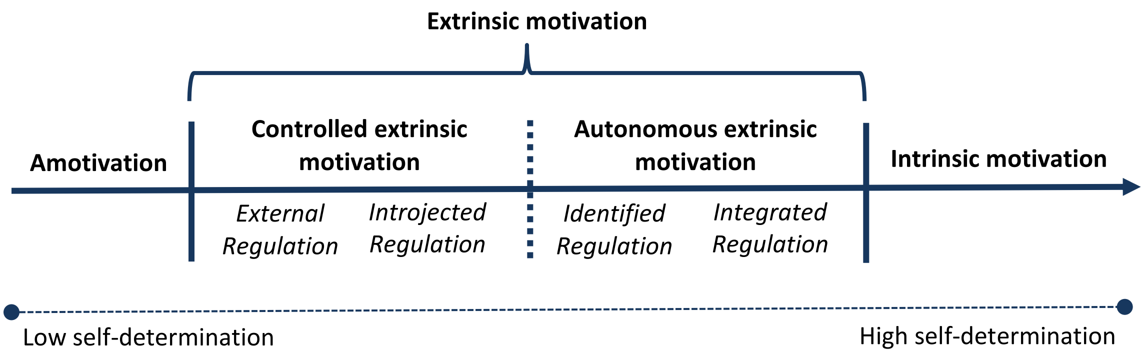

Figure 2.3 The self-determination continuum (280)

Recently, a systematic review and meta-analysis of child and adolescent studies demonstrated the grading of associations between behavioural regulations and physical activity (279). As predicted by SDT, the pooled analysis showed stronger correlations between motivation for physical activity and physical activity behaviour across increasing levels of self-determination (279). Specifically, the pooled effect sizes for each behavioural regulation were: *Intrinsic* (.29), *Identified* (.26), *Introjected* (.06), *External* (-.08), and *Amotivation* (-.14), with statistical significance reached for all constructs except for *Introjected* regulation. As seen in this review, integrated regulation is typically not measured in studies of young people, as a coherent sense of self is not considered to be developed until adulthood (281). This study supports one of the central tenets of SDT, that higher quality forms of motivation are more strongly associated with behaviour (280). Importantly, this review also examined studies investigating the relationship between motivation towards PE and leisure-time physical activity, showing significant associations (279). These data provide support for the Trans-Contextual Model (282), which posits that autonomous motivation for physical activity in one context (e.g., PE or school sport) can translate to autonomous motivation for physical activity in other contexts (e.g., during leisure-time). In addition, experimental evidence is beginning to emerge demonstrating the utility of targeting basic psychological needs in the school setting as a strategy for increasing youth physical activity (283, 284). However, further investigation using high quality experimental trials is warranted.

2.5.3 Social Cognitive Theory

Bandura's Social Cognitive Theory (SCT) is founded on the concept of 'reciprocal determinism', which suggests that behaviour is the result of a complex web of interactions between personal, environmental and behavioural factors (68). As shown in Figure 2.4, SCT outlines a set of key determinants of behaviour and the mechanisms through which they operate. According to this theory, self-efficacy is the central determinant of behaviour, operating both directly on behaviour and indirectly through all other constructs in the model. In a health context, self-efficacy can be described as the belief in one's ability to exercise control over their behaviours to achieve a desired health outcome (285). Self-efficacy is thought to indirectly affect health behaviour by influencing an individual's perceptions of the benefits or consequences (i.e., outcome expectations), their perceptions of facilitating and impeding factors (i.e., socio-structural factors), and their subsequent goals or intentions regarding the behaviour (i.e., goals). Using physical activity as an example, an individual with a high degree of physical activity self-efficacy would be expected to: (i) perceive physical activity as personally beneficial; (ii) perceive fewer social and environmental barriers to participation; (iii) have physical activity goals and intend to be regularly active; and (iv) be habitually active (285, 286).

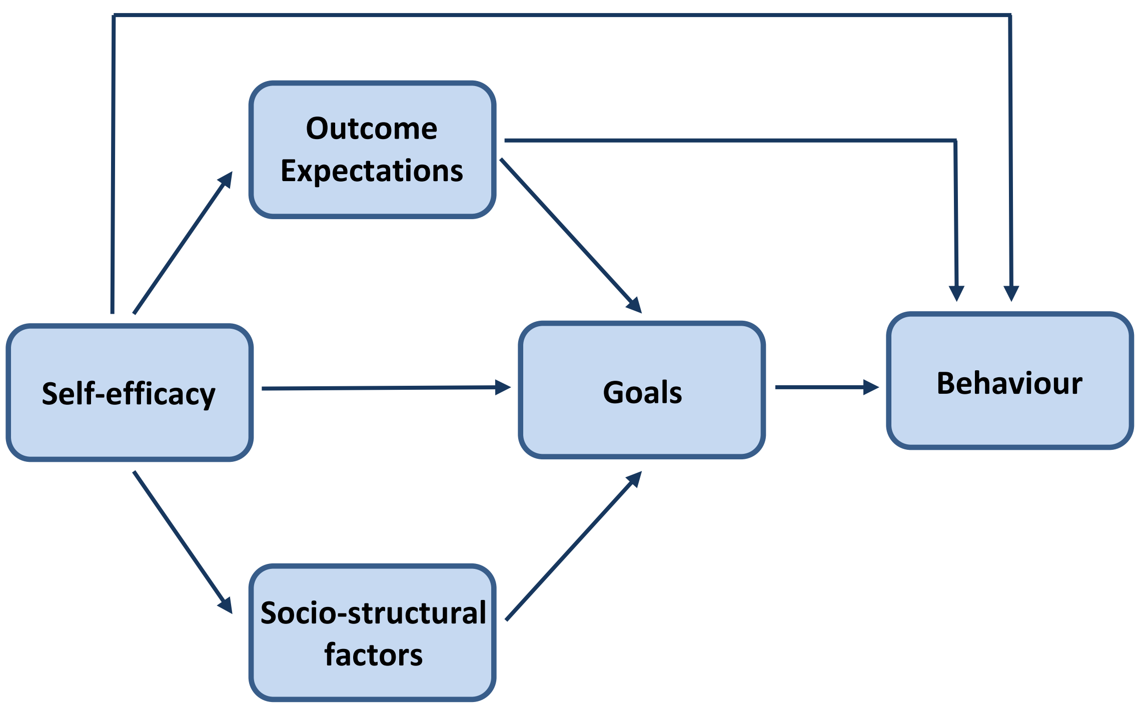

Figure 2.4 Bandura's Social Cognitive Theory model of health behaviour (285)

SCT has demonstrated utility in explaining significant portions of variance in physical activity behaviour among adolescents (278). However, not all constructs in the model have been consistently supported (287), suggesting that some constructs may be more universally important for explaining physical activity behaviour than others. Research has demonstrated consistent associations between self-efficacy and physical activity behaviour across numerous age groups (70, 133). In addition, physical activity programs can influence self-efficacy (288), and there is strong support for self-efficacy as a mediator of physical activity in theory-based interventions (289). It is important to note, however, that despite integrating strategies aimed at promoting self-regulation of health behaviour, most previous school-based interventions have not included long-term follow-up, precluding conclusions on the efficacy of their programs for long-term behaviour maintenance (26). This represents a clear gap within the behavioural intervention literature. Regardless, targeting self-efficacy would appear to be a worthwhile evidence-based strategy for physical activity behaviour change. Additionally, addressing self-efficacy may be of particular importance for intervention programs aiming to deliver or encourage potentially unfamiliar physical activities.

2.5.4 Testing hypothesised mediators

It has been recommended that intervention studies conduct statistical mediation analysis to determine the effectiveness of individual intervention components and hypothesised mediators (290). This may be of particular importance for multi-component interventions, as it is often difficult to disentangle the relative effectiveness of individual strategies for a given outcome when multiple strategies have been used (29). Broader dissemination of successful trials will likely require a scaled back version of the original intervention, including only the most necessary and effective intervention components. Yet, despite often targeting theoretical mediators, few previous interventions have conducted mediation analyses, resulting in limited empirical support for specific intervention strategies (289). Consequently, systematic reviews of youth interventions have been unable to provide strong recommendations regarding effective strategies for future research and practice (26, 29). There is a clear need for interventions, particularly multi-component interventions, to explore the effectiveness of their selected strategies using robust statistical mediation techniques. This will enable a better understanding of the applicability of specific health behaviour theories for addressing behaviour change in youth populations.

2.6 Summary

Based on the evidence found within the existing literature, the following was determined:

- Emerging evidence has demonstrated the unique health-benefits of muscular fitness for young people. Despite the recognition of these benefits in recent physical activity guidelines, there has not yet been a comprehensive and systematic evaluation of the range of health outcomes conferred by muscular fitness during childhood and adolescence.

- Although international recommendations suggest that movement skill development should be the primary focus of youth RT programs, there is currently no assessment tool for evaluating RT skill competency and a limited understanding of the potential benefits of developing RT skills.

- The prevalence of poor health behaviours appears to be highest among the most economically disadvantaged youth, and is also moderated by sex. These findings may have implications for the design of interventions attempting to improve these behaviours.

- There are clear sex differences in the prevalence of excessive screen-time and SSB consumption. Specifically, young males are significantly more likely than females to exceed screen-time recommendations and consume unhealthy quantities of SSBs.

- Although males are more active than females at all ages, few Australian adolescent males accrue the amount of physical activity considered necessary to achieve health benefits.

- Overweight and obesity is a serious and potentially growing health issue among children and adolescents, particularly for those living in low-income communities.

- There has been a proliferation of school-based interventions in recent years. However, many prior studies remain limited by the use of small sample sizes, short follow-up durations and inadequate study designs, making firm conclusions regarding the efficacy of these approaches challenging.

- There have been few school-based interventions targeting adolescents, and even fewer that have targeted boys or girls separately. Apart from the PALs pilot study, there has been only one small school-based program specifically targeting adolescent males, which was limited by a small sample size and short-term follow-up assessments.

- The PALs pilot study has demonstrated the efficacy of a gender-targeted intervention for economically disadvantaged adolescent boys. However, further testing using a larger sample and longer follow-up duration is needed.

- The mechanisms of change in intervention studies are rarely explored, resulting in limited empirical evidence regarding the most effective strategies for improving health outcomes. Statistical mediation analysis is a recommended approach for examining these mechanisms.

- Psychological theory may have utility in explaining and improving health behaviours among youth. In particular, social cognitive theories that recognise the dynamic interaction between individuals and their social environments may be used to guide the development of behavioural interventions.

CHAPTER 3: THE HEALTH BENEFITS OF MUSCULAR FITNESS FOR CHILDREN AND ADOLESCENTS

Preface:

This chapter presents the results of a systematic review and meta-analysis of studies examining the health benefits of muscular fitness for children and adolescents. This study was conducted to investigate *Secondary aim 1* of this thesis.

The contents of this chapter were published in *Sports Medicine* in September, 2014.

Citation:

Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sports Medicine*. 2014; 44(9), 1209-1223.

Abstract

Background. Physical fitness during childhood and adolescence has been identified as an important determinant of current and future health status. While research has traditionally focused on the association between cardio-respiratory fitness and health outcomes, the association between muscular fitness (MF) and health status has recently received increased attention.

Objective. The aim of this systematic review and meta-analysis was to evaluate the potential physiological and psychological benefits associated with MF among children and adolescents.

Methods. A systematic search of six electronic databases (PubMed, SPORTDiscus, Scopus, Embase, PsycINFO and OVID MEDLINE) was performed on the 20th May, 2013. Cross-sectional, longitudinal and experimental studies that quantitatively examined the association between MF and potential health benefits among children and adolescents were included. The search yielded 110 eligible studies, encompassing six health outcomes (i.e., adiposity, bone health, cardiovascular disease [CVD] and metabolic risk factors, musculoskeletal pain, psychological health and cognitive ability). The percentage of studies reporting statistically significant associations between MF and the outcome of interest was used to determine the strength of the evidence for an association and additional coding was conducted to account for risk of bias. Meta-analyses were also performed to determine the pooled effect size if there were at least three studies providing standardised coefficients.

Results. Strong evidence was found for an inverse association between MF and total and central adiposity, and CVD and metabolic risk factors. The pooled effect size for the relationship between MF and adiposity was r = -0.25 (95% CI = -0.41 to -0.08). Strong evidence was also found for a positive association between MF and bone health and self-esteem. The pooled effect size for the relationship between MF and perceived sports competence was r = 0.39 (95% CI = 0.34 to 0.45). The evidence for an association between MF and musculoskeletal pain and cognitive ability was inconsistent/uncertain. Where evidence of an association was found, the associations were generally low-to-moderate.

Conclusion. The findings of this review highlight the importance of developing MF during youth for a number of health-related benefits.

3.1 Background

Physical fitness can be defined as the capacity to perform physical activity and is primarily determined by genetics and training (3, 291). For most individuals, changes in the frequency, intensity, duration or type of physical activity will produce changes in physical fitness - although the amount of adaptation can vary considerably (292). The fitness components that have been shown to directly relate to improvements in health are cardio-respiratory fitness (CRF) (also known as cardiovascular fitness, cardio-respiratory endurance and maximal aerobic power), flexibility, muscular strength, local muscular endurance and body composition (2, 293-295). More recently, the term 'muscular fitness' (MF) has been used to represent muscular strength, local muscular endurance and muscular power. Generally defined, muscular strength is the ability to generate force with a muscle or group of muscles; local muscular endurance is the ability to perform repeated contractions with a muscle or group of muscles under sub-maximal load; and muscular power refers to the rate at which muscles perform work (2, 4, 295).

Typically, children exhibit a gradual linear increase in muscular strength and muscular power from three years of age until puberty for boys, and until about 15 years for girls (296, 297). These changes are closely associated with changes in body size and fundamental movement skill aptitude. After this time, boys show a dramatic acceleration of muscular strength until the age of 17 and beyond, and girls show a pronounced plateauing and regression in late adolescence and beyond (295). Similarly, during childhood both boys and girls make gradual improvements in local muscular endurance, exhibiting similar relative endurance levels (adjusted for body mass) (295). Importantly, the literature clearly states that performance of any movement task requires varying degrees of MF, given that all movements of the body engage the muscular system to move the skeleton (295). Consequently, a stronger, more enduring and more powerful musculoskeletal system will enable children and adolescents to perform bodily movements more efficiently and effectively, and may decrease their susceptibility to sports-related injuries (40).

Recent global physical activity guidelines for youth emphasise participation in high intensity physical activity and include a recommendation to perform 'muscle and bone strengthening' physical activities on at least three days per week (108). Furthermore, supervised and appropriate resistance training activities have been recommended for children and adolescents in a recent international position statement (37). Despite these guidelines and strong evidence for maintaining high levels of physical fitness, a decline in fitness levels in children and youth has been reported worldwide (215-217, 225, 226, 298-301). While much of the focus has been centred on the decline in CRF, a decline in levels of MF has also been observed in young people (215, 220, 221, 302). However, it must be noted that there is no reliable standard assessment battery for the assessment of MF in children and adolescents, making comparisons over time, and between nations and groups challenging (303, 304).

Traditionally, research investigating the link between physical fitness and health outcomes has focused on CRF, clearly demonstrating that it is strongly associated with health (3, 304). However, several studies among adults examining the benefits of MF have also shown strong links to health (52, 160, 172). These studies have not only demonstrated that MF is directly linked to all-cause mortality, but also that a threshold effect exists whereby no additional reduction in mortality risk is gained by increasing MF beyond a certain level (52, 160, 172). The impetus for promoting adequate levels of MF in children and adolescents is based on the growing body of evidence associating MF with an array of health benefits. The emerging body of evidence has demonstrated that MF is favourably associated with adiposity (13), insulin sensitivity (174), bone health (178), psychological health and academic performance (180, 181). Importantly, current literature suggests that many of these benefits are independent of CRF, providing a strong rationale for integrating different types of training into youth fitness programs (305) . Recent studies also support the benefits of MF for improving sports performance and for injury prevention in young people (306). Additionally, levels of MF in childhood have been shown to track into adulthood (3, 307) and are linked to future cardiovascular disease (CVD) risk (53, 160).

While there have been reviews of the benefits of health-related fitness in youth and the importance of MF for CVD risk reduction (3, 13), it appears no previous systematic review has examined the association between MF in youth and the range of physiological and psychological benefits. Therefore, the purpose of this review is to systematically examine the association between MF in children and adolescents and the potential health benefits in each of these domains.

3.2 Methods

3.2.1 Identification of studies

A systematic search of six electronic databases (PubMed, SPORTDiscus, Scopus, Embase, PsycINFO and OVID MEDLINE) was performed on 20th May, 2013 following consultation with an academic librarian. The following search strings were used: Musc* AND (strength OR endurance OR power) OR (“resistance training” OR “weight training”) AND (adolescen* OR teen* OR child* OR student* OR youth* OR school* OR young*) AND (health OR risk OR consequence* OR benefit* OR psych* OR behavio* OR effect*). No limits on date of publication were imposed. However, only articles published in refereed journals and in English language were considered for review. Conference proceedings, abstracts and theses were not included. Relevant articles were identified through two stages of screening performed independently and compared by two researchers. In the first stage, titles and abstracts of the search results were checked for relevance. In the second stage, full texts were located and assessed for eligibility. The reference lists of all included articles and previous reviews on the topic were also checked to identify any articles that were not located through the database search.

3.2.2 Criteria for inclusion/exclusion

Two authors independently assessed the eligibility of studies based on the following criteria: (i) Study participants were school-aged youth (i.e., 4-19 years) in the general population. Studies with targeted groups from special populations were excluded (e.g., athletes, clinically obese, subjects with mental illness etc). Although studies have found that resistance training may be protective against sports-related injuries (40), the benefits of MF for young athletes was beyond the scope of this review; (ii) Study provided a quantitative assessment of MF (e.g., strength, power or local muscular endurance); (iii) Study provided a quantitative assessment of at least one potential benefit (e.g., insulin resistance, adiposity, self-esteem etc); (iv) Study provided a quantitative analysis of the association between MF and the potential benefit(s); and, (v) Published in English in a peer reviewed journal. Following independent assessment of eligibility, the two lists of included articles were compared. Any discrepancies were discussed and agreed upon prior to inclusion or exclusion. Consensus was reached on all articles included in the review.

3.2.3 Criteria for risk of bias assessment

Two authors independently assessed the risk of bias of included studies, which occurred at the study level. The criteria for assessing risk of bias was based on the Consolidated Standards of Reporting Trials (CONSORT) statement (308) and the STrengthening Reporting of OBservational studies in Epidemiology (STROBE) statement (309). A risk of bias score was allocated to each study by assigning a value of 0 (criteria not met) or 1 (criteria met) based on the following: (i) Study sites or participants were randomly selected and the randomisation procedure was adequately described; (ii) Adequate description of the study sample (i.e., number of participants, mean age and sex); (iii) Adequate assessment/reporting of MF (i.e., validity/reliability of fitness test reported and/or detailed description of testing protocols); (iv) Adequate assessment of the potential benefit (i.e., validity/reliability of outcome measure reported and/or measurement procedure adequately described) and (v) Adjustment for confounders (i.e., age and sex) in the statistical analyses where necessary. The scores for each criterion were summed to provide a total score out of 5. Studies that scored 0-2 were considered to have a 'high risk' of bias, those that scored 3 were considered to have a 'moderate risk' of bias, and those scoring 4-5 were considered to have a 'low risk' of bias. Inter-rater agreement for the risk of bias assessment was determined by the percentage agreement between raters. Furthermore, *Kappa* analysis was conducted using SPSS software, version 21.0 (SPSS Inc, Chicago, Illinois).

3.2.4 Categorisation of variables and level of evidence

Data were extracted into an Excel spreadsheet using a template designed specifically for the review. A separate author checked all of the extracted data for accuracy. If any additional data (e.g., coefficients for the associations) were required, the corresponding author of the included study was contacted by email. The outcome variable(s) of each study were grouped into two broad categories: 'physiological' (e.g., adiposity) and 'psychological and cognitive' (e.g., self-esteem). Results were coded using the method first employed by Sallis et al. (134), and more recently used by Lubans et al. (61). If 0-33% of studies reported a significant association, the result was classified as no association (0). If 34-59% of studies reported a significant association or if fewer than four studies reported on the outcome, the result was classified as being inconsistent/uncertain (?). If ≥60% of studies found a significant association, the result was classified as positive (+) or negative (-) depending on the direction of the association. Additional coding was performed to account for risk of bias using the method proposed by Lubans et al. (61). If ≥60% of studies with low risk of bias found a significant association then the result was classified as strong positive (++) or strong negative (- -) depending on the direction of the association. If studies employed multiple analyses, only findings from the highest level of analysis (i.e., multivariate) were considered.

3.2.5 Meta-analyses

Meta-analyses were conducted to determine the pooled effect size between MF and the outcome of interest. Meta-analyses were conducted if at least three studies provided standardised coefficients between MF and potential benefits. Analyses were conducted using comprehensive meta-analysis software, version 2 for Windows (Biostat company, Englewood NJ, USA) (310) with random effects models. Heterogeneity was determined by Cochrane's Q statistic and I^2 values. For interpretation, I^2 values of 25, 50, and 75 were considered to indicate low, moderate and high heterogeneity, respectively (311). Publication bias was analysed using Rosenthal's *classic fail-safe N* (312) and Duval and Tweedie's *trim and fill* procedure (313). Correlations between variables were interpreted as follows: 0-0.19 (no correlation), 0.2-0.39 (low correlation), 0.4-0.59 (moderate correlation), 0.6-0.79 (moderately high correlation), and ≥0.8 (high correlation) (314).

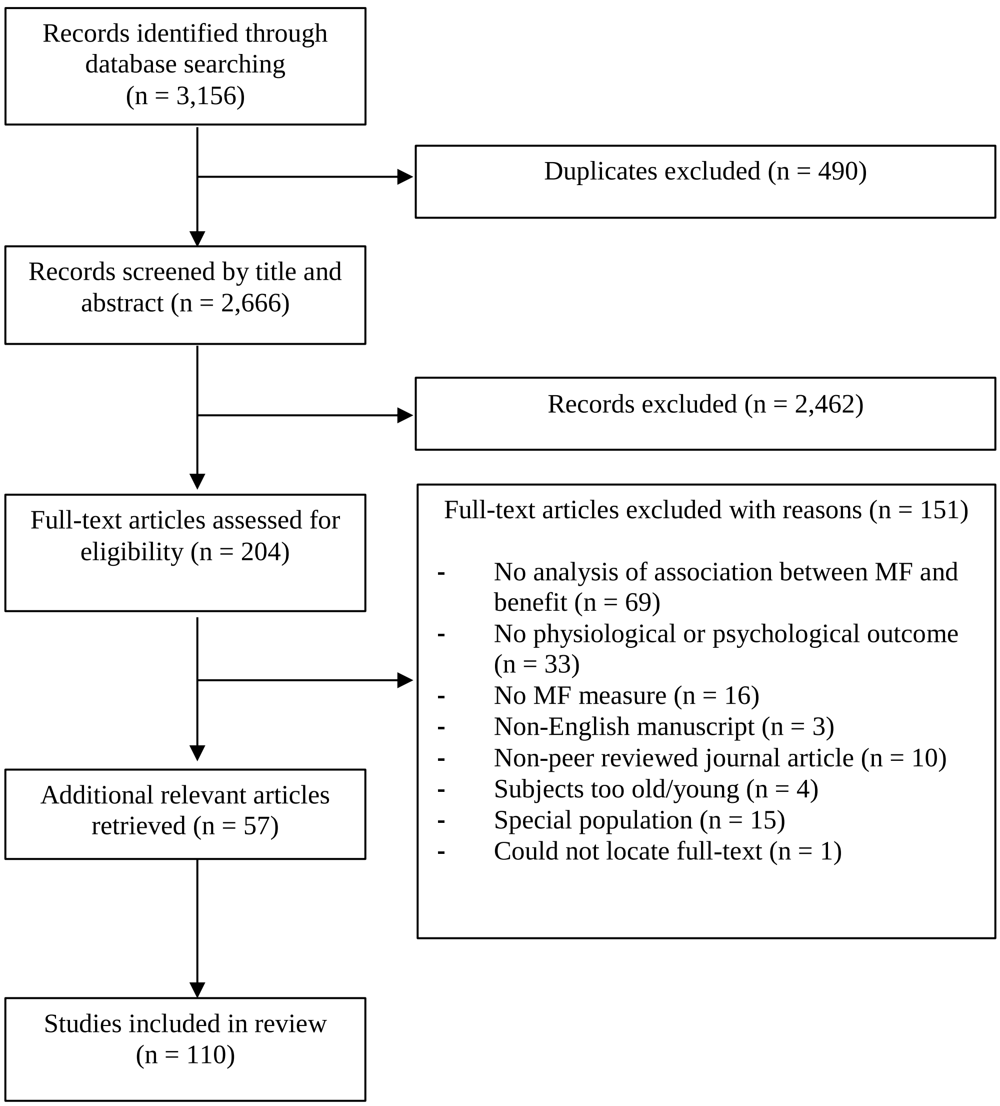

Figure 3.1 Flow of studies through the review process

3.3 Results

3.3.1 Overview of studies

The systematic search yielded 2666 potentially relevant articles following the removal of duplicates (Figure 3.1). After full text screening and checking the reference lists of included studies and previous reviews for additional relevant articles, a total of 110 studies were included. Of the included studies, 86 were cross-sectional, 20 were longitudinal and four were experimental. The number of study participants ranged from 20 (315) to 1,142,599 (160). Further details on study characteristics are presented in Table 3.1.

3.3.2 Overview of study quality

There was 95% agreement between raters for risk of bias and consensus was achieved on all included studies following discussion. Inter-rater agreement was found to be high (*Kappa* = 0.86, $p < 0.001$). The results of the risk of bias assessment can be found in Table 3.2. Overall, one study (1%) was considered to have a high risk of bias, 34 studies (31%) were considered to have a moderate risk of bias, and 75 studies (68%) were considered to have a low risk of bias. 'Random selection of study sites or participants' was the most poorly satisfied criterion with 54 studies (49%) scoring zero. The most consistently satisfied criterion was 'adequate description of the study sample' with only four studies (4%) scoring zero.

Table 3.1 Summary of included studies

Study	Sample; age (SD); sex (M/F); location	Study design	Analyses	MF measure(s)	Benefits assessed	Findings
Afghani et al. (316)	n=466; 12-16 yrs; (300/166); China	Cross-sectional	Bivariate correlation	GS	Forearm and heel BMD and BMC	There were significant moderate correlations between grip strength and forearm and heel BMC and BMD.
Almuzaini (317)	n=44; 11-19 yrs; (44/0); Saudi Arabia	Cross-sectional	Bivariate correlation	GS; Isokinetic strength and endurance (knee flexors and extensors); VJ	BMI; Sum of 4 skinfolds; %BF	BMI was positively associated with GS, Isokinetic strength and VJ. Sum of 4 skinfolds was not associated with any MF measure. %BF was negatively associated with VJ.
Andersen (318)	n=259; 16.5(0.6) yrs at baseline; (117/142); Denmark	Longitudinal (2 year follow-up)	Stepwise multiple regression	Biceps curls; Sit ups; Back extension CMJ; Seated ball throw (iron ball)	BMI	Change in BMI was associated with change in back extension. All other relationships were non-significant.
Andersen (319)	n=9413; 17.1(0.6) yrs; (3956/5457); Denmark	Cross-sectional	Logistic regression	BME (Biering-Sørensen test); VJ	Back pain (Self-reported)	VJ was not associated with back pain. BME was inversely associated with back pain after adjustment for height and sex. OR's for back pain were 0.89 (95% CI, 0.78–1.02), 0.78 (95% CI, 0.68–0.89), and 0.71 (95% CI, 0.62–0.82) for the upper three quartiles compared with the lowest quartile of BME, respectively. The highest quartile of BME had 20% lower risk of back pain compared with the lowest quartile.
Annesi (320)	n=25; 5-11 yrs; (17/8); USA	Experimental (12 weeks)	Multiple linear regression	1 minute push-ups	BMI	A unique contribution to the overall variance in BMI was made by change scores in muscular strength but not changes in CRF.
Ara et al. (321)	n=114; 9.4 (1.5) yrs; (114/0); Spain	Cross-sectional	Bivariate correlation; Linear regression	Max isometric strength; squat jump; CMJ	%BF	%BF and total and regional fat mass were significantly associated with jump heights of the squat jump and CMJ and with maximal strength.

Ara et al. (322)	n= 1068; 7-12 yrs; NR; Spain	Cross-sectional	t-test; Bivariate correlation	GS; SLJ; Sit ups; BAH	Weight status (BMI); Sum of 6 skinfolds; Trunk skinfolds	Correlations between sum of 6 skinfolds, trunk skinfolds, BMI and BAH were moderate and positive.
Artero et al. (56)	n=2472; 13-18.5 yrs; (1196/1278); Spain	Cross-sectional	ANCOVA	GS, BAH; SLJ	Weight status (BMI)	Overweight and obese boys and girls had significantly better GS compared with underweight and normal weight. BAH and SLJ were significantly better for normal weight compared with overweight and obese. Associations may be related to differences in body composition.
Artero et al. (173)	n=709; 14.9(1.3) yrs; (346/363); Europe	Cross-sectional	Multiple linear regression; ANCOVA	Relative GS, SLJ; MFS	Clustered metabolic risk	MF was negatively associated with clustered risk independent of CRF (β=-0.249, p=<0.001). After adjustment for CRF, the odds of having high clustered risk in the lowest quartile compared with the highest quartile was 5.3. Significant differences in clustered risk between MF levels persisted among non-overweight and overweight participants.
Artero et al. (323)	n= 709; 14.9(1.3) yrs; (346/363); Europe	Cross-sectional	Partial correlation; ANCOVA; Multiple linear regression; Logistic regression	Relative GS, SLJ; MFS	Clustered inflammation score	MF was significantly associated with the individual biomarkers and clustered inflammation score independent of CRF and insulin resistance (β range = -0.298 to -0.049). Adjustment for adiposity attenuated the associations. After adjustment for CRF and insulin resistance, the odds of having high clustered inflammation were significantly greater for those with low MF. Decreasing values of inflammatory score were observed across incremental levels of MF in both non-overweight and overweight adolescents ($P<0.05$).
Barnekow-Bergkvist et al. (324)	n=278; 16.1(0.3) yrs at baseline; (157/121); Sweden	Longitudinal (18 year follow-up)	Multiple logistic regression	Two hand lift; GS; Bench press	Experiencing lower back or neck/shoulder pain symptoms	High bench press performance during adolescence was associated with a significantly decreased risk of neck-shoulder problems in adulthood among men. High two-hand lift performance during adolescence was associated with a

						significantly decreased risk of low back problems in adulthood among women.
Barnekow-Bergkvist et al. (325)	n=278; 16.1(0.3) yrs at baseline; (157/121); Sweden	Longitudinal (18 year follow-up)	Bivariate relative risk; Multiple logistic regression.	Two hand lift; Sit ups; Bench press	BMI	Higher performance in the bench press was associated with greater odds of high BMI for males. Higher performance in the two-hand lift was associated with increased odds of high BMI for females but not males at age 34.
Barnekow-Bergkvist et al. (326)	n=36; 16.0(0.3) yrs; 15-17 years (at baseline); (0/36); Sweden	Longitudinal (20 year follow-up)	ANCOVA; Stepwise multiple regression	Hanging leg lift; GS; Two hand lift	Multiple-site BMD	MF during adolescence independently predicted BMD of the whole body, arms, legs and trochanter in adulthood.
Benson et al. (174)	n=126; 10-15 yrs; (71/55); New Zealand	Cross-sectional	Simple and Multiple stepwise regression; Logistic regression	1RM bench press; 1RM leg press; Absolute and relative strength composite	Insulin sensitivity (HOMA2-IR)	All strength variables were associated with insulin resistance. High and moderate strength groups were 98% less likely than the low strength group to have high insulin resistance. The association for the high strength group was slightly attenuated but persisted after adjustment for CRF. If relative strength was used in the model, the protective effect was no longer significant.
Benson et al. (42)	n=78; 12.3(1.3) yrs; (46/32); New Zealand	Experimental (8 week RCT)	Simple and Multiple stepwise regression	1RM bench press; 1RM leg press; Absolute and relative strength composite	WC	The decrease in WC of the whole cohort (INT and CON combined) over the study period was highest among those with higher relative upper body strength at baseline (r= 0.257, p= 0.036). The improvement in WC among the whole group was greatest in those with the greatest change in upper body absolute (r= -0.34, p= 0.006) and relative (r= -0.40, p= 0.001) strength. However, when separated by treatment group this association was only significant among control subjects and only for relative strength.
Bovet et al. (327)	n=4343; 12-15 yrs; (2202/2141); Seychelles	Cross-sectional	Locally weighted regression	Push-ups; Sit ups; Lateral jump; VJ; Basketball	BMI	For all tests except the ball throw, healthy weight subjects performed better than overweight or obese subjects. There were a significantly higher proportion of healthy

				throw		weight subjects performing above the 75th percentile compared with overweight/obese peers for the VJ, lateral jump, push-ups and sit ups. In the basketball throw a higher proportion of obese subjects performed above the 75th percentile compared with healthy weight subjects.
Brandon & Fillingim (328)	n=386; 9(0.9) yrs; (19/187); USA	Cross-sectional	Bivariate correlation	1 minute Sit ups	Elevated blood pressure (High BP $\geq$ 108/76)	There was a significant inverse association between systolic BP and Sit up performance among those with elevated BP. The same relationship was not significant among those with low BP, nor was the association between Sit ups and diastolic BP for either group.
Brunet et al. (329)	n=1140; 6-10 yrs; (591/549); Canada	Cross-sectional	Bivariate correlation; Partial correlation	1 minute Sit ups; SLJ	BMI; WC	BMI and WC, and MF were significantly inversely associated for both genders and these correlations were higher among older children.
Butterfield et al. (330)	n=65; 5-8 yrs; NR; USA	Cross-sectional	Multiple linear regression	GS; 1 minute Sit ups	BMI	BMI was significantly associated with GS (Beta= .27, p<.05) and significantly associated with Sit ups (Beta= - .26, p<.05)
Cardon et al. (331)	749; 8-12 yrs; (367/382); Belgium	Cross-sectional	ANOVA	GS; BAH; SLJ	Back and neck pain (Self-reported)	There were no significant differences in performance on any of the MF tests between subjects experiencing pain and those not experiencing pain.
Castelli et al. (195)	n=259; 9.5(0.7) yrs; (132/127); USA	Cross-sectional	Bivariate correlation; Two step hierarchical regression	Fitnessgram: Push-ups; Sit ups	Academic achievement (ISAT tests)	CRF and BMI were significant predictors of achievement across all three ISAT tests but Push-ups and Sit ups performance were not.
Castelli & Valley (332)	n=230; 7-12 yrs; (140/90); USA	Cross-sectional	Bivariate correlation; Two-step hierarchical regression	Fitnessgram: Push-ups; Sit ups	BMI	Push-ups and Sit ups were inversely associated with BMI
Castro-Piñero et al.	n=2778; 6-17.9 yrs; (1513/1265); Spain	Cross-sectional	ANOVA	Push-ups; BAH, Pull ups; Sit	Weight status (BMI)	Underweight and normal weight children scored significantly better than overweight

(333)				ups; Curl ups; SLJ; VJ; Basketball throw		and obese on the SLJ, VJ and Push-ups for boys, and in the BAH for both boys and girls.
Chen et al. (334)	1999 sample: n=13,935; 6-18 yrs; (7,031/6904); Taiwan 2001 sample: n=24,586; 6-18 yrs; (12,367/12,219); Taiwan.	Cross-sectional	ANOVA	1 minute Sit ups	Weight status (BMI)	In both samples the normal weight group had significantly higher Sit ups performance compared with the overweight/obese group.
Chen et al. (335)	n=878,207; 7-18 yrs; (444,652/433,555); Taiwan	Cross-sectional	Simple relative risk	1 minute Sit ups; SLJ	Weight status (BMI)	The risk of poor MF (i.e., <25th percentile) was higher for overweight and obese subjects compared with normal weight subjects.
Cheng et al. (336)	n=179; 12-13 yrs; (92/87); China	Cross-sectional	Bivariate correlation; Stepwise multiple regression	GS; 1 minute Sit ups; VJ	Distal radius BMC; Spine BMD	Significant positive associations were found for both BMC and BMD and performance on all MF tests except for between BMC and Sit ups for boys and BMC and VJ for girls. VJ was a significant predictor of BMD in boys and Sit ups was a significant predictor of BMD in girls.
Cheng et al. (337)	n=179; 12-13 yrs; (92/87); China	Longitudinal (3 year follow-up)	Bivariate correlation; Stepwise multiple regression	GS; Knee flexion torque; 1 minute Sit ups; VJ	Distal radius BMC; Spine BMD	Mean score in the flexion test was significantly correlated with BMC and BMD in both genders in cross-sectional analyses. Longitudinally, peak flexion torque was a significant predictor of BMD for girls only.
Clark et al. (338)	n=1590; 12-16yrs; (787/803); Northern Ireland	Cross-sectional	Logistic regression	GS; VJ	Bone fracture (Parental report)	Aerobically fit subjects were more likely to have had a fracture. GS and VJ moderated the CRF-fracture relationship such that the association existed for those with low GS and VJ but not for those with high GS and VJ. Compared to those in the high MF groups, those in the low MF groups had increased odds of having had a fracture.

Coe et al. (181)	n=312; 12.1(0.9) yrs; (162/150); USA	Cross-sectional	Bivariate correlation	Fitnessgram: Push-ups; Sit ups	Yearly academic achievement; Terra Nova standardised test score; %BF	Push-ups and Sit ups were weakly associated with grades and the Terra Nova test score. %BF was inversely associated with both Push-ups and Sit ups.
Cureton et al. (339)	n=49; 8-11 yrs; (49/0); USA	Cross-sectional	Bivariate correlation; Multiple regression	Sit ups; Pull ups; SLJ	Body density (Hydrostatic weighing); Sum of 10 skinfolds; Sum of 2 skinfolds	Significant moderate inverse correlations were found between Pull ups and Sit ups and sum of 10 and sum of 2 skinfolds. Significant positive associations were found between body density and SLJ and Pull ups.
Deforche et al. (340)	n=3214; 12-18 yrs; NR; Belgium	Cross-sectional	ANOVA	GS; Sit ups; BAH; SLJ	Obesity (BMI over 90th percentile)	Non-obese subjects recorded significantly better performances in SLJ, Sit-ups and BAH. By contrast, obese subjects showed greater GS than the non-obese subjects.
Du Toit et al. (341)	n=212; 9-12 yrs; (94/118); South Africa	Cross-sectional	Bivariate correlation; Stepwise discriminant analysis	Total strength composite (from 5 MF tests)	Average of academic marks (eight core subjects)	Significant weak to moderate correlations were found between MF and academic performance. These were more consistent for girls and those in the 11- and 12-year age groups. Wall sitting, sit and reach, and Sit ups discriminated most between high and low achievers but this was not significant.
Duppe et al. (342)	n=102; 15-16 yrs; (58/44); Sweden	Cross-sectional	Bivariate correlation; Partial correlation	Isokinetic strength (quadriceps)	Multiple site BMD and BMC	A positive correlation was found between strength and BMD at almost all measured sites in boys. In girls the relationship was seen only between muscle strength and total body BMD. Adjustment for age and weight showed that strength was not an independent predictor of BMD at any site, in either sex.
Dwyer et al. (343)	n=7961; 7-15 yrs; NR; Australia	Cross-sectional	Bivariate correlation; Linear regression	GS, Flexion and extension strength (shoulder and leg); Push-ups; Sit ups; SLJ	Scholastic ability (rated by school principal on a 5-point scale)	Boys and girls with a higher scholastic rating performed better in the Sit ups and SLJ in most age groups, shown by weak but consistent significant associations. Regression analysis showed that Sit ups performance was a significant predictor of scholastic ability even after adjustment for

						BMI, Parental involvement measures and SES.
Edwards et al. (344)	n=800; 11-13 yrs; NR; USA	Cross-sectional	ANOVA	Fitnessgram: Push-ups; Pull ups	MAP test scores (Maths and reading ability level)	There were no significant differences in reading or maths test scores between those in the HFZ or the NIZ for Push-ups or Pull ups, although it was borderline significant for Maths score and push-ups.
Feldman et al. (345)	n=502; 13.8(0.1) yrs; (264/238); Canada	Longitudinal (6- and 12-month follow-up).	Multiple logistic regression	Isometric abdominal strength	Low back pain (Self-reported)	There was no significant difference in abdominal strength between those with and without back pain at either follow-up period. Logistic regression analysis determined that abdominal strength was not associated with back pain at 6- or 12-months.
Fogelholm et al. (177)	n=2348; 15-16 yrs; (1167/1181); Finland	Cross-sectional	Two-way ANOVA; Linear regression	Sit ups; 5-jump test	Weight status (BMI): (weight/height self-reported)	Overweight and obese subjects performed poorer than their normal weight peers irrespective of PA level. Results of the regression analysis indicated that weight status (unadjusted for PA) was a significant predictor of performance in the Sit ups and in the 5-jump.
Fonseca et al. (346)	n=144; 15-18 yrs; (65/79); Brazil	Cross-sectional	Bivariate correlation; Stepwise multiple regression	1 minute Sit ups; 1 minute Push-ups	Multiple site BMD	Significant associations were found for Push-ups and BMD among females but not males. Sit ups were associated with BMD at all sites among males but not females. Lean body mass and Sit ups significantly predicted total body BMD (b= 0.338, $p<0.01$, R^2 = 43%) for males but not females. Sit-ups were not predictive of BMD of the lumbar spine for either sex.
Foo et al. (179)	n=283; 15(0.5) yrs; (0/283); China	Cross-sectional	ANOVA; Multiple regression	GS	Total body and forearm BMC and bone area	GS was a significant independent predictor of proximal forearm BMC. GS was not a predictor of either total body or distal forearm BMC. GS was also a significant independent predictor of bone area of both the distal forearm and proximal forearm but not of the total body.

Freitas et al. (347)	n=450; 8-16 yrs at baseline; (231/219); Portugal	Longitudinal (7 year follow-up)	Stepwise multiple linear regression	Eurofit: GS; Sit ups; BAH; SLJ	Overweight/obesity (BMI, Sum of 5 skinfolds, and WC)	MF at baseline among the three age groups was predictive of adiposity 7 years later. Sit ups, GS and SLJ were significant predictors of adiposity among boys and BAH and SLJ were significant predictors among girls. The variance explained by MF was generally small ranging from 1 - 4% for males and 1 - 28% for girls across all age groups.
García-Artero et al. (348)	n=460; 15.2(1.4); (248/212); Spain	Cross-sectional	Partial correlation; Polynomial contrast; ANCOVA	Eurofit: GS; BAH; SLJ; GSI	Lipid-metabolic index	Polynomial contrast showed a linear relationship between the GSI and lipid-metabolic index among females after adjusting for age, maturation, and CRF. A significant difference in lipid metabolic index between the first and third tertile of GSI was observed among females but not males.
Ginty et al. (349)	n=128; 16.8(0.5) yrs; (128/0); UK	Cross-sectional	Bivariate correlation; multiple linear regression	Back strength; GS	Multiple site BMC, BMD and BA	Back strength but not GS was significantly associated with time spent on high impact physical activities. GS was associated with BMC, BMD, and bone area at all measured sites. After size adjustment GS was only related to radius and trochanter BMC. Back strength was associated with BMC, BMD, and bone area at all measured sites. After size adjustment back strength was only related to BMC at multiple sites.
Gonzalez-Suarez & Grimmer-Somers (350)	n=380; 11-12 yrs; (167/213); Philippines	Cross-sectional	Kruskall-Wallis test; Bivariate correlation; Logistic regression	SLJ	Weight status (BMI)	Normal weight subjects performed significantly better than overweight and obese subjects in the SLJ. Overweight and obese subjects, adjusted for age and gender, were significantly more likely to perform below the median in the SLJ compared with normal weight subjects.
Gonzalez-Suarez et al. (351)	n=1021; 11.1(0.9); (513/508); Philippines	Cross-sectional	Bivariate correlation; ANOVA	1 minute Sit ups; SLJ	Weight status (BMI); WC	Obese boys and girls performed worse than normal weight and overweight in both the Sit ups and SLJ. Overweight and obese subjects were more likely than normal

						weight subjects to perform below the median in the SLJ and Sit ups, with the exception of overweight girls in the Sit ups. There were significant weak inverse correlations between BMI and WC and both Sit ups and SLJ for all subjects. Associations were stronger for males.
Gracia-Marco et al. (352)	n=390; 14.8(1.2); (182/191); Spain	Cross-sectional	ANCOVA	GS; SLJ	Multiple site BMC	Non-active adolescents performing worse in GS and SLJ had lower BMC. Non-active adolescents with better SLJ (tertile 3) showed higher whole body BMC than active ones in this tertile. Active adolescents with the worst GS showed higher BMC in the whole body and lower limbs than non-active adolescents.
Grøntved et al. (53)	n=332; 15.6(0.4) yrs at baseline; NR; Denmark	Longitudinal (6- and 12-yr follow-up)	Multiple linear regression; Multiple logistic regression	Relative isometric strength	Individual CVD risk factors and combined CVD risk score	Strength in youth was significantly associated with individual risk factors and the combined CVD risk score in young adulthood (adjusted for age, sex, recruitment period, and CRF). In multivariable-adjusted analyses including CRF, each 1 SD increase of isometric muscle strength in youth was associated with 0.59 lower odds of general overweight or obesity in young adulthood.
Grund et al. (353)	n=88; 5-11 yrs; (49/39); Germany	Cross-sectional	ANOVA; Bivariate correlation	Isometric strength of the quadriceps and Ischiocruralis	Weight status (BMI); Skinfolds	There were no significant differences in nutritional state between strength groups among the whole group. However, for older children the weakest group had higher BMI and skinfolds when compared with strongest group.
Hands et al. (354)	n=1585; 14.1(0.2) yrs; (814/771); Australia	Cross-sectional	Bivariate correlation; t-test; Multiple regression	Sit ups; Seated chest pass	BMI	BMI was weakly associated with chest pass and Sit ups among both genders.
Hasselstrom et al. (355)	n=203; 15-19 yrs; (88/115); Denmark	Longitudinal (8 year follow-up)	Linear regression	Combined relative strength score	Individual CVD risk factors and combined CVD risk score	Strength at baseline was inversely associated with %BF 8 years later in men but not women. Change in strength over 8

						years was inversely associated with waist girth and %BF at follow-up in men but not women. Change in strength over 8 years was associated with change in %BF over 8 years in men but not women. No other risk factors were significantly related for either gender.
Haugen et al. (356)	n=1839; 15 yrs; (950/889); Norway	Cross-sectional	Bivariate correlation; Mediation analysis	Push-ups; SLJ	Physical self-perceptions: Perceived athletic competence; Perceived physical appearance	Push-ups and SLJ were positively associated with perceived athletic competence, perceived physical appearance and PA among both genders. Push-ups and SLJ were found to mediate the relationship between PA and perceived athletic competence among both genders. The relationship between PA and perceived physical appearance was mediated by Push-ups and SLJ for males only.
Heroux et al. (357)	n=736; 9-13 yrs; (374/362); Canada. n= 93; 10-13 yrs; (98/95); Mexico. n=179; 9-13 yrs; (86/93); Kenya.	Cross-sectional	Linear regression	GS	Triceps skinfold; WC; Weight status (BMI)	GS was not significantly associated with body composition variables in the Kenyan sample. GS was positively associated with BMI and WC but not skinfold among boys and girls in the Mexican and Canadian samples but only explained 9-14% of the variance (R^2 range = 0.09 - 0.14). The association was strongest for Mexican girls (R^2 = 0.32).
Hoekstra et al. (358)	n=2016; 12 and 15 yrs; (1018/998); Northern Ireland	Cross-sectional	Bivariate correlation; Linear regression	GS; VJ	Individual CVD risk factors	Associations were found between CVD risk factors and MF, adjusted for confounders. Adjustment for CRF attenuated most associations. However, the association between skinfolds remained significant as did diastolic blood pressure for 15 yr old girls. No interaction between MF and CRF was found in the association with CVD risk factors.
Hruby et al. (359)	n=2793; grades 1-7; (1456/1337); USA	Longitudinal (4 year follow-up)	Logistic regression	Sit ups; Pull ups; BAH	Weight status (BMI)	Following adjustment for multiple confounders, achieving and maintaining ‘adequate’ fitness over the four years was

						associated with increased odds of being a healthy weight at follow-up.
Huang & Malina (360)	n=102,765; 9-18 yrs; (51825/50940); Taiwan	Cross-sectional	Non-linear quadratic model	1 minute Sit ups; SLJ	BMI	Poorer performance in Sit-ups and SLJ was evident in boys and girls in each age group with higher BMIs. The relationship becomes parabolic during adolescence and peaks of the parabola are sharper in boys than girls.
Huberty et al. (361)	n=826; 6-11 yrs; (391/435); USA	Cross-sectional	Non-linear mixed modelling (PROC NLMIXED procedure)	Fitnessgram: Push-ups; Sit ups	Weight status (BMI)	Weight status was not a significant factor in describing differences in the mean number of Push-ups or Sit ups. Weight status was a significant predictor in the model of meeting/exceeding the national standards for Push-ups and borderline significant for Sit ups.
Huotari et al. (362)	1976: n=643; 15 yrs; (312/331); Finland 2001: n=579; 15 yrs; (308/271); Finland	Cross-sectional	General linear models	Sit ups; BAH; Pull ups; SLJ; MFI	BMI	In both sexes MFI was significantly lower among overweight/obese than normal weight participants in both study years.
Janz et al. (363)	n=112; 10.5 (at baseline); (54/58); USA	Longitudinal (5 year follow-up)	Partial correlation; Multiple linear regression	GS	Individual CVD risk factors	Change in GS and average GS over the five year period were significantly associated with WC and sum of skinfolds at follow-up, following adjustment for multiple confounders. GS explained 5% of the variance in year-5 WC
Johnson et al. (364)	n=625; 11-19 yrs; (290/335); Nigeria	Cross-sectional	t-test; Bivariate correlation	BME (Biering-Sørensen test)	Low back pain; BMI; Hip circumference; Waist-to-hip ratio; WC	There was a significant difference in BME between those with and without current back pain and those that had or hadn't had a past history of back pain. There were weak but significant inverse correlations between BME and BMI, Hip circumference, and waist to hip ratio. WC was borderline significant.
Johnson et al. (365)	n=625; 11-19 yrs; (290/335); Nigeria	Cross-sectional	Chi square test of association;	BME (Biering-Sørensen test)	Low back pain	The relative risks (OR and 95% CI) of developing back pain among those that had

			Logistic regression			poor back muscles' endurance compared with those with moderate and good back endurance were (OR 0.52; CI 0.21–0.82) and (OR 0.97; CI 0.48–1.96) respectively. Chi square test of association result indicates that level of back muscle endurance was significantly associated with LBP in adolescents.
Joshi et al. (366)	n=6625; 5-17 yrs; (3084/3541); USA	Cross-sectional	Logistic regression; Chi-square test	Fitnessgram: Sit ups; Trunk lifts; Push-ups	Weight status (BMI)	There was a significant difference in Sit ups and Push-ups between normal weight and obese subjects in favour of normal weight. No significant differences were observed between weight groups for the trunk lift.
Kardinaal et al. (367)	n=1116; 11-15 yrs; (0/1116); Europe	Cross-sectional	Bivariate correlation; Multiple regression	GS	Radius BMC and BMD	A number of bone parameters (notably BMC and BMD) were moderately to strongly associated with GS. In the multivariate model GS was an independent predictor of most bone parameters after additional adjustment for age and tanner stage.
Kim et al. (368)	n=6297; 5-14 yrs; NR; USA	Longitudinal (12 month follow-up)	Multiple logistic regression	Fitnessgram: Sit ups; Pull ups; BAH	Weight status (BMI)	Baseline upper body strength significantly predicted incidence of overweight 1 year later for boys and girls. However, adjustment for baseline BMI z-score attenuated the association.
Lloyd et al. (369)	n=200; 10-12 yrs; (91/109); USA	Cross-sectional	Bivariate correlation	Sit ups; Push-ups; Pull ups	Sum of 2 skinfolds; BMI	Skinfolds and BMI were significantly correlated with Push-ups and Sit ups. Approximately, 15% of the variance in Sit ups and 12% of the variance in Push-ups could be explained by skinfolds.
Lubans & Cliff (370)	n=106; 14.9(0.7); (54/52); Australia	Cross-sectional	Product of coefficients test	1RM bench press and leg press (absolute and relative)	Physical self-perceptions: Physical self-worth; Perceived physical strength	Physical self-worth was significantly associated with absolute strength for boys and with relative strength for girls. Perceived physical strength mediated the relationship between absolute strength and physical self-worth for boys. In girls the

						relationship between relative strength and perceived physical strength was not significant, nor was the mediated effect.
Mafanya & Rhoda (371)	n=181; 16(1.1) yrs; (97/84); South Africa	Cross-sectional	Logistic regression	Neck flexor endurance	Neck pain (Self-reported)	There was a significant association between neck pain and neck flexor muscle endurance.
Magnussen et al. (372)	n=1642; 9-15 yrs; (870/772); Australia	Cross-sectional	Linear regression	Isokinetic strength score; Push-ups; SLJ	Individual CVD risk factors and combined CVD risk score	Individual CVD risk factors and the combined risk score were associated with all MF phenotypes. Muscular endurance and power remained significant after adjustment for BMI. In multivariate analyses muscular power, CRF and the power x CRF interaction were all significant predictors of the combined CVD risk score.
Malina et al. (373)	n=6700; 7-17 yrs; (0/6700); Belgium	Cross-sectional	Partial correlation; t-test	Arm pull; BAH; Leg lifts; Sit ups; VJ; SLJ	Sum of 5 skinfolds	Significant partial correlations were found between skinfolds and the MF tests across age groups. Comparisons of MF between the leanest and fattest 5% showed that leaner girls performed significantly better than the fatter girls.
Malina et al. (374)	n=686; 6-13 yrs; (344/342); Mexico	Cross-sectional	MANCOVA	GS (absolute and Relative); Sit ups; SLJ	Weight status (BMI)	Grip strength was significantly lower for all normal weight subjects except for grade 1-3 boys. However, when compared against relative values normal weight was significantly better than overweight. No significant differences between weight groups were observed for SLJ or Sit ups performance.
Marsh (375)	n=192; 13-15 yrs; (113/79); Australia	Cross-sectional	Bivariate correlation; Partial correlation	Modified pull ups; Basketball throw; SLJ	Self-esteem/Physical self-perceptions: Appearance; Strength; Endurance; Flexibility; Health; Coordination; Activity; Body fat; Sports competence;	MF was associated with a number of physical self-perceptions as well as physical self-concept and global self-esteem.

					Global physical self-concept; Global self-esteem.	
Martínez-Gómez et al. (376)	n=198; 13-17 yrs; (102/96); Spain	Cross-sectional	Multiple linear regression; ANCOVA	GS; SLJ; MFS	Adipocytokines	MFS was significantly and inversely associated with Adiponectin and Leptin. A significant difference was found between high and low MFS groups for both Adiponectin and Leptin.
Martinez-Gomez et al. (187)	n=1025; 14.8(1.2); (476/549); Europe	Cross-sectional	Partial correlation; Multiple regression	GS; SLJ; MFS	Inflammatory biomarkers; BMI	Weak but significant associations were found between MFS and BMI. WC was not related. MFS was significantly associated with inflammatory biomarkers, adjusted for confounders.
Mikkelsson et al. (377)	n=1121; 12-17 yrs at baseline; (801/880); Finland	Longitudinal (25 year follow-up)	Logistic regression	Sit ups	Tension neck; low back pain; knee injury (Self-reported)	Higher Sit ups at baseline was associated with reduced risk of tension neck in adulthood for women in the univariate model. This became borderline significant in the multivariate model. There was an increased risk of knee injury in men with high Sit ups at baseline in the multivariate model. No association was found for Sit ups and low back pain.
Minck et al. (378)	n= 181; 13.0; (83/98); Holland	Longitudinal (15 year follow-up)	Longitudinal linear regression with generalised estimating equations	Arm pull; BAH; VJ; Ten leg lifts	Sum of 4 skinfolds	In adjusted analyses skinfolds was longitudinally associated with VJ and leg lifts.
Moliner-Urdiales et al. (379)	n=363; 12.5-17.5 yrs; (177/186); Europe	Cross-sectional	Multiple regression	GS; VJ; SLJ	Adiposity: Sum of 6 skinfolds; WC; Bodpod; DXA	All measures of total and central adiposity were inversely associated with VJ and SLJ. A positive association was observed for GS and total adiposity measured by DXA only and between GS and WC.
Morano et al. (380)	n=260; 12.2(0.9); (140/120); Italy	Cross-sectional	Bivariate correlation; ANOVA	SLJ; Medicine ball throw	Body image; BMI; Physical self-perceptions: Coordination; Body	SLJ was inversely associated with BMI while ball throw was positively associated. SLJ was moderately and positively associated with perceived coordination,

					fat; Sports competence; Physical ability	perceived sports competence, and perceived physical ability. SLJ was moderately and inversely associated with perceived body fat and body dissatisfaction for both genders. Ball throw was weakly and positively associated with perceived body fat in both genders.
Mota et al. (381)	n= 229; 12-15 yrs; (0/229); Portugal	Cross-sectional	ANCOVA; Partial correlation; Logistic regression	Fitnessgram: Sit ups, Push-ups	Individual CVD risk factors and MRS	Analyses adjusted for confounders, found that girls in the highest MF group had lower BMI, better lipid profile, and had a lower MRS than those in the lowest MF group. MF was negatively associated with individual CVD risk factors and the MRS. Compared to those in the low MF group, those in the high and middle groups had significantly lower odds of a high MRS.
Newcomer et al. (382)	n=96; 10-19 yrs; (53/43); NR	Longitudinal (4 year follow-up)	Logistic regression	Back strength	Low back pain (Self-reported and diagnosed)	Subjects with higher back strength had a significantly higher percentage of positive responses to experiencing back pain ever and in the past year, after adjustment for confounders. There was also a significant positive association between 4-year increase in back flexor strength and past year back pain but not back pain ever. No significant association was found for 4-year change in back extensor strength and back pain. Diagnosed back pain was not associated with back strength.
O'Sullivan et al. (383)	n=1328; 14.1(0.2); NR; Australia	Cross-sectional	Multivariable multinomial logistic regression	BME (Biering-Sørensen test)	Back pain (Self-reported)	For females but not in males, better BME was associated with decreased odds for back pain made worse by sitting compared with both no back pain and back pain not made worse by sitting. The association for females between BME and back pain made worse by sitting remained similar after adjustment for covariates.
Ortega et al. (384)	n=2859; 13-18.5 yrs; (1357/1502);	Cross-sectional	Non-parametric	Eurofit: GS; BAH; SLJ	Low CRF related to future CVD risk	The group of adolescents with CRF indicative of future CVD risk performed

	Spain		Mann-Whitney test			significantly worse in GS (boys only), SLJ, and BAH
Ortega et al. (160)	n=1142599; 10-19 yrs; (1142599/0); Sweden	Longitudinal (median 24 year follow-up)	Cox proportional hazards regression	GS; Knee extension strength; Elbow flexion strength	All-cause, CVD-, Cancer-, and Suicide-related mortality; Risk of psychiatric diagnosis	Higher strength was associated with approximately 20% reduced risk of all-cause mortality and 35% reduced risk of CVD-related mortality. Higher strength was associated with a 20-30% lower risk of death from suicide and 15-65% reduced risk of any psychiatric diagnosis. No association was found for cancer-related mortality. The effect size for low strength and all-cause mortality was similar to that for high BMI and blood pressure.
Padilla-Moledo et al. (180)	n=690; 6-17.9 yrs; (368/322); Spain	Cross-sectional	Multiple regression; Binary logistic regression	SLJ; Basketball throw; MFI	Psychological positive health; Health complaints; Health risk behaviours	With the exception of quality of peer relationships, the MFI was positively associated with all psychological positive health indicators. MFI was also inversely associated with tobacco and alcohol use. Additional adjustment for BMI didn't change the findings.
Pate et al. (385)	Sample 1: n=2520; 6-16 yrs; NR; USA Sample 2: n=2262; 6-18 yrs; NR; USA	Cross-sectional	Bivariate correlation; Stepwise multiple regression; Kruskal-Wallis test	1 minute Sit ups	Sum of 2 skinfolds	Sit ups were weakly and inversely associated with skinfolds for both genders Among sample 1, significant differences in Sit-ups were found between weight groups for both genders in favour of leaner subjects. In sample 2, nearly identical findings were observed.
Perry et al. (386)	n=1608; 14.1(0.2) yrs; (825/783); Australia	Cross-sectional	Logistic regression	Back extension; Sit ups; SLJ; Basketball throw	Back pain (Self-reported and diagnosed)	Increased odds of experiencing back pain in the past month was associated with greater abdominal endurance in girls. Increased odds of diagnosed back pain was associated with both reduced back endurance and greater back endurance Lower odds of back pain ever was associated with greater SLJ.
Pino-Ortega et al. (387)	n=293; 10(0.8) yrs; (137/156); Spain	Cross-sectional	Multinomial logistic regression	GS; SLJ	Weight status (BMI)	The odds of being in the high GS group was significantly lower among normal weight subjects compared with overweight. Conversely, normal weight subjects had

						significantly higher odds of being in the high SLJ group compared with overweight subjects.
Pissanos et al. (388)	n=80; 6-10 yrs; (40/40); USA	Cross-sectional	Stepwise multiple linear regression	1 minute Sit ups; SLJ	Sum of 2 skinfolds	Skinfolds were significantly inversely associated with SLJ but not Sit ups.
Pongprapai et al. (389)	n=259; 6-12 yrs; (125/134); Thailand	Cross-sectional	ANOVA	Sit ups	Weight status	There were significant differences in Sit ups between weight groups for both genders in favour of leaner subjects.
Ransdell et al. (315)	n=20; 14-17 yrs; (0/20); NR	Experimental (2-arm uncontrolled trial)	Bivariate correlation	Modified Push-ups; Sit ups	Physical self-perceptions: Sports competence; Physical condition; Body attractiveness; Strength and muscularity; Physical self-worth	Changes in MF over the intervention period were not significantly associated with changes in any physical self-perceptions.
Raudsepp & Jurimae (390)	n=77; 10.5(0.6) yrs; (0/77); NR	Cross-sectional	Bivariate correlation	Eurofit: GS; Sit ups; BAH; SLJ	Sum of 5 skinfolds	GS and Sit ups were not related to skinfolds. SLJ and BAH were inversely associated with skinfolds.
Raudsepp & Jurimae (391)	n=203; 7-10 yrs; (203/0); NR	Cross-sectional	Bivariate correlation; Partial correlation	Eurofit: GS; Sit ups; BAH; SLJ	Sum of 5 skinfolds	SLJ and BAH were significantly associated with skinfolds among all age groups. Associations remained after additional adjustment for age and MVPA. Sit ups was associated with skinfolds among 8 and 10 yr olds but GS was not related to skinfolds among any age group.
Rice et al. (392)	n=35; 14-18 yrs; (0/35); NR	Cross-sectional	Bivariate correlation; Stepwise multiple regression	1RM leg press and bench press; Isokinetic strength	Whole body and spine BMC and BMD	Leg strength was significantly associated with all bone variables while Isokinetic strength was significantly positively correlated with BMC. The regression analysis indicated that Leg strength was not an independent predictor of any bone mass variables.
Ruiz et al. (393)	n=416; 13-18.5 yrs; (230/186); Spain	Cross-sectional	Multiple regression; ANCOVA	GS; SLJ; MFS	Inflammatory biomarkers; Skinfolds; %BF	After adjustment for multiple confounders including CRF, MFS was significantly inversely associated with specific

						inflammatory biomarkers among overweight adolescents. Overweight adolescents with high MFS had significantly lower skinfolds and %BF than those with low MFS.
Ruiz et al. (394)	n=1820; 13-18.5 yrs; (862/958); Spain	Cross-sectional	ANCOVA, Binary logistic regression	GS; SLJ	Cognitive performance (Test of educational ability: verbal, numeric and reasoning skills)	GS and SLJ were not associated with cognitive performance.
Sacchetti et al. (395)	n=497; 8-9 yrs; (256/241); Italy	Cross-sectional	Kruskal-Wallis test; t-test	Medicine ball throw; SLJ	Weight status (BMI)	For both genders SLJ became worse across increasing weight categories. The opposite occurred for the Medicine ball throw.
Sallis et al. (396)	n=528; 10.5(0.5) yrs; (274/254); USA	Cross-sectional	Multiple linear regression; Partial correlation	Fitnessgram: Pull ups; Sit ups	Sum of 2 skinfolds	Pull ups and Sit ups were inversely associated with skinfolds.
Salminen et al. (397)	n=76; 15 yrs; (34/42); Finland	Cross-sectional	t-test	6-stage Sit ups; Isometric abdominal hold; BME	Low back pain	Endurance of the abdominal and back muscles was significantly lower in the group with back pain. No differences were found for 6-stage Sit ups.
Salminen et al. (398)	n= 62; 15 yrs; (29/33); Finland	Longitudinal (3 year follow-up)	ANOVA	6-stage Sit ups; Isometric abdominal hold; BME	Low back pain	Diminished abdominal and back muscle endurance at baseline was associated with increased frequency of back pain. Low muscle endurance at baseline did not predict future back pain.
Sjölie et al. (399)	n=86; 14.7(0.6) yrs at baseline; (50/38); Norway	Longitudinal (3 year follow-up)	Binary logistic regression; ANOVA	BME (modified Biering-Sørensen test)	Low back pain (Self-reported)	There was a significant difference in BME at baseline between those with and without back pain. Those with higher BME had significantly decreased odds of back pain at baseline after adjustment for confounders. There was a significant difference in baseline BME between those with and without back pain at follow-up for girls but not boys. Baseline BME significantly predicted back pain at follow up after adjustment for confounders.

Slaughter et al. (400)	n=68; 7-12 yrs; (68/0); USA	Cross-sectional	Bivariate Correlation	SLJ; VJ	Sum of 2 skinfolds; %BF	SLJ and VJ were moderately inversely associated with both %BF and skinfolds.
Slaughter et al. (401)	n=50; 7-12 yrs; (0/50); USA	Cross-sectional	Bivariate Correlation	SLJ; VJ	%BF	SLJ and VJ were not significantly associated with %BF.
Smith et al. (402)	n=1435; 14(0.2) yrs; (733/702); Australia	Cross-sectional	Linear regression	BME (Biering-Sørensen test)	Global self-esteem; Self-efficacy; Depressed mood; Behavioural and emotional problems; BMI; Low back pain	Back pain in the last month was not associated with BME. Higher BMI was inversely associated with BME. Self-efficacy and self-esteem were positively associated with BME. Behavioural problems score was inversely related to BME. In the multivariate model BMI was the most significant factor related to BME.
Steene-Johannessen et al. (175)	n=1592; 9 and 15 yrs; (854/738); Norway	Cross-sectional	ANOVA; Partial correlation; Multiple regression; Logistic regression	GS; Sit ups; BME; SLJ; MFS	Individual CVD risk factors and combined CVD risk score	There were significant partial correlations between MFS and both individual and combined CVD risk factors. CVD risk declined with increasing MFS among all age and sex sub-groups. MFS was a significant predictor of combined CVD risk score, following adjustment for confounders including CRF. The association was found for overweight and non-overweight youth. Overweight youth in the lowest tertile of MFS showed the poorest cardiovascular profile.
Steene-Johannessen et al. (403)	n=836; 9 yrs; NR; Norway	Cross-sectional	Partial correlation; ANOVA; Multiple regression	GS; Sit ups; BME; SLJ; MFS	Inflammatory biomarkers	There were significant inverse partial correlations between MFS and inflammatory markers for both genders. There was a strong graded relationship across quintiles of MFS, with inflammation levels decreasing from low to high MFS. MFS was a significant predictor of C-reactive protein and Leptin levels independent of CRF and WC.
Thorsen et al. (404)	n=47; 16.9(0.3) yrs; (47/0); Sweden	Cross-sectional	Bivariate correlation	Isokinetic strength	Lipoprotein	Lipoprotein was positively correlated with isokinetic leg strength.
Tokmakidis et al. (405)	n=709; 8.9(1.6); (381/328); Greece	Cross-sectional	MANOVA; MANCOVA	Sit ups; SLJ	Weight status (BMI)	Normal weight and overweight males performed better than obese males in SLJ

						and Sit ups. For females, normal weight performed better than overweight and obese in the SLJ and Sit ups. Associations were unchanged or became stronger when corrected for age.
van Langendonck et al. (406)	n=21; 8.7(0.7) yrs; (0/21); Belgium	Cross-sectional	Bivariate correlation; Partial correlation	Isokinetic strength; Combined strength score	Multiple site BMD, BMC, and bone area	Significant associations were found between the strength score and BMC at all sites, BMD at most sites, and bone area at all sites. Controlling for height revealed somewhat lower but still significant associations. Controlling for lean mass caused all of the associations to become non-significant.
Vicente-Rodríguez, G. et al. (178)	n=278; 13-18.5 yrs; (109/169); Spain	Cross-sectional	Hierarchical multiple regression	Eurofit: GS; BAH; SLJ	Whole body BMC and BMD	For males GS, BAH, and SLJ were all independent predictors of whole body BMC. For females GS and SLJ were also independent predictors but BAH was not. No independent relationships were observed in males or females between MF variables and bone mass after the models were adjusted for lean mass.
Wang et al. (407)	n=258; 10-13 yrs; at baseline; (0/258); Finland	Longitudinal (2 year follow-up)	Hierarchical lineal models with random effects.	Upper and lower body maximal strength	Multiple site BMC	BMC of arm and leg correlated significantly with strength of elbow flexors and knee extensors, respectively. Similarly, the change in BMC and change in strength were also correlated significantly in the upper and lower limbs.
Weeks et al. (408)	n=81; 13.8(0.4) yrs; (37/44); Australia	Experimental (8 month RCT)	Forward stepwise multiple regression	VJ	Multiple site BMC, BMD and bone area	Change in VJ was not a significant predictor of change in any of the measured bone parameters.
Witzke & Snow (409)	n=54; 14.6(0.5) yrs; (0/46); USA	Cross-sectional	Bivariate correlation; Stepwise regression	Leg strength	Multiple site BMC and BMD	Leg strength was significantly correlated with multiple site BMD but was not an independent predictor of BMD at any site in the regression analysis. Leg strength was significantly correlated with BMC at some sites.

Woods et al. (212)	N= 94; 9-11 yrs; (38/56); USA	Cross-sectional	Bivariate correlation; Multiple regression	Combined strength score; Combined endurance score; Pull ups; Push-ups; BAH; VMPU; NYMPU	%BF	Combined strength and muscular endurance scores were not correlated with %BF. However, all individual MF tests were associated with %BF. Pull ups, VMPU, BAH and Push-ups were all significant predictors of %BF in multivariate analyses. NYMPU was not a significant predictor of %BF.

Abbreviations. %BF = percent body fat; **1RM** = 1 repetition maximum; **ANCOVA** = analysis of covariance; **ANOVA** = analysis of variance; **BA** = bone area; **BAH** = bent arm hang; **BMC** = bone mineral content; **BMD** = bone mineral density; **BME** = back muscle endurance; **BMI** = body mass index; **BP** = blood pressure; **CI** = confidence intervals; **CMJ** = counter movement jump; **CON** = control; **CRF** = cardio-respiratory fitness; **CVD** = cardiovascular disease; **DXA** = dual-energy x-ray absorptiometry; **F** = female; **GS** = grip strength; **GSI** = general strength index; **HFZ** = healthy fitness zone; **HOMA2-IR** = homeostatic model assessment of insulin resistance; **INT** = intervention; **ISAT** = Illinois standards achievement test; **LBP** = low back pain; **M** = male; **MANCOVA** = multiple analysis of covariance; **MANOVA** = multiple analysis of variance; **MAP** = mean arterial pressure; **MF** = muscular fitness; **MFI** = muscular fitness index; **MFS** = muscular fitness score; **MRS** = metabolic risk score; **MVPA** = moderate-to-vigorous physical activity; **NIZ** = needs improvement zone; **NR** = not reported; **NYMPU** = New York modified pull ups; **OR** = odds ratio; **PA** = physical activity; **RCT** = randomised controlled trial; **SES** = socioeconomic status; **SD** = standard deviation; **SLJ** = standing long jump; **VJ** = vertical jump; **VMPU** = Vermont modified pull ups; **WC** = waist circumference

Table 3.2 Risk of bias checklist with scores assigned

Citation	Random selection of study participants	Description of study sample	Assessment of muscular fitness	Assessment of health-related outcome	Confounder adjustment	Total /5
Afghani et al. (316)	1	1	0	1	0	3
Almuzaini (317)	0	1	1	1	0	3
Andersen (318)	1	1	1	0	1	4
Andersen (319)	1	1	1	0	1	4
Annesi (320)	0	1	1	1	0	3
Ara et al. (321)	1	1	1	1	1	5
Ara et al. (322)	1	0	1	1	1	4
Artero et al. (56)	1	1	1	1	1	5
Artero et al. (173)	1	1	1	1	1	5
Artero et al. (323)	1	1	1	1	1	5
Barnekow-Bergkvist et al. (324)	1	1	1	1	1	5

Barnekow-Bergkvist et al. (325)	1	1	0	1	1	4
Barnekow-Bergkvist et al. (326)	1	1	1	1	1	5
Benson et al. (174)	0	1	1	1	0	3
Benson et al. (42)	1	1	1	1	1	5
Bovet et al. (327)	1	1	0	1	1	4
Brandon & Fillingim (328)	0	1	0	1	1	3
Brunet et al. (329)	0	1	1	1	1	4
Butterfield et al. (330)	0	0	1	1	1	3
Cardon et al. (331)	1	1	1	1	1	5
Castelli et al. (195)	0	1	1	1	1	4
Castelli & Valley (332)	0	1	1	0	1	3
Castro-Piñero et al. (333)	1	1	1	1	0	4

Chen et al. (334)	1	1	1	1	1	5
Chen et al. (335)	1	1	1	1	1	5
Cheng et al. (336)	0	1	1	1	1	4
Cheng et al. (337)	0	1	1	1	1	4
Clark et al. (338)	0	1	1	1	1	4
Coe et al. (181)	0	1	1	1	0	3
Cureton et al. (339)	0	1	1	1	1	4
Deforche et al. (340)	1	1	1	1	1	5
Du Toit et al. (341)	0	1	1	1	1	4
Duppe et al. (342)	1	1	0	0	1	3
Dwyer et al. (343)	1	1	0	0	1	3
Edwards et al. (344)	1	1	1	1	1	5
Feldman et al. (345)	0	1	0	1	1	3
Fogelholm et al. (177)	1	1	0	0	1	3

Fonseca et al. (346)	0	1	1	1	0	3
Foo et al. (179)	1	1	1	1	1	5
Freitas et al. (347)	1	1	1	1	1	5
García-Artero et al. (348)	1	1	1	1	1	5
Ginty et al. (349)	0	1	0	1	1	3
Gonzalez-Suarez & Grimmer-Somers (350)	1	1	1	1	1	5
Gonzalez-Suarez et al. (351)	0	1	1	1	1	4
Gracia-Marco et al. (352)	1	1	1	1	1	5
Grøntved et al. (53)	1	0	1	1	1	4
Grund et al. (353)	0	1	1	1	1	4
Hands et al. (354)	1	1	1	1	1	5
Hasselstrom et al. (355)	1	1	1	1	1	5
Haugen et al. (356)	0	1	1	1	1	4
Heroux et al. (357)	0	1	0	1	1	3

Hoekstra et al. (358)	1	1	1	1	1	5
Hruby et al. (359)	1	1	1	1	1	5
Huang & Malina (360)	1	1	1	1	1	5
Huberty et al. (361)	0	1	1	1	1	4
Huotari et al. (362)	1	1	1	0	1	4
Janz et al. (363)	0	1	1	1	1	4
Johnson et al. (364)	1	1	1	0	0	3
Johnson et al. (365)	1	1	1	0	0	3
Joshi et al. (366)	0	1	1	1	1	4
Kardinaal et al. (367)	1	1	0	1	1	4
Kim et al. (368)	0	1	1	1	1	4
Lloyd et al. (369)	0	1	1	1	1	4
Lubans & Cliff (370)	0	1	1	1	0	3
Mafanya & Rhoda (371)	0	1	1	1	0	3

Magnussen et al. (372)	1	1	1	1	1	5
Malina et al. (373)	1	1	0	1	1	4
Malina et al. (374)	0	1	1	1	1	4
Marsh (375)	0	1	0	1	1	3
Martínez-Gómez et al. (376)	0	1	1	1	1	4
Martinez-Gomez et al. (187)	1	1	1	1	1	5
Mikkelsson et al. (377)	1	1	1	0	1	4
Minck et al. (378)	0	1	0	1	1	3
Moliner-Urdiales et al. (379)	1	1	1	1	1	5
Morano et al. (380)	0	1	1	1	1	4
Mota et al. (381)	0	1	1	1	1	4
Newcomer et al. (382)	0	1	1	1	1	4
O'Sullivan et al. (383)	0	0	1	1	1	3

Ortega et al. (384)	1	1	1	0	1	4
Ortega et al. (160)	1	1	1	1	1	5
Padilla-Moledo et al. (180)	1	1	1	1	1	5
Pate et al. (385)	0	1	0	1	1	3
Perry et al. (386)	0	1	1	1	1	4
Pino-Ortega et al. (387)	1	1	1	1	0	4
Pissanos et al. (388)	0	1	1	1	1	4
Pongprapai et al. (389)	1	1	0	0	0	2
Ransdell et al. (315)	1	1	1	1	1	5
Raudsepp & Jurimae (390)	0	1	1	0	1	3
Raudsepp & Jurimae (391)	0	1	1	1	1	4
Rice et al. (392)	0	1	1	1	0	3
Ruiz et al. (393)	1	1	1	1	1	5
Ruiz et al. (394)	1	1	1	1	1	5

Sacchetti et al. (395)	1	1	1	1	1	5
Sallis et al. (396)	0	1	1	0	1	3
Salminen et al. (397)	1	1	1	1	1	5
Salminen et al. (398)	1	1	1	1	1	5
Sjölie et al. (399)	0	1	1	1	0	3
Slaughter et al. (400)	0	1	1	1	0	3
Slaughter et al. (401)	0	1	1	1	0	3
Smith et al. (402)	0	1	1	1	1	4
Steene-Johannessen et al. (175)	1	1	1	1	1	5
Steene-Johannessen et al. (403)	1	1	1	1	1	5
Thorsen et al. (404)	0	1	0	1	1	3
Tokmakidis et al. (405)	0	1	1	1	1	4
van Langendonck et al. (406)	0	1	0	1	1	3

Vicente-Rodríguez, G. et al. (178)	1	1	1	1	1	5
Wang et al. (407)	0	1	1	1	0	3
Weeks et al. (408)	0	1	0	1	1	3
Witzke & Snow (409)	0	1	1	1	1	4
Woods et al. (212)	0	1	1	1	1	4

3.3.3 Physiological benefits

A summary of the associations between MF and each of the potential benefits can be found in Table 3.3.

3.3.3.1 Adiposity

Fifty-one studies reported on the association between MF and measures of adiposity (e.g., body mass index [BMI], sum of skinfolds, waist circumference [WC] etc). Forty-two studies were cross-sectional, seven were longitudinal, and two were experimental. A number of measures were used, both between and within studies, to measure adiposity. These measures can be broadly classified as measuring either total body fatness (e.g., BMI) or central body fatness (e.g., WC). Of the 48 studies reporting on the association between MF and measures of total body fatness, 43 (90%) reported significant inverse associations. These associations were generally low-to-moderate. Nine of these studies however, also reported a significant positive association between one measure of MF and adiposity. Positive associations were only found for tests of MF in which the subject was not required to support their body weight during movement (e.g., handgrip strength). Performance in MF tests in which the subject was required to either lift their body weight (e.g., curl ups, push-ups) or propel their body through space (e.g., vertical jump, standing long jump) was consistently found to be inversely associated with adiposity. Of the 37 studies with a low risk of bias, 33 (89%) found a significant association providing strong evidence of an inverse association with MF.

Fourteen studies examined the association between MF and central adiposity, which was most commonly measured by WC. Thirteen studies were classified as having low risk of bias. Overall, ten studies (71%) found a significant association as did nine (69%) studies with a low risk of bias suggesting strong evidence of an inverse association between MF and central adiposity. There was one instance of a positive association being reported between handgrip strength and WC (379). The associations for central adiposity were also generally low-to-moderate in magnitude.

A meta-analysis was conducted to determine the pooled effect size between MF and adiposity. All studies reporting partial correlation coefficients between MF and any adiposity variable were included. Using a random effects model, the pooled effect size was r = -0.29 (95% CI = -0.44 to -0.12), Z = -3.33, p = 0.001 (Figure 3.2). Significant between-study heterogeneity was observed, $Q(7)$ = 174.89, p = <0.001 and I^2 (96.00) indicated that 96% of the observed variance was explained by true systematic effect size differences. Publication bias was considered unlikely with Rosenthal's *fail-safe N* (312) indicating that 686 unpublished studies with an effect size of zero would be required to alter the point estimate to not being statistically significant. However, Duval and Tweedie's *trim and fill* procedure, which attempts to improve the symmetry of smaller studies around the point estimate within the funnel plot, detected an asymmetrical distribution. Consequently, one study was trimmed and the adjusted effect size was slightly weaker (r = -0.25, 95% CI = -0.41 to -0.08).

3.3.3.2 Bone health

Seventeen studies examined the association between MF and measures of bone health. Thirteen studies were cross-sectional, three were longitudinal, and one was experimental. Bone mineral density, bone mineral content, and bone area were the most commonly examined indices of bone health in included studies and one study (338) investigated the effect of muscular strength on fracture risk. Overall, 12 studies (71%) reported a significant association. Of the nine low risk of bias studies, eight (89%) reported a statistically significant finding suggesting strong evidence of a positive association. The evidence from prospective studies was less conclusive. Of the three longitudinal studies (326, 337, 407), two (326, 407) found that MF and bone mass were significantly related. However, in the only randomised controlled trial (RCT) (408), changes in MF were not significantly related to changes in bone mass.

3.3.3.3 CVD and metabolic risk factors

Twenty studies examined the association between MF and CVD and metabolic risk factors. Fifteen studies were cross-sectional and five were longitudinal. Overall, 15 studies (75%) found a significant association. Of the 17 low risk of bias studies, 13 (76%) reported that CVD and metabolic risk factors were significantly associated with MF, suggesting strong evidence of an inverse association. Strong evidence was found for an association between MF and clustered CVD risk with six (86%) of the seven studies examining this outcome reporting statistically significant findings. MF was also found to be significantly related to insulin resistance (173-175), inflammatory biomarkers (187, 323, 376, 393, 403), and both all-cause mortality and mortality due to CVD (160).

3.3.3.4 Musculoskeletal pain

Fifteen studies examined the association between MF and musculoskeletal pain. Nine were cross-sectional and six were longitudinal. These studies generally investigated the role of local muscular endurance of the trunk flexors and extensors in relation to lower back or neck pain. Overall, nine studies (60%) reported finding a significant inverse association between MF and musculoskeletal pain. Of the eight low risk of bias studies, four (50%) found that MF and pain symptoms were significantly associated suggesting inconsistent/uncertain evidence of an inverse association. The results of longitudinal studies were equivocal with three (324, 377, 399) of the six studies reporting that MF and musculoskeletal pain were related.

3.3.4 Psychological and cognitive benefits

3.3.4.1 Psychological benefits

Eight studies, seven cross-sectional and one experimental, investigated the association between MF and psychological benefits. Six were classified as having a low risk of bias. Six studies investigated the association between MF and self-esteem/physical self-perceptions, while the remaining studies investigated other psychological indices including life satisfaction, depressed mood, and risk of mental illness and suicide. Of the studies investigating the link between MF and self-esteem/physical self-perceptions, five (83%) found a significant association for one or a number of constructs. Self-perceptions were examined using instruments developed for the general population. However, the names of certain subscales can vary between instruments. For example, Harter's self-perception profile for adolescents (410) measures perceived *athletic* competence whereas Whitehead's children's self-perception profile (411) measures perceived *sports* competence. Similar subscales were grouped together for this summary. The constructs shown to be consistently related with MF were perceived physical appearance (including perceived body fatness) (356, 375, 380), perceived sports competence (including perceived athletic competence and physical ability) (356, 375, 380), overall physical self-worth (370, 375) and global self-esteem (375, 402). Conversely, the single experimental study (315) showed that changes in MF were not related to changes in any physical self-perceptions. The studies investigating other psychological outcomes also generally reported significant findings.

A meta-analysis was conducted to determine the pooled effect size between perceived sports competence and MF, as this was the only construct for which data were available from at least three studies. The random effects model yielded an overall effect size of $r = 0.42$ (95% CI = 0.36 to 0.47), $Z = 12.55$, $p < 0.001$, indicating a moderate positive association (Figure 3.3). Between-study heterogeneity was not significant $Q(4) = 8.35$, $p = 0.08$. However, I^2 (52.09) indicated that 52% of the observed variance could be explained by systematic differences in effect sizes, suggesting moderate heterogeneity. Publication bias was considered unlikely as demonstrated by Rosenthal's *classic fail-safe N* (312), which indicated that 471 unpublished studies with an effect size of zero would be required to cause the pooled point estimate to become statistically insignificant. Duval and Tweedie's *trim and fill* procedure (313) detected asymmetry in the distribution of observed effect sizes. Consequently, the adjusted value became slightly weaker (r = 0.39, 95% CI = 0.34 to 0.45).

3.3.4.2 Cognitive benefits

Six studies investigated the association between MF and cognitive benefits (e.g., academic performance), all of which were cross-sectional. Four studies were considered to have a low risk of bias. Of the six included studies, three (50%) reported a significant association between MF and cognitive ability. Only one of the low risk of bias studies reported a significant association, suggesting inconsistent/uncertain evidence of an association between MF and cognitive benefits.

Table 3.3 Summary of studies examining the association between health benefits and muscular fitness

Benefits	**Associated with MF**	**Not associated with MF**	**Summary coding**	
	references	**references**	**n/N[a] for benefit (%)**	**association (+/-)[b]**
Physiological benefits				
Adiposity				
Total	(53, 56, 177, 187, 212, 317, 320-322, 327, 329, 330, 333-335, 339, 340, 347, 350, 351, 354, 355, 357, 359-363, 366, 369, 373, 374, 378-381, 385, 387-389, 391, 395, 396, 400, 405)	(318, 353, 368, 390, 401)	45/50 (90)	- -
Central	(173, 175, 322, 329, 347, 355, 357, 363, 379, 381)	(42, 53, 187, 353)	10/14 (71)	- -
Bone health	(178, 179, 316, 326, 336, 338, 346, 349, 352, 367, 406, 407)	(337, 342, 392, 408, 409)	12/17 (71)	++
CVD and metabolic risk factors	(53, 160, 173-175, 187, 323, 348, 372, 376, 381, 384, 393, 403, 404)	(325, 328, 355, 358, 363)	15/20 (75)	- -
Musculoskeletal pain	(319, 324, 364, 365, 371, 383, 386, 397, 399)	(331, 345, 377, 382, 398, 402)	9/15 (60)	?
Psychological and cognitive benefits				
Self-esteem	(356, 370, 375, 380, 402)	(315)	5/6 (83)	++
Cognitive ability	(181, 341, 343)	(195, 344, 394)	3/6 (50)	?

Abbreviations. MF = muscular fitness; CVD = cardiovascular disease

[a] n/N = number of studies reporting a statistically significant finding/ total number of studies reporting on the benefit

[b] ++ = strong evidence of a positive association; - - = strong evidence of an inverse association; ? = inconsistent/uncertain

Study name	Subgroup within study	Statistics for each study				
		Correlation	Lower limit	Upper limit	Z-Value	p-Value
Artero (2011)	Males/females	-0.489	-0.543	-0.431	-14.209	0.000
Hasselstom (2002)	Females	0.120	-0.087	0.317	1.138	0.255
Hasselstom (2002)	Males	-0.310	-0.497	-0.095	-2.794	0.005
Janz (2002)	Males	-0.320	-0.477	-0.143	-3.462	0.001
Martinez-Gomez (2012)	Males/females	-0.056	-0.119	0.008	-1.717	0.086
Mota (2010)	Females	-0.190	-0.312	-0.062	-2.891	0.004
Steene-Johannessen (2012)	Females	-0.508	-0.571	-0.440	-12.422	0.000
Steene-Johannessen (2012)	Males	-0.402	-0.469	-0.330	-10.019	0.000
		-0.286	-0.436	-0.120	-3.329	0.001

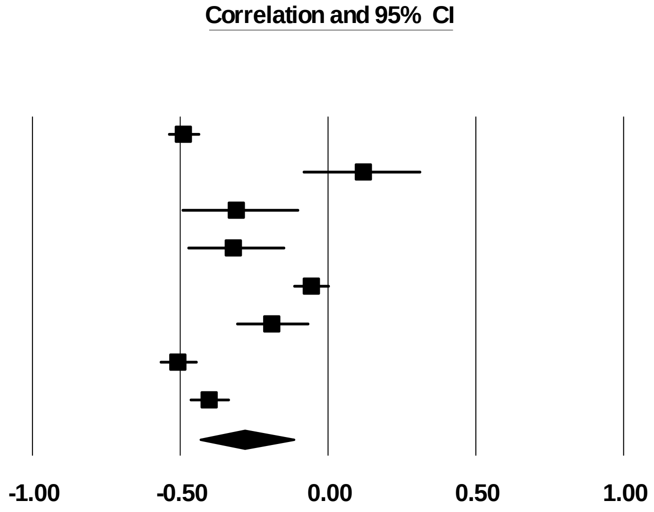

Figure 3.2 Forest plot showing the relationship between muscular fitness and adiposity for included studies

Study name	Subgroup within study	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Haugen (2013)	Females	0.440	0.385	0.492	14.056	0.000
Haugen (2013)	Males	0.350	0.293	0.405	11.246	0.000
Marsh (1996)	Males/females	0.390	0.261	0.506	5.571	0.000
Morano (2011)	Females	0.450	0.295	0.582	5.243	0.000
Morano (2011)	Males	0.510	0.376	0.623	6.587	0.000
		0.415	0.357	0.471	12.553	0.000

Statistics for each study

Correlation and 95% CI

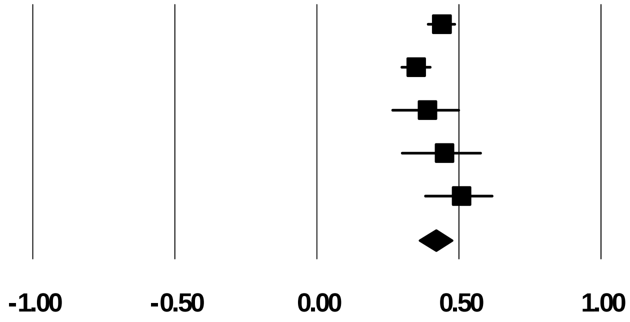

Figure 3.3 Forest plot showing the relationship between muscular fitness and perceived sports competence for included studies

3.4 Discussion

3.4.1 Overview of findings

The aim of this systematic review and meta-analyses was to comprehensively evaluate the range of physiological and psychological health benefits associated with MF among children and adolescents. Overall, 110 studies encompassing six health outcomes (i.e., adiposity, bone health, CVD and metabolic risk factors, musculoskeletal pain, psychological health and cognitive ability) were reviewed. Strong evidence for an inverse association with MF was found for adiposity, and CVD and metabolic risk factors. We also found strong evidence for a positive association between MF and bone health and self-esteem (including physical self-concept, perceived physical appearance, and perceived sports competence). The evidence of an association between MF and musculoskeletal pain and cognitive ability was considered to be inconsistent/uncertain.

3.4.2 Physiological benefits

3.4.2.1 Adiposity

The findings of this review provide strong evidence of an inverse association between MF and both total and central adiposity. The associations were generally low-to-moderate as demonstrated by the pooled effect size of r = -0.25. Excess body fat was consistently associated with poor performance in MF tests that require lifting or propulsion of the body mass. Notably, data from the healthy lifestyle in Europe by nutrition in adolescence (HELENA) study (379), adjusted for multiple confounders, showed consistent moderate inverse associations between jumping-based MF tests and adiposity measured using multiple methods including dual-energy X-ray absorptiometry. Cross-sectional evidence was supported by longitudinal studies which showed reductions in adiposity over time with increases in muscle strength (347, 355, 363). Furthermore, in a large sample of nearly 2800 US children (359) it was found that both achieving and maintaining 'adequate' MF over a four-year period resulted in significantly greater odds of being a healthy weight at follow-up.

These data are suggestive of a cause and effect association by which improvements in MF lead to reductions in body fatness. The specific mechanisms through which this may occur are likely to be complex, numerous and interacting. However, as obesity is driven by an energy imbalance (227), with energy surplus being stored as fat tissue, it can reasonably be hypothesised that the protective effects of MF are related to its role in energy expenditure. Skeletal muscle is known to be a highly energetic tissue, contributing substantially to basal metabolic rate (11). Therefore, improvements in MF may reflect increases in skeletal muscle mass, the metabolic efficiency of muscle (i.e., lipid oxidation and glucose transport capacity) or both, resulting in greater overall daily energy expenditure (11, 379). Improvements in MF may also make physical activity easier to perform and hence more enjoyable (332), resulting in greater activity energy expenditure over time. However, this association is probably bidirectional with increases in both fitness and fatness likely to impact on physical activity participation (177, 379).

Contrary to the findings of weight-bearing MF tests, the literature consistently showed a positive association between handgrip strength and adiposity. A number of investigators have attributed this to higher levels of lean mass among the overweight youth (340, 379). However, Artero et al. (56) found that, at least for boys, the higher handgrip strength observed among overweight adolescents could not be explained by differences in fat-free mass, concluding that unmeasured morphological and/or neurological factors might be influencing the association. While it is possible that weight-bearing tests of MF (i.e., standing long jump, vertical jump etc) are simply capturing variation in body mass and not necessarily variation in MF, we do not believe this to be the case. Milliken et al., (412), found that vertical jump and standing long jump performance were significant predictors of 1RM leg press, the criterion measure of lower body strength. Therefore, these tests can be considered appropriate for assessing the relationship between MF and health outcomes. Further, longitudinal studies have shown that changes in MF measured both in absolute terms (347) and relative to body weight (355, 363) are inversely associated with adiposity. Despite the apparent contradiction there appears to be clear evidence of the importance of MF for adiposity among youth, which may occur through both physiological and psycho-behavioural mechanisms.

3.4.2.2 Bone health

Youth has been identified as a critical stage for determining lifelong skeletal health (11). During puberty in particular bone tissue is highly responsive to osteogenic stimuli (408). This has led researchers to investigate the potential of optimising peak bone mass during youth for the primary prevention of osteoporosis in adulthood (413, 414). A high bone mass during youth is also protective against the risk of immediate fracture (85), especially as participation in ‘risky’ physical activities is highest during this time (11). While peak bone mass is predominantly determined by genes (415), a number of modifiable determinants including physical activity, calcium intake and MF have been identified (416-418). The findings of our review support the latter with the majority of low risk of bias studies demonstrating a significant association between MF and bone health. However, as the majority of studies were cross-sectional, we are unable to form strong conclusions regarding the prospective association between MF and bone health. In one of the few longitudinal studies, Cheng et al. (337) found that MF was not a predictor of bone mass among a sample of Asian adolescents. However, bone mass is in part racially determined (419, 420) and consequently these findings may not be generalisable to different ethnic groups. In a school-based RCT, Weeks et al. (408) found that changes in bone mass measured at multiple sites could be explained by changes in lean mass but not by changes in MF. Alternatively, a 20-year follow-up study found site specific associations between curl ups performance during adolescence and bone mineral density in adulthood (326).

One consistent finding between studies was of the importance of lean mass in explaining bone mass variation. Lean mass was found to be a strong predictor of bone mass, in some cases independently explaining more than 60% of the observed variance (178, 179). Associations between MF and bone mass on the other hand were considerably weaker. As improvements in muscular performance would be expected to accompany increases in lean mass, MF may be most useful as an inexpensive and reproducible surrogate for lean mass; enabling the identification of youth with a heightened risk of poor skeletal health (178). Alternatively, MF may be a proxy for past physical activity, indirectly influencing bone mineralisation through increasing lean mass during pubertal growth (421). More longitudinal and experimental studies are required to ascertain the relative contribution of physical activity and MF - and their interaction with lean mass - to improvements in bone health. Regardless, the rationale for increasing peak bone mass during youth through activities that both require and develop MF appears sound.

3.4.2.3 CVD and metabolic risk factors

While the clinical symptoms of CVD typically manifest in adulthood, evidence suggests that the genesis of CVD occurs in youth; with elevated levels and clustering of known risk factors evident in childhood (161, 162). As CVD risk factors track from youth to adulthood (422), adolescence represents an opportunity to mitigate population-level health burden through preventive strategies. The studies included in this review provide strong evidence for the importance of MF during youth for CVD risk and extend on the inconclusive findings from an earlier systematic review (13). In addition to clustered CVD risk, studies also demonstrated that MF was associated with insulin resistance (173-175), inflammatory biomarkers (187, 323, 376, 393, 403) and both all-cause and CVD-related mortality (160). .

CRF is known to be a strong predictor of CVD risk (3) but importantly, MF was found to be associated with CVD risk independent of CRF and other confounders (173, 175). This was confirmed longitudinally among Danish adolescents taking part in the European Youth Heart Study

(53), suggesting that there is both a combined and additive effect of MF on CVD outcomes. The association was found to be non-linear with the greatest benefits achieved by increasing MF levels from low to moderate and little additional benefit received thereafter (173, 175, 381). Interestingly, the protective effect of MF was found to be most distinct amongst overweight youth (173, 175). This finding is encouraging as overweight youth are a group already at increased risk of CVD and metabolic disorders in later life (423, 424). Increasing MF in overweight youth, particularly from low to moderate, may be an effective strategy for improving the health trajectory of this 'at risk' group. Additionally, overweight youngsters tend to experience greater self-efficacy and enjoyment in MF-based activities compared to those that demand a greater cardio-respiratory capacity (55). Intervention programs involving a 'muscular' focus (e.g., resistance training) may therefore result in greater adherence and satisfaction among overweight youth, as demonstrated in previous studies (425, 426). Future research should determine the clinical significance of changes in MF during youth for CVD and metabolic outcomes in later life (53).

3.4.2.4 Musculoskeletal pain

A sharp increase in musculoskeletal pain symptoms has been observed during the time around puberty (427) and pain symptoms during youth have been shown to predict pain in adulthood (428). Furthermore, the prevalence of back pain among children and adolescents may be as high as 25% (429). The findings of studies included in this review were equivocal indicating that the association between MF and musculoskeletal pain remains unclear, which is consistent with the findings of an earlier review (13). While some studies found that increased trunk muscle strength and local muscular endurance were protective against back and neck pain, others found no association. One study reported that greater back strength increased the risk of low back pain (382) while another reported that both reduced and greater back muscular endurance were associated with back pain (386). It is important to note that cross-sectional studies cannot determine causality and reverse causation is equally plausible – low activity levels and poor MF may cause back pain or vice versa (331). Evidence from longitudinal studies should confirm or refute causality but at present they too appear somewhat equivocal. The available evidence currently supports the potential for an inverse association between MF and musculoskeletal pain. However, more high quality longitudinal investigations are required to confirm previous findings and explain the contradictory reports identified within other studies.

3.4.3 Psychological and cognitive benefits

3.4.3.1 Psychological benefits

Poor mental health is a significant public health issue for youth (430) and mental illness is expected to be the leading disease burden globally by 2020 (431). Identifying the determinants of mental health problems is important for informing public health strategies, particularly those with a preventive focus. Global self-esteem, an important element of wellbeing (432), is typically considered to be at the apex of a hierarchical framework made up of domain specific constructs (i.e., physical self-worth), which are further subdivided into specific self-perceptions (375). The findings of this review suggest evidence of an association between MF and physical self-perceptions namely, perceived physical appearance (including perceived body fatness) and perceived sports competence (including perceived physical ability and athletic competence). Furthermore, there is evidence for an association between MF and overall physical self-worth and global self-esteem. According to Harter's competence motivation theory, actual competence precedes perceived competence in the causal pathway (433). Perceptions of competence are hypothesised to subsequently influence physical activity participation through decreased motivation to be active. As suggested by Stodden et al. (65) this can result in a self-perpetuating cycle of disengagement among less capable youth. Successful sports performance is largely dependent on fitness-related attributes, therefore the moderate association found between MF and perceived sports competence is not overly surprising. However, this association reinforces the argument for developing adequate fitness, particularly during childhood, in order to improve opportunities for success and increase the likelihood of lifelong physical activity. Increasing physical activity can be considered an important public health objective not only for the known physical health benefits but also for its role in the prevention and treatment of psychological ill health (90). The finding that a low level of muscular strength during adolescence was associated with a greater risk of psychiatric diagnosis and suicide in later life (160) highlights the relevance of MF for positive psychological health.

3.4.3.2 Cognitive benefits

There was considerable heterogeneity between measures used to assess cognitive ability making comparisons between these particular studies problematic. As such, these findings must be interpreted with caution. In addition, as all of the studies reviewed herein were cross-sectional, no evidence on causality can be provided. The evidence for an association between MF and cognitive ability was considered inconsistent/uncertain. While Dwyer et al. (343) found significant associations between MF and 'scholastic ability' among 7-15 year old youth, this was a subjective rating made on a simple 5-point scale and therefore may not represent true academic ability. Coe et al. (181) and Du Toit et al. (341) also reported significant associations between MF and academic performance, but analyses were not adjusted for important covariates. Alternatively, the studies that controlled for potential confounders such as age and sex (195, 344, 394), found no association between MF and academic ability. Previous research has linked CRF and physical activity to cognitive ability (434, 435) however, it is unknown whether physical activity and CRF improve cognitive functioning or whether they are simply markers of motivated and high achieving youth (394). Potential mechanisms for this association have been hypothesised and include neuroplastic responses from increased blood flow and the release of brain derived neurotrophic factor (436). Alternatively, CRF may influence executive control enabling better performances in complex cognitive tasks (437). While there appears to be support for the importance of CRF, the available evidence is unclear on the link between MF and cognitive ability.

3.4.4 Strengths and limitations

Although other reviews on this topic are available (3, 13), they have focused on the benefits and 'predictive validity' of health-related fitness in general. While longitudinal data can provide stronger evidence for the link between MF and health, it is important to acknowledge and review evidence from cross-sectional studies. To the authors' knowledge this is the first review to provide a systematic and comprehensive evaluation of the range of physiological and psychological benefits associated with MF among children and adolescents. Furthermore, our review provides an update of the evidence reported within earlier reviews. Strengths of our review include the large number of included studies covering a variety of relevant domains and additional coding for risk of bias in the quantitative synthesis. However, the former also introduced some limitations. Discussion of the broad range of potential benefits of MF precluded a more detailed examination of potential moderators of the observed associations. Whether or not the associations were moderated by age, sex or ethnicity is likely to be of importance to researchers, physical educators and health professionals. However, this was beyond the scope of our review. Further, it must be noted that we did not review the benefits of MF for the prevention of sports-related injuries. Previous research has indicated that resistance training as part of a preparatory conditioning program is effective for reducing the risk of injury during sports participation (40). Additionally, as inactive children are at greater risk of injury in both physical education and leisure-time physical activity contexts (438), resistance training may also assist those not participating in organised sport to safely engage in physical activity. However, in order for our review to be generalisable to the wider youth population we excluded studies specifically targeting young athletes during the screening process.

3.4.5 Future research

The paucity of longitudinal and experimental studies prevented us from drawing stronger conclusions on causal relationships for a number of outcomes. Experimental studies have measured changes in MF and the outcomes included in this review (43, 264, 425, 439). However, these studies often focus on examining time and group effects, and usually fail to investigate the *association* between changes in MF and changes in the outcome. In this respect, the importance of MF specifically for these outcomes can be deduced but not confirmed. More high quality longitudinal and experimental studies are required to investigate causality and to determine the clinical significance of changes in MF for health-related outcomes. In particular, further study of the effects of MF on psychological wellbeing is needed. Large scale longitudinal studies examining the effect of resistance training or changes in MF on aspects of cognitive ability (i.e., executive function) are also warranted. Few studies included in our review reported standardised coefficients, preventing more comprehensive meta-analyses of the associations between MF and potential benefits. Future studies should report standardised coefficients to allow for simpler comparisons of study findings and to enable more thorough meta-analyses of the associations between MF and health outcomes. Finally, as was evident in studies examining the relationship between MF and adiposity, the association can change - and even reverse - depending on whether an ‘absolute’ or ‘relative’ (i.e., divided by body mass) measure of MF is used. In future studies, investigators should consider the type of MF test used and decide on the most appropriate method for expressing MF in their analyses. As many weight-bearing MF tests are highly correlated with body mass/adiposity (212), analyses of the relationship between MF and the health outcome of interest should adjust for these variables in order to ascertain the independent contribution of MF.

3.5 Conclusion

This systematic review comprehensively evaluated the range of potential benefits of MF among children and adolescents. We conclude that:

i) There is strong evidence for a positive association between MF and bone health and self-esteem, although the associations are low-to-moderate;

ii) There is strong evidence of an inverse association between MF and total and central adiposity, and CVD and metabolic risk factors, although the associations are also low-to-moderate; and

iii) The associations between MF and musculoskeletal pain and cognitive ability are inconsistent/uncertain.

The findings of this review lend support to current physical activity guidelines that recommend youth regularly engage in muscle-strengthening physical activities (108). School- and community-based youth programs should include activities that develop muscular strength, local muscular endurance and muscular power in addition to other health- and skill-related components of physical fitness. These findings are of relevance to physical educators, health care professionals, policy makers, and researchers interested in paediatric health.

CHAPTER 4: MEASURING ADOLESCENTS' RESISTANCE TRAINING MOVEMENT SKILL COMPETENCY: DEVELOPMENT AND EVALUATION OF THE RESISTANCE TRAINING SKILLS BATTERY

Preface:

This chapter presents the results of a study evaluating the reliability and construct validity of a test battery developed to assess adolescents' resistance training skill competency. This study was conducted to investigate *Secondary aim 2* of this thesis.

The contents of this chapter were published in the *Journal of Strength and Conditioning Research* in May, 2014

Citation:

Lubans DR, **Smith JJ**, Harries SK, Barnett L, Faigenbaum AD. Development, test-retest reliability and construct validity of the Resistance Training Skills Battery. *Journal of Strength and Conditioning Research*. 2014; 28(5): 1373-1380.

Abstract

Objective. The aim of this study was to describe the development and assess test-retest reliability and construct validity of the Resistance Training Skills Battery (RTSB) for adolescents.

Methods. The RTSB provides an assessment of resistance training skill competency and includes six exercises (i.e., body-weight squat, push-up, lunge, suspended row, standing overhead press and front support with chest touches). Scoring for each skill is based on the number of performance criteria successfully demonstrated. An overall resistance training skill quotient (RTSQ) is created by adding participants' scores for the six skills. Participants (44 males and 19 females, mean age = 14.5 ± 1.2 years) completed the RTSB on two occasions separated by seven days. Participants also completed the following fitness tests, which were used to create a muscular fitness score (MFS): handgrip strength, timed push-up and standing long jump tests. Intraclass correlation (ICC), paired samples t-tests and typical error were used to assess test-retest reliability. To assess construct validity, gender and RTSQ were entered into a regression model predicting MFS.

Results. The rank order repeatability of the RTSQ was high (ICC = 0.88). The model explained 39% of the variance in MFS ($p < .001$) and RTSQ ($r = .40$, $p < .001$) was a significant predictor.

Conclusion. This study has demonstrated the construct validity and test-retest reliability of the RTSB in a sample of adolescents. The RTSB can reliably rank participants in regards to their resistance training competency and has the necessary sensitivity to detect small changes in resistance training skill proficiency.

4.1 Introduction

Despite the extensive benefits of physical activity, a large proportion of the world's population remain inactive (14). Approximately 80% of adolescents are not accumulating at least 60 minutes of moderate-to-vigorous physical daily, of which 2-3 days per week should involve muscle strengthening activities (14). Resistance training is activity designed specifically to enhance muscular fitness (i.e., muscular strength, power and endurance) by progressively increasing the workload placed on the muscles (5). Resistance training with qualified instruction and supervision is now recognised as a safe, effective and worthwhile activity for adolescents (40, 440, 441), and numerous studies have demonstrated the health- and fitness-related benefits of resistance training for children and adolescents, which include: increased muscular fitness (42, 264, 266, 442), decreased body fat (42, 264), improved blood lipid profiles (42) and positive changes in physical self-concept (69, 264).

Resistance training programs are typically evaluated using product type fitness tests that assess muscular strength and local muscular endurance. There have been concerns regarding the use of fitness testing with children and adolescents, such as their lack of validity and reliability and the potential stigmatisation of children (443, 444). However, if used appropriately, fitness testing can help: (i) support students' understanding of the effects of activity on fitness, (ii) facilitate the learning of physical fitness concepts,(iii) provide useful information to parents on their children's health status and iv) help children link health-related fitness to present and future health status (443). Despite these potential contributions, existing fitness tests are product measures that do not provide feedback on actual movement skill technique. Alternatively, process oriented assessment involves assessing the presence or absence of the criteria you need to successfully complete an exercise or skill (i.e., your technique).

Although there are existing process measures for identifying injury risk factors in athletes (445), to our knowledge, there are no validated movement skill batteries for evaluating resistance training skill competency. Therefore, the aim of our study was to develop and assess the test-retest reliability and construct validity of the Resistance Training Skills Battery (RTSB) for adolescents. The RTSB was designed to serve the following purposes: (i) evaluate the efficacy of school- and community-based resistance training programs, (ii) assess individual progress and provide feedback in resistance training programs, and (iii) use as a measurement instrument in research focusing on movement skill competency.

4.2 Methods

4.2.1 Experimental approach to the problem

Fourteen experts in youth resistance training were contacted to determine their willingness and availability to assess the content validity of the RTSB. Each of the experts had a doctorate degree in a relevant field (e.g., kinesiology, exercise physiology, physical education), had published in international refereed journals and was currently employed at an Australian, American, British or Canadian university or college. Eight experts responded and provided feedback on the instrument within eight weeks of the original mailing. Experts were provided with a copy of the RTSB and asked to comment of the following: (i) the importance of developing a resistance training skill battery, (ii) the selected resistance training exercises and (iii) the skill performance criteria for each skill identified by the research team. Feedback from experts was then collated and the necessary modifications were made to the original measure. Examples of modifications include: consistency in the number of repetitions for each exercise, changes to the exercises, addition/removal of performance criteria and the inclusion of pictures depicting the different exercises. A complete description of the expert feedback and suggested amendments to the RTSB can be found in Appendix 13.

The six exercises included in the final RTSB (i.e., body-weight squat, push-up, lunge, suspended row, standing overhead press and front support with chest touches) were chosen because: (i) they were considered safe and developmentally appropriate for adolescents, (ii) they require minimal equipment and/or access to facilities and (iii) they represent the movements commonly used in adolescent resistance training programs (5, 440, 441). Competency in these movements will provide the foundation for developing physical strength in a range of bodily movements, notably: i) trunk stability (front support and chest touches), upper body pushing strength (push-up), upper body pulling strength (suspended row), lower body bilateral strength (squat), and lower body unilateral strength (lunge). Furthermore, exercises such as the body-weight squat, standing overhead press and push-up provide the foundation for more advanced lifts, including the clean and jerk and bench press. The six exercises included in the RTSB target the major muscle groups: lower body (squat/lunge), chest, back and arms (push-up and suspended row), shoulders (standing overhead press) and core (front support with chest touches). Finally, the RTSB was designed to be administered in a school setting and does not require access to a gymnasium or weight room, but does require bar (e.g., wooden bar or PVC pipe) and a suspended bar or suspension straps and anchor point for administration.

4.2.2 Subjects

Study approval was sought and obtained from the University of Newcastle Research Ethics Committee, the Newcastle and Maitland Catholic Schools Diocese and the school principal from one secondary school in Newcastle, New South Wales (NSW), Australia. Information letters, parental permission forms and participant assent forms were sent home with students and those who returned signed forms were permitted to participate in the study. Eligible participants were school students in year 7 to 10 (aged 12 to 16 years) from the study school (Table 4.1). The final sample included 44 males and 19 females (mean age = 14.5 ± 1.1 years). Participants were ineligible if they had a medical condition or physical injury preventing testing or training, as self-reported by parents and participants prior to start of study.

4.2.3 Procedures

Assessments were conducted by trained research assistants at the study school on two occasions seven days apart (Trial 1 and Trial 2, hereafter called T1 and T2). On muscular fitness tests, a 7-day separation period is commonly used (381). A period of one week was considered sufficient time to reduce the learning effect of the testing procedures without introducing additional error due to maturation. All research assistants participated in a full-day training workshop in preparation for the assessments.

Participants completed the assessments at school during the same time of day (i.e., between 9am and 3pm) for T1 and T2 in gender-matched groups (i.e., all males or all females) of three or four. Participants completed the exercises individually under the supervision of the research assistant. Standardised warm-up activities were not performed before participants completed the RTSB because all of the exercises included body-weight resistance or a bar with no weight. Prior to performing each skill, participants observed demonstrations by a research assistant and only questions pertaining to the exercise protocol (e.g., number of repetitions) were permitted. General encouragement was provided by the research assistants, but no skill specific feedback or teaching points were provided at T1 or T2. Participants completed two sets of four repetitions for each skill in the following order: (i) body-weight squat (ii) push-up (iii) lunge (iv) suspended row (v) standing overhead press and (vi) front support with chest touches. Participants were given 20-30 seconds to recover between sets and also between exercise skills (total time taken to complete the RTSB was 8-10 minutes per participant). All skills were recorded using a digital video camera positioned at a 45 degree angle to the participant to enable front- and side-on views. This was considered the best viewing position to enable the assessor to properly evaluate each skill during video analysis.

Table 4.1 Characteristics of study participants

Characteristics	**Males (*n* = 44)**		**Females (*n* = 19)**		**Total (*N* = 63)**	
	Mean/*n*	**SD/%**	**Mean/*n***	**SD/%**	**Mean/*n***	**SD/%**
Age (years)	14.3	1.2	14.8	1.1	14.5	1.2
Born in Australia	43	97.7	19	100	62	98.4
English language spoken at home[a]	44	100	19	100	63	100
Cultural background						
Australian	40	90.9	18	94.7	58	92.1
European	2	4.5	-	-	2	3.2
Asian	-	-	1	5.3	1	1.6
Other	2	4.5	-	-	2	3.2
Body mass (kg)	59.7	12.1	58.5	9.2	59.3	11.3
Height (m)	1.68	0.10	1.64	0.06	1.67	0.09
BMI (kg/m^2)	20.92	2.84	21.44	2.63	21.08	2.77
BMI Category						
Healthy weight	36	81.8	14	73.7	50	79.4
Overweight	8	18.2	5	26.3	13	20.6
Obese	-	-	-	-	-	-
Handgrip strength test (kg)	27.5	3.1	22.0	3.1	25.9	7.2
Timed push-up test (repetitions)	16.0	8.4	8.4	9.8	13.7	9.5
Standing long jump test (cm)	171	26	143	23	162	28

SD, standard deviation; BMI, body mass index.

[a] Participants who speak English at home.

The structure and scoring format of the RTSB was based on the Test of Gross Motor Development 2 (446). Each of the exercises in the RTSB includes four (push-up and suspended row) or five (body-weight squat, lunge, standing overhead press and front support with chest touches) performance criteria. A full description of the exercises and their corresponding performance criteria are included in Appendix 14. An experienced research assistant, who held a Bachelor's degree in physical education and had over five years of resistance training experience, assessed all of the skills in the current study. Before assessing the skills, the research assistant and the lead investigator viewed a sample of videos to establish what was considered "acceptable" for each of the performance criteria for the six skills. For example, this involved identifying what was considered to be an acceptable level of lateral movement (approx. 10cm) in the front support with chest touches exercise. This information was then used to identify participants (three for each skill level) with high (i.e., all criteria performed correctly), moderate (i.e., most criteria performed correctly) and low (i.e. few criteria performed correctly) resistance training skill competency. These examples were then used as a reference and the research assistant was encouraged to review these examples before scoring the videos.

As participants may require several repetitions before they demonstrate a skill to their best ability, scoring of the RTSB was based on their "best repetition technique". This was defined as the repetition during which the participant satisfied the highest number of performance criteria. For example, if the participant satisfied two of the criteria on their first repetition and then three criteria on their second repetition, they were awarded a score of three for the set. Participants were awarded a 1 for each performance criterion that was correctly demonstrated and a 0 if the criterion was not performed appropriately. Scores of 0.5 were not awarded. Totals for the two sets were added to obtain a raw score for each skill (i.e., a total of eight for skills involving four criteria and 10 for those involving five criteria). To ensure that there was not a learning effect between set 1 and set 2, the difference in group (i.e., males and females) means were calculated. For females, the difference between sets ranged from 0.1 for the push-up to -0.1 for the suspended row. For males, the difference between sets ranged from -0.2 for the lunge to 0.1 for the push-up. Overall these findings do not support the existence of a learning effect. The skill scores were then added to create a resistance training skill quotient (RTSQ) (possible range 0 to 56).

As there are no existing measures for assessing youth resistance training skill competency, it was not possible to assess the criterion validity of the RTSB. However, we tested the construct validity of the RTSB by examining the relationship between overall resistance training skill competency (i.e., RTSQ) and a muscular fitness score (MFS), which combined participants' results for the handgrip strength, timed push-up and standing long jump tests (173). It would be expected that resistance training skill competency would be associated positively with muscular fitness thereby providing a rationale for the assessment of resistance training technique. Relative values (i.e., participant result divided by their body weight) for the handgrip test were first computed to account for differences in body size. Values were then standardised using the following formula: standardised value = (value minus the group mean) divided by the standard deviation of the group. The MFS was then computed by summing the standardised values of the grip strength, timed push-up and standing long jump tests. These tests were selected because they have good test-retest reliability (447, 448) and validity when assessed against upper- and lower-body criterion muscle strength measures in adolescents (449).

Body mass was measured in light clothing without shoes using a portable digital scale (Seca 770, Wedderburn) to the nearest 0.1kg and stature was measured to the nearest 0.1 cm using a portable stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia). Body mass index (BMI) was calculated using the standard equation (body mass[kg]/stature[m]^2) and the International Obesity Task Force (IOTF) cut-points were used to classify participants as healthy weight, overweight or obese (450).

Strength of the hand and forearm muscles was assessed using a grip dynamometer (Smedley's TTM Tokyo). The grip-span was adjusted to suit the hand size of the participant prior to performance. Subjects were asked to squeeze the dynamometer continuously as hard as possible for two to three seconds with the elbow in full extension down by the side of the body. The test was performed three times each for the left and right hands, alternating hands after each trial. The score in kilograms was recorded. The average of the scores for the right and left hands was used in the analysis.

The 90-degree timed push-up test was used as a measure of upper body muscular endurance. Testing procedures were explained to the participants prior to the test. The test began with participants in the push-up position with hands and toes touching the floor, arms approximately shoulder width apart and back straight. Participants lowered themselves to the floor in a controlled manner until a 90-degree angle was formed at the elbow then pushed back up. Push-ups were performed in time with a metronome, which was set at 40 beats per minute, allowing for one push-up every three seconds. The test concluded when participants either failed to lower themselves to the required depth on three non-consecutive repetitions (warnings verbalised by assessor), failed to maintain the movement in time with the metronome, or upon volitional failure. Assessors did not provide verbal encouragement during the conduct of the test.

Muscular power was assessed using the Standing long jump test. Testing procedures were explained to participants prior to performance. Subjects began with their toes behind a line marked at zero centimetres and performed a maximal long jump, taking off and landing with two feet. The distance reached (in cm), in line with the heel of the rearmost foot was recorded. The test was performed twice separated by a rest period of approximately ten seconds. The average of the two scores was used in the analysis.

4.2.4 Statistical analyses

Statistical analyses were completed using PASW Statistics 17 (SPSS Inc. Chicago, IL) software and alpha levels were set at $p < 0.05$. Inter-trial differences were calculated by subtracting T1 from T2 and independent samples t-tests were used to explore gender differences for inter-trial differences. Three types of reliability were assessed: rank order repeatability, change in mean and typical error. Intraclass correlation (ICC) was used to provide an estimate of rank order repeatability. ICC provides an indication of how well the ranking (i.e., from lowest value to highest value) of participants in one trial is replicated in subsequent trials. For the current study, an ICC > 0.70 was considered to be acceptable. Change in mean was assessed using paired samples t-tests to identify systematic (e.g., learning or maturation effects) and random change in trial results. Bivariate correlations between the inter-trial difference (T2-T1) and the mean of the trials [(T2-T1)/2)] were used to explore proportional bias. Finally, typical error (i.e., standard error of measurement) was used to explore within-subject variation. Atkinson and Nevill (451) have argued that researchers should consider the purpose of their measures before determining the appropriate degree of error. The RTSB was primarily developed to evaluate the efficacy of school- and community-based resistance training programs. Therefore, it requires the sensitivity to detect small improvements in both individual skills and overall skill competency. As each resistance training skill is performed twice and the performance criteria is summed for each skill (i.e., a score of 8 or 10), an increase of two units represents an improvement in one key performance criteria for one skill. Similarly, an increase in six units on the RTSQ indicates an improvement in three performance criteria (e.g., 3 from 1 skill or 1 from 3 skills). Therefore, we suggest that the RTSB requires the sensitivity to detect a difference of two for the individual skills and six for the RTSQ. The construct validity of the RTSB was tested using multiple regression modeling. Age, gender and RTSQ scores were included as independent variables in the regression model, while MFS was the dependent variable. Age was not significantly associated with MFS and was subsequently removed from the final model.

4.3 Results

No injuries or adverse events occurred during assessments. Based on the IOTF cut-points, 36 (81.8%) of the males and 14 (73.7%) of the females were classified as healthy weight (Table 4.1). Eight males and five females were considered to be overweight. Mean values, standard deviations and inter-trial differences for the individual skills and the RTSQ are reported in Table 4.2. The inter-trial difference for the RTSQ was significantly higher in females (-1.7) than in males (0.3). Females' scores ranged from 4 to 10 (out of 10) for the squat to 33 to 52 (out of 56) for the RTSQ. Males' scores ranged from 3 to 10 (out of 10) for the chest touches to 36 to 53 (out of 56) for the RTSQ.

The ICC estimates, changes in mean and typical error are reported in Table 4.3. The ICC values for individual exercises ranged from 0.67 (95% CI = 0.54, 0.80) for the standing overhead press to 0.87 (95% CI = 0.78, 0.92) for the suspended row. The ICC for the RTSQ was (0.88, 95% CI = 0.80, 0.93).

The change in mean was small (range = -0.4 to 0.3), but statistically significant for the lunge and suspended row. There was some evidence of proportional bias for the front support with chest touches, indicating that the inter-trial difference was inversely related to the mean of trials (r = -0.26, $p < 0.05$). The typical error of the individual skills ranged from 0.6 for lunge and suspended row to 1.2 for the body-weight squat and front support with chest touches. Typical error for the RTSQ was small (RTSQ = 2.5, 95% CIs = 2.1, 3.0).

The final regression model explained 39% of the variance in MFS ($p < .001$). Both gender ($r = .52$, $p < .001$) and RTSQ ($r = .40$, $p < .001$) were significantly associated with MFS, suggesting that participants with higher levels of resistance training skill competency scored higher on the tests of muscular fitness.

Table 4.2 Results from resistance training skills tests in males (*n* = 44) and females (*n* = 19).

Tests		1st Trial (T1)			2nd Trial (T2)			Inter-trial difference (T2 –T1)		
	Range	All	Males	Females	All	Males	Females	All	Males	Females
Body-weight squat[a]	4 to 10	8.0 (1.7)	7.9 (1.7)	8.4 (1.6)	7.8 (1.9)	7.8 (1.9)	7.7 (2.0)	-0.2 (1.7)	-0.0 (1.5)	-0.7 (2.1)
Push-up[b]	4 to 10	6.4 (1.4)	6.6 (1.4)	5.8 (1.2)	6.1 (1.6)	6.5 (1.5)	5.2 (1.4)	-0.3 (1.4)	-0.1 (1.3)	-0.6 (1.5)
Lunge[a]	6 to 10	9.0 (1.2)	8.9 (1.1)	9.0 (1.2)	9.2 (1.1)	9.1 (1.2)	9.4 (0.9)	0.3 (0.9)	0.2 (0.9)	0.4 (0.7)
Suspended row[b]	4 to 8	6.9 (1.1)	6.9 (1.1)	6.9 (1.2)	6.7 (1.2)	6.7 (1.3)	6.9 (1.1)	-0.3 (0.8)	-0.3 (0.7)	-0.1 (0.9)
Standing overhead press[a]	5 to 10	7.5 (1.4)	7.3 (1.4)	8.2 (1.3)	7.7 (1.5)	7.5 (1.5)	8.1 (1.5)	0.1 (1.5)	0.3 (1.5)	-0.1 (1.5)
Front support with chest touch[a]	3 to 10	5.7 (2.0)	5.6 (2.0)	5.9 (2.2)	5.6 (1.7)	5.7 (1.7)	5.4 (1.5)	-0.0 (1.6)	0.2 (1.5)	-0.5 (1.7)
RTSQ[c]	33 to 53	43.6 (5.4)	43.4 (5.4)	44.2 (5.7)	43.2 (5.3)	43.6 (5.1)	42.4 (5.7)	-0.4 (3.5)*	0.3 (3.3)	-1.7 (3.7)*

Note. Mean (SD) reported; RTSQ = gross resistance training skill quotient.

*$p < 0.05$ difference between males and females.

[a]Possible scores 0 to 10.

[b]Possible scores 0 to 8.

[c]Possible scores 0 to 56.

Table 4.3 Reliability of resistance training skills tests in adolescent males and females (N = 63).

Tests	ICC (95% CIs)	Change in mean		r^a	Typical error (95% CIs)[b]
		Mean (SD)	*p*		
Body-weight squat	0.69 (0.48, 0.81)	-0.2 (1.7)	0.276	0.15	1.2 (1.1, 1.5)
Push-up	0.73 (0.54, 0.84)	-0.3 (1.4)	0.126	0.21	1.0 (0.8, 1.2)
Lunge	0.83 (0.71, 0.90)	0.3 (0.9)	0.022*	-0.06	0.6 (0.5, 0.8)
Suspended row	0.87 (0.78, 0.92)	-0.3 (0.8)	0.041*	0.10	0.6 (0.5, 0.7)
Standing overhead press	0.67 (0.54, 0.80)	0.1 (1.5)	0.440	0.08	1.0 (0.9, 1.3)
Front support with chest touch	0.76 (0.61, 0.86)	-0.0 (1.6)	0.815	-0.26*	1.2 (1.0, 1.4)
RTSQ	0.88 (0.80, 0.93)	-0.4 (3.5)	0.429	-0.05	2.5 (2.1, 3.0)

Note. SD = standard deviations; ICC = intra class correlation; CIs = confidence intervals; RTSQ = resistance training skill quotient.

[a]Bivariate correlations between the difference (T2-T1) and the mean [(T2-T1)/2].

[b]Typical error used to identify within subject variation.

*$p < 0.05$.

4.4 Discussion

The aim of this study was to develop and assess the validity and reliability of the Resistance Training Skills Battery for adolescents. Based on feedback from eight experts in pediatric resistance training and movement skill development, the final measure included six skills representing the basic movements commonly used in youth resistance training programs. Our findings indicate that the RTSB has acceptable construct validity based on the significant association between skill competency and muscular fitness. Furthermore, our findings suggest that the RTSB can be used to reliably rank adolescents on their overall resistance training competency and has the necessary sensitivity to detect improvements in resistance training skill proficiency in adolescents.

The importance of developing correct resistance training technique is emphasised in position statements from the American Academy of Pediatrics (452), the Australian Strength and Conditioning Association (453), the Canadian Society for Exercise Physiology (441), the National Strength and Conditioning Association (5) and the United Kingdom Strength and Conditioning Association (440). To our knowledge, this is the first resistance training skills test for adolescents. Although injury rates from supervised youth resistance training are relatively low, using incorrect technique with unsafe behaviour may increase the risk of both minor and serious injuries (38, 40, 452). It seems prudent for adolescents to develop proficiency in basic resistance training skills such as those included in the RTSB before progressing to more advanced exercises. Moreover, progression in a resistance training program should be based on technical proficiency and an understanding of fundamental resistance training principles. For example, physical education lessons taught by qualified teachers could address the importance of developing proper exercise technique and the RTSB could be used to assess students' resistance training skill competency over a semester.

The RTSB was primarily conceived as a tool for assessing the efficacy of school- and community-based resistance training programs. Based on the changes in mean and typical error results, the RTSB can be used reliability to detect small changes in individual skills and overall resistance training competency. There was some evidence of systematic bias for the lunge and suspended row, as observed by a significant increase between trials for the lunge and a significant group decrease for the suspended row. While statistically significant, these differences are not considered to be clinically meaningful (diff. = 0.3 for the lunge and diff. = -0.3 for the suspended row). The importance of discussing reliability findings in terms of practical and or clinical significance has been noted in the sports science literature (454). The change in mean and typical error was small for the individual skills (typical error ≤ 1.2) and the RTSQ (typical error ≤ 2.5). In recent years, there has been an increase in the number of studies evaluating the effects of school- and community-based resistance training programs for both healthy weight (67, 264, 266, 455) and overweight/obese youth (426). These studies typically report their effect on muscular fitness, body composition, metabolic health and sometimes psychological wellbeing. Assessment of resistance training competency may provide additional evidence for program efficacy and learned behaviours. We also suggest that pediatric researchers, health care providers and physical education teachers use the RTSB to provide constructive feedback to participants, which will likely enhance performance, motivation and self-concept.

The RTSB was designed to be used in pediatric research focusing on the importance of resistance training skill competency. The construct validity of the RTSB and its capacity to reliably rank participants (i.e., from least to most skillful), has implications for researchers and practitioners interested in the psychological and physiological benefits of resistance training competency. In the current study, resistance training skill competency (i.e., RTSQ) was significantly associated with muscular fitness, suggesting that more skilled children performed better on the tests of muscular fitness. This is an important finding and provides evidence for the construct validity of the measure. Importantly, resistance training skill competency was significantly associated with fitness after controlling for gender. Competency in a range of fundamental movement skills (FMS; e.g., running, leaping, throwing, kicking) is considered to provide the foundation for a physically active lifestyle (61, 456) and as children progress from participating in traditional team sport activities to lifetime physical activities, studies examining the relationship between skill competency and health outcomes may provide additional evidence for the benefits of regular participation in resistance training activities during childhood and adolescence. Furthermore, longitudinal studies may assess the relationship between changes in RT skill competency and rates of physical activity-related injury in young people.

Self-Determination Theory (SDT) (457) and the Exercise and Self-esteem Model (EXEM) (458) describe the importance of competence and how it influences motivation and self-concept. According to SDT, perceived competence is one of three basic psychological needs that drive intrinsic motivation (457), which has been found to influence physical self-concept in young people (459). Similarly, the EXEM (458) proposes that beliefs about one's ability to perform specific exercises or training activities generalise to a broader perceived physical competence. Providing participants with quantifiable feedback regarding their resistance training competency may help satisfy their basic psychological needs and increase their intrinsic motivation for exercise. This information may complement feedback from fitness test results and provide additional information for self-monitoring (including goal setting), which has been identified as an important strategy for promoting physical activity in young people (460, 461). For example, Dishman and colleagues (460) demonstrated that physical activity self-management strategies (e.g., thoughts, goals, plans, and acts) mediate the relationship between self-efficacy and behaviour in adolescent girls. This finding suggests that adolescent girls with high levels of self-efficacy are more likely to self-monitor their physical activity behaviour, which in turn, is associated with more physical activity. Providing adolescents with feedback on their resistance skill competency and encouraging them to set performance goals (i.e., competency goals) may improve their exercise self-efficacy and their exercise adherence, indirectly via self-monitoring. Studies examining the role of resistance training skill competency on physical activity self-efficacy and behaviour in experimental studies are needed to further explore these hypotheses.

Interestingly, popular fitness test batteries such as FITNESSGRAM®, which was designed to promote lifelong physical activity and fitness, do not include process measures of FMS competency or more specific measures of resistance training competency. This is disappointing because both perceived (462) and actual movement skill competency (463) are important determinants of physical activity behaviour in young people. Based on anecdotal evidence from the research assistants, the adolescents enjoyed completing the process-oriented RTSB. Because the performance criteria were not revealed publicly, the testing environment was more consistent with a mastery climate. Evidence suggests that adolescents who perceive their PE lessons as having a mastery climate are more intrinsically motivated to participate (464). Alternatively, a performance climate in PE is associated with less self-determined forms of motivation (465). In traditional fitness testing lessons, effort and ability are on public display, which can be a source of anxiety for some students (444). It may not be feasible for teachers to assess students' skills using video cameras in class; however, it is possible that qualified PE teachers and/or research assistants may be trained to reliably assess skills live in the school setting as is commonly done in the motor assessment literature. As new technologies emerge, real-time assessment and feedback of students' movement skills may become possible using portable digital devices (e.g., smartphones and tablets).

It should be emphasised that our findings may not be generalisable to youth with pathologies or physical injury. Also, our study sample was relatively small and not representative of all adolescents. All of the skills in the current study were assessed by the same research assistant in a relatively homogenous group of adolescents. Further work is needed to determine to test the validity and reliability of the RTSB with different adolescent populations and researchers.

4.5 Practical applications

Considering the importance of muscular fitness for young people (372) and the popularity of youth resistance training programs, the development of a RTSB that was purposely designed to assess exercise movement competency is a valuable tool for researchers and practitioners. Based on our findings, the RTSB can be used by researchers and practitioners in school- and community-based resistance training programs to evaluate intervention effects and provide additional information for participants to enhance their exercise adherence. This study has demonstrated the construct validity and test-retest reliability of the RTSB in a sample of adolescents. The RTSB can reliably rank participants in regards to their resistance training competency and has the necessary sensitivity to detect small changes in resistance training skill proficiency.

CHAPTER 5: STUDY PROTOCOL FOR THE ATLAS CLUSTER RCT: A SCHOOL-BASED INTERVENTION TARGETING HEALTH-RELATED FITNESS IN ADOLESCENT BOYS FROM LOW-INCOME COMMUNITIES

Preface:

This chapter presents the protocols for the ATLAS cluster RCT, including extensive detail on the study design, intervention components, assessment protocols, and analytical procedures. The ATLAS cluster RCT was conducted to investigate the *Primary aim* of this thesis.

The contents of this chapter were published in *Contemporary Clinical Trials* in January, 2014

Citation:

Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: An obesity prevention intervention for adolescent boys from schools in low-income communities. *Contemporary Clinical Trials*. 2014; 37(1): 106-119.

Abstract

Background. The negative consequences of unhealthy weight gain and the high likelihood of pediatric obesity tracking into adulthood, highlight the importance of targeting youth who are 'at risk' of obesity. The aim of this paper is to report the rationale and study design for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) obesity prevention intervention for adolescent boys living in low-income communities.

Methods/Design. The ATLAS intervention will be evaluated using a cluster randomised controlled trial in 14 secondary schools in the state of New South Wales (NSW), Australia (2012 to 2014). ATLAS is an 8-month multi-component, school-based program informed by Self-Determination Theory and Social Cognitive Theory. The intervention consists of teacher professional development, enhanced school-sport sessions, researcher-led seminars, lunch-time physical activity mentoring sessions, pedometers for self-monitoring, provision of equipment to schools, parental newsletters, and a smartphone application and website. Assessments were conducted at baseline and will be completed again at 9- and 18-months from baseline. Primary outcomes are body mass index (BMI) and waist circumference. Secondary outcomes include BMI z-scores, body fat (bioelectrical impedance analysis), physical activity (accelerometers), muscular fitness (grip strength and push-ups), screen-time, sugared-sweetened beverage consumption, resistance training skill competency, daytime sleepiness, subjective wellbeing, physical self-perception, pathological video gaming, and aggression. Hypothesised mediators of behaviour change will also be explored.

Discussion: ATLAS is an innovative school-based intervention designed to improve the health behaviours and related outcomes of adolescent males in low-income communities.

Trial registration: Australian New Zealand Clinical Trials Registry No: ACTRN12612000978864

5.1 Background

The development of youth obesity is driven by a number of complex and interacting factors (232). While non-modifiable mechanisms are partly to blame, there is strong evidence for the influence of modifiable factors such as physical activity, sedentary behaviour and dietary intake in the genesis of youth obesity (232). Worldwide, there is an estimated 170 million children classified as overweight or obese, with a number of countries reporting combined overweight and obesity prevalence in excess of 20% and as in the US, up to 36% (196). Similarly, approximately 25% of Australian youth are overweight or obese with higher rates found among those from economically disadvantaged communities (121). Gender appears to be an additional risk factor, as the prevalence of overweight and obesity among Australian males is higher than females in both adolescents (121) and adults (210). Consequently, male youth living in disadvantaged communities can be considered a particularly vulnerable group for the development of obesity.

Physical activity confers numerous physiological and psychological benefits during youth including increased bone mineral density, reduced adiposity and higher self-esteem (72). Furthermore, evidence indicates a dose-response relationship between physical activity and health, in which greater benefits are achieved with increasing levels of activity (72). Adolescence is a stage during which physical activity declines sharply (22) and global data suggest that 80% of adolescents are not accumulating sufficient activity to accrue associated health benefits (14). Moreover, physical activity levels are substantially lower among disadvantaged youth (121).

Compounding a reduction in physical activity during adolescence is the amount of time spent in sedentary behaviours. Sedentary behaviour is distinct from lack of physical activity and is considered a unique behavioural construct that has an independent relationship with health (466). The term sedentary behaviour incorporates a range of behaviours that require minimal energy expenditure and generally involve sitting or lying down (467). Of the various sedentary behaviours, screen-based recreation (screen-time) contributes the most to leisure-time sedentary behaviour among youth (144). International guidelines recommend limiting screen-time to less than two hours per day, but 83% of Australian (34), 71% of English, 64% of Canadian and 54% of US adolescent boys exceed these guidelines (35). Reducing screen-time has been identified as an important strategy for preventing the development of obesity and improving the psychosocial health of young people (143, 246).

Schools have been identified as important institutions for the promotion of health behaviours because they have access to almost all youth and the necessary facilities and personnel (468).

However, school-based obesity prevention interventions targeting adolescents have had mixed success (28). Our understanding of the factors that contribute to successful interventions is still developing however, it has been recommended that interventions be designed and evaluated among those most at risk (469, 470) such as youth from low-income communities. Furthermore, as both the determinants and the prevalence of obesity are moderated by gender (471), gender-specific programs may be more suitable and efficacious (67, 262, 267). Methodologically rigorous trials targeting economically disadvantaged groups and tailored for specific genders are clearly warranted. The aim of this paper is to provide the rationale and study description for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) program, an innovative obesity prevention intervention for adolescent boys living in low-income communities.

5.2 Methods/Design

5.2.1 Study design

The ATLAS intervention will be evaluated using a cluster randomised controlled trial (RCT) (Figure 5.1). The 8-month intervention will target adolescent males in Year 8 (second year of secondary school) in 14 co-educational, public secondary schools in New South Wales (NSW), Australia. Assessments were conducted at baseline [November-December (Term 4) 2012], and will be repeated post-program [July-September (Term 3) 2013] and at 18-months post baseline [April-June (Term 2) 2014]. Follow-up data collection for the hypothesised mediators will occur during term 2, 2013 (May-June). These data were collected prior to post-program assessments in recognition that for true mediation to occur, the change in cognitions should precede the change in behaviour. The design, conduct and reporting of this cluster RCT will adhere to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for group trials (472). Ethics approval for this study was obtained from the Human Research Ethics Committees of the University of Newcastle, Australia and the NSW Department of Education and Communities. School principals, teachers, parents and students provided informed written consent.

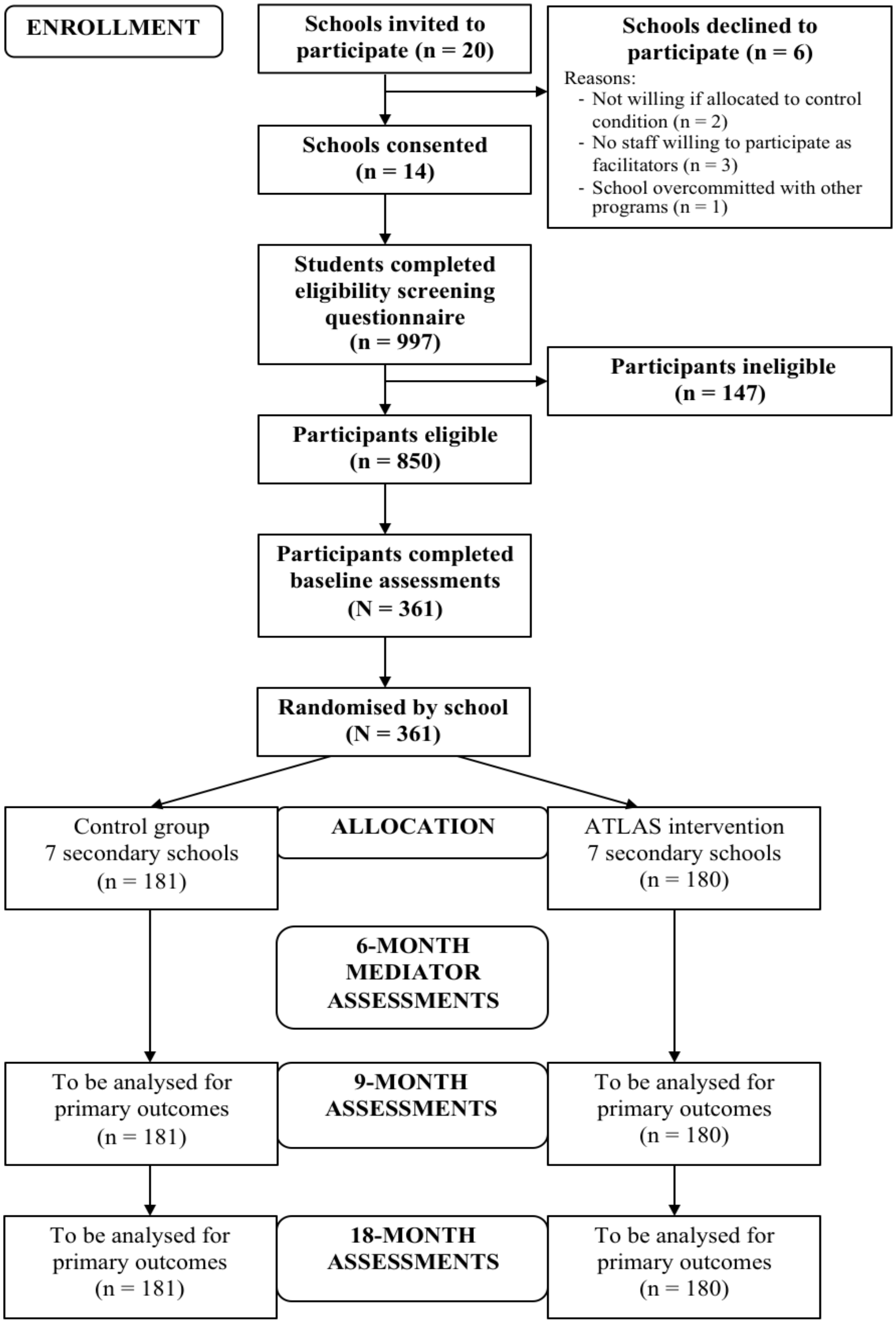

Figure 5.1 Study design and flow

5.2.2 Sample size calculation

A power calculation was conducted to determine the sample size required to detect changes in the primary outcomes (i.e., Body Mass Index [BMI] and waist circumference) at the primary end-point of 9-months (473, 474). Based on the existing literature, a difference of 0.4 kgm^{-2} was considered to be clinically meaningful in the study sample. Power calculations were based on 80% power with alpha levels set at $p < 0.05$ and assumed a school clustering effect of 0.03 (an intraclass correlation coefficient [ICC] of .03 was observed in our pilot study) (475). Baseline post-test correlations ($r = .97$) and standard deviation (SD = 1.1 kgm^{-2}) estimates were also taken from our pilot study (67). It was calculated that a study sample of N = 280 students (i.e., 20 students from 14 schools) would provide adequate power to detect a between-group difference of approximately 0.4 kgm^{-2}. Similarly, the proposed sample size would be adequately powered to detect a between-group difference of 1.5cm in waist circumference ($r = .96$, SD = 11.6 cm). Considering potential drop out among participants of 20% at the primary end point of 9-months (67, 267), we aimed to recruit 350 participants from 14 schools (i.e., 25 from each school).

5.2.3 Setting and participants

The Socio-Economic Indexes for Areas (SEIFA) of relative socioeconomic disadvantage was used to identify eligible secondary schools. The SEIFA index (scale 1 = *lowest* to 10 = *highest*) summarises the characteristics of people and households within an area and was developed using the following data: employment, education, low income, family breakdown, financial wellbeing, family type, housing stress, overcrowding, home ownership, family support, lack of wealth (no car or telephone), foreign birth and Indigenous status. Secondary schools located in the Newcastle, Hunter, and Central Coast areas of NSW with a SEIFA index of ≤ 5 (lowest 50%) and an enrolment of at least 100 students in the targeted year group were eligible to participate in the study.

5.2.4 Eligibility screening

Prior to baseline assessments, all male students in the targeted year group at the study schools were asked to complete a two-item screening questionnaire. The questionnaire was used to identify students that may be 'at risk' of obesity based on their physical activity and screen-time behaviours. Students were considered to be 'at risk' if they did not meet the current physical activity and/or screen-time guidelines for Australian adolescents (≥ 2 hours of screen-based recreation and/or < 7 days per week of moderate- to-vigorous intensity physical activity [MVPA] of at least 60 minutes duration per day) (476). Data from a statewide survey in NSW indicate that approximately 57% and 32.5% of low socio-economic status (SES) males of similar age meet the physical activity and screen-time guidelines, respectively (121). All eligible students received information and consent forms. The recruitment target was 25 students per school however; up to 30 students from each school could be accepted. The first 30 students from each school to return their completed consent form were included in the study.

Table 5.1 Intervention components, behaviour change techniques, and targeted constructs in the ATLAS intervention.

Intervention component	Dose	Description	Behaviour change strategies	Hypothesised mediators
Teachers				
1. Teacher professional development	2 x 6 hour workshops	Teachers attend two professional development workshops during the study period (pre- and mid-program). The workshops provide a rationale for the program, outline the intervention strategies (i.e., program components, behavioural messages) and explain the theory behind the intervention.	▪ Provide instruction ▪ General encouragement ▪ Plan social support or social change ▪ Provide information about behaviour health link	▪ Motivation in school sport ▪ Perceived autonomy ▪ Perceived competence ▪ Perceived relatedness
	1 x fitness instructor session	Each school will receive one visit during their regularly scheduled sport session from a practicing fitness instructor (i.e., personal trainer). The fitness instructor will deliver the session while the teacher observes and completes the session observation checklist.		
Parents				
2. Parent newsletters	4 x newsletters	Parents of study participants will receive four newsletters containing information on the potential consequences of excessive screen-use among youth, strategies for reducing screen-based recreation in the family home, and tips for avoiding conflict when implementing rules. They will also be provided with their child's baseline fitness test results.	▪ Provide feedback on performance ▪ Plan social support or social change ▪ General encouragement ▪ Provide information about behaviour health link ▪ Behaviour contract	▪ Motivation to limit screen-time ▪ Household screen-time rules

Students					
3.	Researcher-led seminars	3 x 20 mins	Participants will attend three interactive seminars delivered by members of the research team. Seminars will provide key information surrounding the program's components and behavioural messages including current recommendations regarding youth physical activity, screen-time, and resistance training, and will outline the student leadership component of the intervention.	▪ Provide information about behaviour health link ▪ Prompt self-monitoring of behaviours ▪ Plan social support or social change ▪ Prompt barrier identification ▪ Prompt specific goal setting	▪ Motivation in school sport ▪ Motivation to limit screen-time
4.	Enhanced school sport sessions	20 x 90 min sessions	Sport sessions will be delivered by teachers at the study schools. Activities will include elastic tubing resistance training, aerobic- and strength-based activities, fitness challenges, and modified ball games. Behavioural messages will be reinforced during the cool-down period.	▪ Information on consequences ▪ Prompt intention formation ▪ Provide instruction ▪ General encouragement ▪ Graded tasks	▪ Motivation in school sport ▪ Perceived autonomy ▪ Perceived competence ▪ Perceived relatedness
5.	Lunch-time physical activity mentoring sessions	6 x 20 min sessions	Students will participate in six lunch-time physical activity mentoring sessions. These self-directed sessions will involve recruiting and instructing grade 7 boys in elastic tubing resistance training.	▪ Model or demonstrate the behaviour ▪ Graded tasks ▪ Prompt identification as a role model	▪ Motivation in school sport ▪ Perceived autonomy ▪ Perceived competence ▪ Perceived relatedness
6.	Smartphone application and website	15 weeks	The smartphone application and website will be used for physical activity monitoring, recording of fitness challenge results, tailored motivational messaging, peer assessment of RT skills, and goal setting for physical activity and screen-time.	▪ Provide information about behaviour health link ▪ Prompt self-monitoring of behaviours ▪ Prompt specific goal setting ▪ Information on consequences ▪ General encouragement	▪ Motivation in school sport ▪ Perceived competence ▪ Physical activity behavioural strategies ▪ Motivation to limit screen-time

7.	Pedometers	17 weeks	Participants will be provided with pedometers for self-monitoring. Students will be encouraged to set goals to increase their daily step counts and monitor their progress using the pedometer. Pedometer step counts can also be entered into the smartphone application for review.	▪ Prompt self-monitoring of behaviours ▪ Prompt specific goal setting	▪ Physical activity behavioural strategies

5.2.5 Blinding and randomisation

Recruitment and baseline assessments were conducted prior to randomisation. Schools were match-paired, based on their size, SEIFA score and geographic location, and then randomly allocated to the intervention or control group using a computer-based random number producing algorithm. Randomisation was performed by a researcher not involved in the current study. Schools will remain in their allocated group for the duration of the study.

5.2.6 Intervention

ATLAS is an 8-month multi-component physical activity and sedentary behaviour intervention for adolescent boys ‘at risk’ of obesity (Figure 5.2). The intervention is based on the Physical Activity Leaders (PALs) RCT (67, 477), a successful pilot study conducted in four secondary schools in the Hunter Region, NSW, Australia. The intervention consists of teacher professional development, researcher-led seminars, enhanced school sport sessions, lunch-time physical activity mentoring sessions, provision of fitness equipment to schools, a smartphone application and website, pedometers for self-monitoring, and parental strategies to reduce screen-time. Table 5.1 includes the intervention components, behaviour change strategies and hypothesised mediators of behaviour change.

5.2.6.1 Theoretical basis of ATLAS

The ATLAS intervention was developed with reference to Self-Determination Theory (SDT) (66) and Social Cognitive Theory (SCT) (68). Specifically, the intervention is guided by the trans-contextual model of motivation (282), which posits that increasing autonomous motivation for physical activity in one context (e.g., physical education or school sport) will result in increased autonomous motivation for physical activity in other contexts (e.g., after school and on weekends). Consequently, the development of autonomous motivation in school sport, through satisfaction of the three basic psychological needs of autonomy, competence and relatedness, is expected to indirectly influence physical activity behaviour during leisure-time (478). A core component of the ATLAS intervention is the provision of professional development for teachers to ensure that students’ basic psychological needs are satisfied in school sport. The basic psychological needs are operationalised through the SAAFE (Supportive, Active, Autonomous, Fair and Enjoyable) teaching principles (479) (Table 5.2), which were outlined to teachers during the pre-program professional development workshop.

These principles are reinforced throughout the intervention period through post-observation feedback to teachers (see process evaluation).

According to Bandura's SCT, perceived self-efficacy (i.e., a belief in one's capability or competence within a specific context) is a central and pervasive determinant of human motivation (480). In activities in which competence dictates the outcome, such as in a variety of physical activities, self-efficacy plays an important role in an individual's decision to engage in the behaviour, the amount of effort expended, and an individual's level of perseverance in the face of difficulty. Considering the decision to incorporate potentially unfamiliar resistance training activities within the ATLAS program, developing self-efficacy was considered an important aspect of the intervention. To enhance self-efficacy, each sport session includes time dedicated to resistance training skill development during which teachers provide feedback on correct resistance training technique. SCT also suggests that for some people certain behaviours (e.g., physical activity) may not in themselves be intrinsically rewarding, regardless of the individual's perceived self-efficacy or their recognition of the expected benefits. Therefore, another set of skills is required to counteract the potentially contravening cognitions associated with the behaviour. According to Bandura, self-regulatory skills (i.e., self-monitoring and goal setting) are important contributors to behavioural 'commitment' and hence behaviour maintenance (286). The relevant implication is that changing activity behaviour requires more than simply developing self-efficacy. It also requires the development of specific cognitive skills, which will support adherence to physical activity into the future. Pedometers were provided to students to assist in self-monitoring of physical activity while goal setting of physical activity and screen-time behaviours was made available through the smartphone application and website and promoted by teachers.

5.2.6.2 Professional development for teachers

Professional development for the ATLAS facilitators (physical education teachers) was delivered through two full-day workshops. As an additional incentive, the workshops were approved by the NSW Institute of Teachers as an accredited component of professional development. In NSW schools, teachers must complete 50 hours of professional development within the first five years of their career by attending institute-approved courses. While this does not apply to all teachers involved in ATLAS, teachers that are within their first five years of service are able to claim 12 hours of professional development time for the two workshops attended. The first workshop was conducted in December 2012 prior to the commencement of the intervention. It provided a background to youth obesity prevention and familiarised teachers with the intervention components (i.e., intervention strategies, behavioural messages, session structure and observations) and the SAAFE teaching principles. To further educate the teachers about the SAAFE principles, the first ATLAS sport session at each study school was delivered by a member of the research team (DRL, PJM, or JJS). Teachers were asked to observe the session and complete the SAAFE evaluation checklist. The checklist outlined specific elements of the session, which apply to each of the principles (see process evaluation). The second workshop was conducted mid-program in April 2013. In this workshop, an overview of the baseline results was provided as well as an outline of SDT and its applications in physical education and school sport.

5.2.6.3 Intervention components and delivery

Overview. The intervention is being delivered over two school terms (i.e., 20 weeks) and focuses on promoting lifetime (e.g., resistance training) and lifestyle physical activities (e.g., walking and riding to school). ATLAS is aligned with current physical activity guidelines, which include a recommendation to engage in muscle and bone strengthening physical activities on at least three days per week (105). In addition to a focus on developing muscular fitness, the intervention also aims to increase low-intensity incidental activity. Non-Exercise Activity Thermogenesis (NEAT), the energy expended through all physical activities outside of purposeful exercise, contributes substantially to overall daily energy expenditure (481). A reduction in NEAT, potentially through increased sedentariness during discretionary time and a reduction in levels of active transport has been implicated in the rise in obesity in developed countries (482). ATLAS encourages participants to increase their NEAT and suggests strategies such as choosing active rather than passive transport options, using stairs instead of lifts where possible, and breaking up sedentary time. The intervention also aims to reduce consumption of sugar-sweetened beverages (SSB's). Regular consumption of SSB's, including carbonated soft drinks (i.e., soda), cordials, and refined fruit juices may contribute substantially to overall daily energy intake and evidence suggests that SSB consumption is associated with higher adiposity among youth (483). In addition, adolescents may have more control over this dietary outcome as other aspects of diet quality (e.g., fruit and vegetable intake) may be predominantly determined by parental influences (i.e., grocery purchasing and meal preparation). This is supported by the findings from the PALs pilot study, in which there was a significant intervention effect for SSB intake but not for consumption of fruit and vegetables despite each of these dietary outcomes being targeted (67). The intervention promotes four key messages relating to energy balance-related behaviours: (i) walk whenever you can; (ii) get some vigorous physical activity on most days; (iii) reduce your recreational screen-time; and (iv) drink more water and less sugary drinks. Students are provided with information regarding these behavioural messages during the researcher-led seminars and teachers reinforce them during the closure section of each sport session.

Enhanced school sport sessions. School sport, while available in a variety of formats (6), is mandatorily provided to junior school students in NSW schools on a weekly basis and occurs in addition to regular physical education classes. The ATLAS enhanced sport sessions occur during the regularly scheduled period allocated to school sport at each school. While the time of day and the day of the week for the sport sessions vary between schools, each school receives a similar amount of school sport time in a normal week. School sport sessions are delivered by teachers at the study schools, at no cost to students, and involve elastic tubing resistance training; fitness challenges, aerobic- and strength-based activities, and modified ball games. In low-income communities in particular, the cost of many school sport activities can be a considerable barrier to participation (6). The sport sessions follow a predetermined structure, which was outlined to teachers during professional development prior to the start of the intervention. The sessions are organised into the following format: (i) warm up: movement-based games and dynamic stretches; (ii) resistance training skill development: Gymstick™ and body-weight exercise circuit; (iii) fitness challenge: short duration, high intensity Crossfit™-style workout performed individually with the aim of completing the workout as quickly as possible; (iv) Games: minor strength and aerobic-based games (e.g., sock wrestling, tag-style games) and small sided ball games that maximise participation and active learning time (e.g., touch football); and (v) cool down: static stretching and discussion of ATLAS messages. Finally, during the second school term, each school will receive one visit during their regularly scheduled sport session from a practicing fitness instructor (i.e., personal trainer). The fitness instructor will deliver the session while the teacher observes and completes the session observation checklist. This component was included to provide additional professional development for teachers.

Sessions will include structured Rough-and-Tumble Play activities as part of the strength-based games section. These are vigorous activities that on the surface may appear to be aggressive except for the playful context in which they take place and include activities such as wrestling, grappling and tumbling (484). Rough-and-tumble play behaviour occurs among a number of mammalian species and is believed to be an important experience for the affective and cognitive development of youth (especially for boys) (485). Furthermore, rough-and-tumble play experiences are thought to contribute to feelings of relatedness and provide opportunities for youth to develop key self-regulation skills thereby reducing the likelihood of using aggressive behaviours in the future (485, 486).

Lunch-time leadership sessions. During the second school term students will have the opportunity to participate in physical activity mentoring sessions. Study participants will be asked to participate in the organisation and conduct of supervised physical activity sessions during six lunchtime periods, approximately 20 minutes in duration. Students will be required to partner with a younger peer and provide corrective feedback during the conduct of a Gymstick™ and bodyweight resistance-exercise circuit.

Smartphone application (app). A smartphone app was developed to support the delivery of the intervention. The application was made available on both iOS and Android platforms. To cater for those without access to a smartphone device, the same functions were available via the ATLAS website, which was developed for the current study. Research suggests that 73% of 12-14 year olds (487) and 90% of adolescents over the age of 15 (488) own mobile devices (i.e., smartphones or tablets). Smartphone ownership among youth has accelerated and doesn’t appear to be moderated by SES (489). Functions of the application/website include: (i) physical activity monitoring through recording daily step counts from pedometers; (ii) recording and review of fitness challenge results; (iii) peer assessment of resistance training skill competency; (iv) goal setting for screen-time and physical activity; and (v) tailored motivational messaging. At the commencement of the intervention, students were asked to select two reasons that motivated them most to be physically active from a list of four possible reasons: (i) to look good; (ii) to improve my health; (iii) to do better at school; and (iv) to spend time with friends. Once the student submitted their preferences, messages based on the two reasons they selected were sent via ‘push notifications’ through the app. The messages were written in vernacular ‘text speak’ in order to connect with students (e.g., *Exercise helps u look fit and feel good. How much exercise have u done 2day?*).

Parent/caregiver strategies to reduce screen-time. During the study period, four newsletters (two per school term) will be mailed to the parents/caregivers of study participants. Each newsletter will contain information on the consequences of excessive screen-time among youth, potential strategies to reduce their adolescent’s screen-time (e.g., removal of screen devices from the bedroom, screen-time curfew), and strategies for preventing conflict when discussing screen-time issues. In addition, the first newsletter will include a behaviour contract and list of potential screen-time rules and the third newsletter will include a physical activity and fitness report card, which provides individualised results from baseline assessments. Reference values for each test will be provided to give context to the results.

Control group: To prevent compensatory rivalry and resentful demoralisation (490), the control schools will be provided with a condensed version of the program following the 18-month assessments. The condensed version of the program will include the professional learning workshops for teachers and resources to conduct the enhanced school sport sessions. As was done for intervention schools, an equipment pack valued at approximately $1000 AUD (including pedometers, elastic tubing devices, boxing gloves, focus pads and hanging gym handles) will also be provided based on individual school requirements.

Table 5.2 SAAFE teaching principles

Principles	Strategies
Supportive – Sessions conducted in a supportive environment	1. Publicly recognise all students' effort, learning, achievements, and improvement. 2. Provide feedback on student effort, process and progress (not results). 3. Identify and manage inappropriate student behaviour (e.g., teasing, over-competitiveness). 4. Promote positive social interactions between students.
Active – Sessions involve a high level of active time	1. Use small-side games, circuits and tabloids to maximise participation. 2. Ensure equipment is plentiful and developmentally appropriate. 3. Monitor in-class physical activity using pedometers 4. Use student leaders to set-up games and activities.
Autonomous – Sessions involve elements of choice and opportunities for graded tasks	1. Ensure that tasks incorporate multiple challenge levels, and give students the freedom to select level of difficulty. 2. Provide students with opportunities to create and modify rules and activities. 3. Provide students with opportunities for leadership roles. 4. Encourage students to assess their own skill performances (e.g., detect and correct their own errors).
Fair – Sessions provide all students with an opportunity to experience success	1. Ensure tasks are not dominated by the most competent students. 2. Modify the tasks to increase the opportunity for success (i.e., make the goals bigger, reduce the number of defensive players, alter the equipment used, revise the task rules). 3. Ensure students are evenly matched in competitive activities. 4. Acknowledge and reward participation and good sportsmanship.
Enjoyable – Sessions are designed to be enjoyable and engaging for all students	1. Include a wide variety of games and activities. 2. Provide engaging and age appropriate tasks. 3. Avoid boring and repetitive activity (e.g., running around the field for a warm-up). 4. Don't use exercise or activity as punishment.

5.2.7 Outcomes

A protocol manual with specific instructions for conducting all assessments was used by research assistants during baseline data collection and will be used during follow-up assessments to ensure consistency. Questionnaires were completed in exam-like conditions using an online survey with Apple iPads and physical assessments were conducted in a sensitive manner (e.g., weight and waist circumference measured out of the view of other students). Demographic information including age, ethnicity, language spoken at home, residential postcode and parents'/caregivers' highest level of education was collected at baseline. A range of primary and secondary outcomes and hypothesised mediators of behaviour change were also measured.

5.2.7.1 Primary outcomes

Height and weight. Weight was measured to the nearest 0.1kg without shoes, in light clothing using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo Japan) and height was recorded to the nearest 0.1 cm using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia). BMI was calculated using the standard equation ($weight[kg]/height[m]^2$) and BMI z-scores were calculated using the 'LMS' method (491).

Waist circumference. Waist circumference was measured to the nearest 0.1cm against the skin using a non-extensible steel tape (KDSF10-02, KDS corporation, Osaka, Japan) in line with the umbilicus.

5.2.7.2 Secondary Outcomes

Body fat percentage. The Imp™ SFB7 bioelectrical impedance analyser (BIA) was used to determine percentage body fat, fat free mass and fat mass. The Imp™ SFB7 (492) is a multi-frequency, tetra polar bioelectrical impedance spectroscopy device and has acceptable test-retest reliability in adolescents (ICC [95%CI] = .95 [.90 to .97]) (493).

Physical activity. Physical activity was assessed using triaxial Actigraph™ accelerometers (model GT3X+), worn by participants during waking hours for seven consecutive days, except while bathing and swimming. Trained research assistants, following standardised accelerometer protocols (494) fitted the monitors and explained the monitoring procedures to students. Data were collected and stored in 5-second epochs. Valid wear time was defined as a minimum of three days with at least 8 hours (i.e., 480 minutes) of total wear time recorded. Non-wear time was defined as 30 minutes of consecutive zeros. A recent review identified eight and 10 hours of wear time as the most commonly used protocols in adolescent studies (495). The mean activity counts per minute (CPM) were calculated, while the thresholds for activity counts proposed by Evenson et al. (496) were used to categorise physical activity into sedentary, light, moderate, and vigorous intensity activity. Moderate and vigorous activity is summed to produce an MVPA variable.

Muscular fitness. The 90-degree push-up test was used as a measure of upper body muscular endurance (497). Testing procedures were explained to the participants prior to the test. The test began with participants in the push-up position with hands and toes touching the floor, arms approximately shoulder width apart and back straight. Participants lowered themselves to the floor in a controlled manner until a 90-degree angle was formed at the elbow then pushed back up. Push-ups were performed in time with a metronome, set at 40 beats per minute, allowing one push-up every three seconds. The test concluded when participants either failed to lower themselves to the required depth on three non-consecutive repetitions (warnings verbalised by assessor), failed to maintain the movement with adequate form in time with the metronome, or upon volitional failure. Assessors did not provide verbal encouragement during the conduct of the test. This test has acceptable test-retest reliability in adolescents (ICC [95%CI] = .90 [.80 to .95])(493).

Strength of the hand and forearm muscles was assessed using a handgrip dynamometer (SMEDLEY'S dynamometer TTM, Tokyo, Japan). As demonstrated by Ortega et al. (3), there is an optimal grip span for grip strength measurements which is partly influenced by the hand size of the participant being assessed. Therefore, the grip-span on the dynamometer was adjusted to suit the hand size of the participant prior to their performance. Subjects were asked to squeeze the dynamometer continuously as hard as possible for three seconds with the elbow in full extension down by the side of the body. The test was performed three times each for the left and right hands, alternating hands after each trial. A recent systematic review identified the hand grip test as a valid test to assess upper body maximal strength among youth (211). In addition, grip strength testing has demonstrated acceptable test-retest reliability among adolescents (447).

Resistance training skill competency. Resistance training skill competency was assessed using video analysis of the Resistance Training Skills Battery (RTSB) (8). The test requires participants to perform six movements (lunge, push-up, overhead press, front support with chest touches, squat, and suspended row) considered to be the foundation for more complex exercises used in resistance training programs. Each skill consists of four or five performance criteria and is scored by adding the total number of criteria successfully demonstrated. Each skill is performed twice, resulting in a total score of either 8 or 10 depending on the number of performance criteria. An overall gross resistance training skill quotient (RTSQ) is created by adding the six scores (possible range 0 to 56). Students were provided with a demonstration of each skill prior to being assessed. They were asked to perform two sets of four repetitions of each skill and were allowed a rest period of up to 15 seconds between sets. The assessor did not provide verbal encouragement or skill specific feedback during the performance of the skill. The RTSB has demonstrated satisfactory concurrent validity ($r = .52$, $p = <.001$) and test-retest reliability (ICC [95%CI] = .88 [.80 to .93]) among a sample of adolescents (8).

5.2.7.3 Student questionnaire

Recreational screen-time. A modified version of the Adolescent Sedentary Activity Questionnaire (ASAQ) (498) was used to determine time spent in screen-based recreation. The ASAQ requires subjects to self-report the total time spent engaged in a variety of recreational screen behaviours (e.g., watching television, playing video games, using the computer). Total screen-time is then determined as the sum of time spent in each screen behaviour. However, evidence suggests that youth often use multiple screen devices simultaneously (e.g., surfing the internet on a laptop while watching television) (499, 500). Although respondents are asked to consider media-multitasking when completing the ASAQ, scoring adjustments are only made if participants' screen-time values are implausible. The modified ASAQ used in the current study required respondents to report the 'total time' spent sitting using screens (of any kind) for anything other than homework on each day of the week. Therefore, rather than providing data on time spent using individual screen devices and summing the times for each, this measure instead provides data on 'total screen-time'. It is believed that this method will provide a more accurate assessment of total screen-time by addressing the issue of screen multitasking (499, 500). Students were also asked to list their three favorite computer/video games.

Sugar-sweetened beverage consumption. Two items from the NSW Schools Physical Activity and Nutrition Survey (SPANS) (121) were used to assess consumption of sugar-sweetened beverages (SSB's). Students were asked to report how many glasses of fruit-based drinks and soft drinks/cordial they consumed on a 'usual' day (range = *none* to *7 or more per day*).

Physical self-concept. Items from the perceived strength subscale of the Physical Self-Description Questionnaire (PSDQ) (501) were used. Students were asked to respond on a 6-point scale (*1 = False, to 6 = True)* how true each statement was for them (e.g., *I am a physically strong person*).

The PSDQ is a valid method for measuring physical self-concept (501) and the perceived strength subscale has satisfactory reliability in the current sample (Cronbach's α = .69) (501).

Subjective wellbeing. Diener and colleagues' psychological flourishing scale (502) was used to measure subjective wellbeing. Students responded on a 7-point scale (*1=Strongly disagree, to 7=Strongly agree*) to how much they agreed with each statement relating to indicators of social wellbeing (e.g., *I lead a purposeful and meaningful life*). A composite score was created by summing the scores for each item (possible range 8 to 56). A high score represents a person with many psychological resources and strengths. This scale has demonstrated satisfactory construct validity (502), and acceptable reliability in the current sample (Cronbach's α = .88).

Pathological video gaming. Gentile's pathological video gaming scale (503) was used to classify participants as problem gamers. The scale contains 11 questions pertaining to cognitions and behaviours indicative of pathological gaming (e.g., *Have you played video games as a way of escaping from problems or bad feelings?*). Students responded either *Yes (= 1), No (= 0)*, or *Sometimes (= 0.5)* to each question. A sum total of ≥ 6 qualifies a subject as a pathological gamer. This scale has demonstrated satisfactory construct validity in a large sample of youth aged 8-18 years (503) and has shown acceptable reliability in the current sample (Cronbach's α = .76).

Aggression. Aggressive behaviour was assessed using an aggression scale designed for young adolescents (504). Students were asked to report how many times in the last week they engaged in 11 specific aggressive behaviours (e.g., *I threatened to hit or hurt someone*). Responses range from 0 to 6 or more times per week for each aggressive behaviour. Items were summed to produce a total aggression score (possible range 0 to 66). This scale has demonstrated satisfactory content and construct validity in adolescent males (504) and has shown acceptable reliability in the current sample (Cronbach's α = .90).

Daytime sleepiness. Three items from the Pediatric Daytime Sleepiness Scale (505) were used to measure daytime sleepiness. Students responded on a 4-point scale *(0 = never, to 4 = always)* to how often they experienced symptoms characteristic of insufficient or inadequate sleep (e.g., *How often do you fall asleep or get drowsy during class periods?*). Items were summed to produce a total daytime sleepiness score (possible range 0 to 12). While the internal consistency of these items in the current sample is slightly lower than what is commonly deemed desirable (Cronbach's α = .63), this is likely the result of only three items being used.

5.2.7.4 Hypothesised mediators

The role of psychological theories and cognitive mediators in the effectiveness of school-based interventions has been identified as a gap in the current research literature (289, 506). Further testing of potential cognitive mediators in methodologically rigorous trials may help elucidate specific intervention strategies that contribute to achieving a significant effect. The hypothesised mediators, including example items and scale reliabilities, are listed in Table 5.3.

Motivation in school sport. Motivational regulations for school sport outlined in SDT were assessed with an adapted scale used by Goudas et al. (507). The original items were designed for use in the physical education context, which were modified to assess motivation for school sport. Students responded to 20 items on a 7-point scale (*1 = not at all true, 7 = very true*).

Psychological needs satisfaction. 19 items from existing validated scales (508, 509) were used to assess autonomy (i.e., choice, volition and internal perceived locus of causality), competence and relatedness needs satisfaction during school sport. Items designed for use within the physical education context were adapted to apply to school sport. Students responded on a 7-point scale (*1 = not at all true, 7 = very true*).

Motivation to limit screen-time. The Motivation to Limit Screen-time Questionnaire (MLSQ) (479) was developed to assess participants' motivation for limiting time spent engaged in sedentary screen-based recreation. The MLSQ contains nine questions relating to the three broad motivational regulations outlined in SDT (i.e., autonomous motivation, controlled motivation, and amotivation) (66). The subscales are weighted to create a single continuous variable known as the relative autonomy index which is calculated using the following: RAI = Σ ([Autonomous x 2] + [Controlled x -1] + [Amotivation x -2]). A positive score represents autonomous motivation to limit screen-time. The MLSQ has demonstrated satisfactory construct validity and test-retest reliability (ICC [95%CI] = .81 [.66 to .89]) in adolescent boys (479).

Screen-time rules: Screen-time rules from a survey developed by Ramirez et al. (510) were adapted for the present study. Students responded either *No*, *Sometimes*, or *Yes* for each of six items relating to screen-time rules within their family home using the common stem: *In your home do your parents/caregivers have the following rules about screen-use?* The items were originally designed to apply specifically to TV/DVD or computer use and were therefore adapted to apply to all screen-time devices (e.g., *No screen-time before homework*). Test-retest reliability for these items is fair (κ = .43 to .61) (511) among adolescents and the presence of these rules has been shown to be significantly inversely associated with screen-time (510).

Physical activity behavioural strategies. Students responded to six items developed by Dewar et al. (512) for use with adolescents. The items relate to the use of social-cognitive strategies for successfully engaging in physical activity. Students were instructed to respond to each item on a 5-point scale (*1 = never to 5 = always*). These items have acceptable test-retest reliability in adolescents (ICC [95%CI] = .91 [.88 to .93]) (512).

5.2.8 Process evaluation

A range of process data will be collected to complement the outcome data. Process measures include: (i) student attendance at sport sessions (i.e., percentage attendance); (ii) student leadership accreditation (i.e., number of students who satisfy the accreditation guidelines); (iii) teacher satisfaction with professional learning workshops (using workshop evaluation questionnaires); (iv) parental involvement using a process evaluation questionnaire (e.g. reading newsletters and using suggested strategies to reduce screen-time); (v) teacher, student and parent satisfaction with all intervention components (using program evaluation questionnaires at the completion of the study); and (vi) intervention fidelity (determined by 4 x sport session observations at each school by the research team). The observations are completed with reference to an observation checklist developed for the intervention. The checklist is used to determine whether the sessions adhered to the proposed session structure (i.e., 'Yes' or 'No' for each component of the session) and also the degree to which the session demonstrated the SAAFE teaching principles. For each of the five SAAFE principles, there are three or four statements pertaining to how the principle should be applied within a session (e.g., *Supportive – teacher provides individual skill specific feedback*). The degree to which each principle is implemented is determined by assigning a score on a 5-point scale for each statement (*1 = not at all true*, *5 = very true)*. Feedback is given to the teachers at the conclusion of the sport session including strengths of the session and areas for improvement. All observations are conducted by an assessor with a background in physical education, after familiarisation with the observation checklist. Teachers used the same checklist to observe the researcher-led session conducted at the beginning of the intervention.

Table 5.3 Hypothesised mediators of physical activity and screen-time.

Mediator	**Response range (No. of items)**	**Example item**	**α[1]**
Motivation in school sport		Common stem: *I take part in school sport…*	
Amotivation	1-7(4)	*But I don't really know why*	.78
External regulation	1-7(4)	*Because I'll get in trouble if I don't*	.77
Introjected regulation	1-7(4)	*Because I would feel bad if I didn't*	.75
Identified regulation	1-7(4)	*Because I want to learn sport skills*	.84
Intrinsic regulation	1-7(4)	*Because school sport is exciting*	.85
Psychological needs satisfaction in school sport			
Autonomy (choice)	1-7(4)	*I can decide which activities I want to practice in school sport*	.77
Autonomy (volition)	1-7(3)	*I really have a sense of wanting to take part in school sport*	.73
Autonomy (Internal perceived locus of causality)	1-7(3)	*I am doing what I want to be doing in today's class*	.76
Competence	1-7(4)	*I feel pretty competent in school sport*	.82
Relatedness	1-7(5)	*In school sport I feel listened to*	.84
Motivation to limit screen-time			
Amotivation	0-6(7)	*I don't see why I should try to limit my screen-time*	.84
Controlled motivation	0-6(7)	*I try to limit my screen-time because my parent(s) will get angry with me if I don't*	.65
Autonomous motivation	0-6(7)	*I try to limit my screen-time because I feel it is important to me*	.74
Physical activity behavioural strategies		Common stem: *In the past three months how often…*	
	1-5(6)	*Did you organise to be physically active with a friend or family member*	.74
Screen-time rules	1-3(7)	*Less than 2 hours of recreational screen-time per day*	NR

Note. NR = not relevant

[1]Cronbach's alpha's derived from the ATLAS study sample

5.2.9 Statistical methods

Statistical analyses of the primary and secondary outcomes will be conducted with linear mixed models using IBM SPSS Statistics for Windows, Version 20.0 (2010 SPSS Inc., IBM Company Armonk, NY) and alpha levels will be set at $p < 0.05$. The models will be used to assess the impact of treatment (ATLAS or control), time (treated as categorical with levels baseline and 9-months) and the group-by-time interaction, these three terms forming the base model. The models will be specified to adjust for the clustered nature of the data and will include all randomised participants in the analysis. Mixed models are robust to the biases of missing data and provide appropriate balance of Type 1 and Type 2 errors (513). Mixed model analyses are consistent with the intention-to-treat principle, assuming the data are missing at random (514). Differences between completers and those who drop out of the study will be examined using Chi-square and independent samples t-tests. Multiple imputation will be considered as a sensitivity analysis if the dropout rate is substantial. Sub-group analyses will be conducted with participants classified as overweight or obese at baseline for all body composition outcomes. Additional moderators of intervention effects (e.g., ethnicity and socio-economic status) will be explored using linear mixed models with interaction terms. Hypothesised mediators of physical activity and sedentary behaviour change will be examined using multilevel linear analysis and a product-of-coefficients test that is appropriate for cluster randomised controlled trials (515).

5.3 Results

The study design and flow can be found in Figure 5.1. Twenty-two public secondary schools in the Hunter and Central Coast, NSW were identified as eligible for inclusion in the study based on their SEIFA score. An information and consent form was sent to the principal of each school followed by contact from a member of the research team. Of the schools that were contacted, 14 consented to participate and 4 declined. The required number of schools was reached prior to a decision from the remaining two schools. Eligibility screening was completed by 997 students, of whom 850 (85%) were considered eligible. In total, 361 participants from 14 secondary schools were assessed at baseline. Due to the nature of the study we are unable to report an accurate consent rate (i.e., percentage of consent letters returned divided by the number of consent letters distributed). However, the recruitment target of 25 students per school was achieved in seven of the 14 schools and five of the remaining seven schools were close to the target (i.e., ≥ 22 students). The final recruitment rate was 94%.

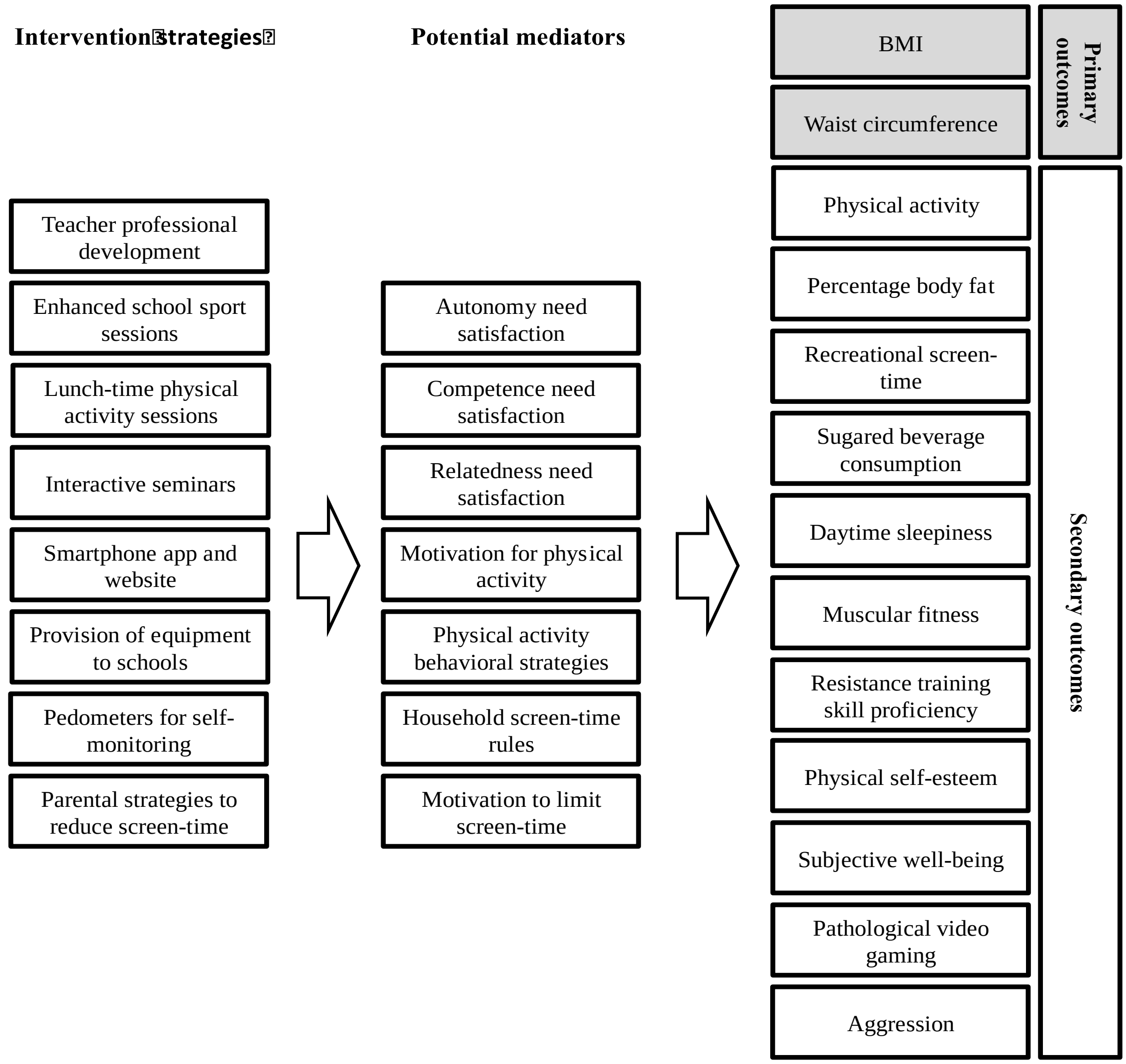

Figure 5.2 ATLAS intervention components, potential mediators and outcomes

5.4 Discussion

Adolescence is a life phase crucial to future health and has been described as a critical period for the prevention of obesity (23, 516). Supporting this contention is strong evidence that obesity tracks into adulthood (59). While the physiological benefits of maintaining a healthy weight across the lifespan are numerous (165), the most immediate benefits of improving the antecedents of obesity may be psychological. Increased physical activity has been linked to short-term improvements in self-esteem in young people (69, 90) and, while more prospective and experimental data are required, evidence suggests that excessive screen-time is associated with lower self-esteem (517) and may even increase the risk of depression (518, 519). Consequently, increasing physical activity and reducing screen-time may be important for improving both the short- and long-term mental health of young people.

It has been noted in the literature that interventions among youth should be differentiated on the basis of gender and SES (475). While a number of studies have targeted minority youth (520, 521) and youth from low-income communities (475, 522), to the authors' knowledge, apart from the PALs pilot study (67) this is the first intervention to specifically target adolescent boys. Previous school-based interventions have demonstrated promise but results have been inconsistent. The Dutch Obesity intervention in Teenagers (DOiT) program (522) resulted in short-term improvements in body composition for boys and girls (523), but after 20 months the improvements observed among boys were no longer significant (30). By contrast, the NEAT Girls program found a significant between-group difference of two percent body fat at 24-months (262), despite non-significant findings immediately post-program at 12-months (267). Further testing through interventions using rigorous methodologies are required to determine the effectiveness of targeted and tailored interventions among youth.

Considering the limited impact of previous obesity prevention interventions (524), it is important that researchers identify potential areas for improvement. In addition to targeting 'at risk' groups, another area for improvement is the method used for participant identification and recruitment. We used a screening questionnaire to identify eligible participants based on their physical activity and screen-time behaviours. All male students in the targeted year group available on the assessment day were screened for eligibility. Previous intervention studies have utilised physical education teachers to select participants (67, 475) however; this method is relatively subjective and may be influenced by teacher bias. By screening students based on self-report of their physical activity and screen behaviours we were able to identify and target students exhibiting behaviours that contribute to weight status in youth (525, 526). Furthermore, this method is replicable and relatively easy to administer.

The link between muscular fitness and health is an emerging area of research, with recent investigations confirming muscular fitness is associated with a variety of health outcomes (3). Evidence suggests that, among youth, muscular fitness levels (i.e., strength, power, and muscular endurance) are related to indices of bone health (349), cardiovascular disease risk factors (173), and may also be protective against future mental health problems and risk of suicide (160). Consequently, there is a strong rationale for building competence in activities that develop muscular fitness among youth. A novel component of the ATLAS intervention is the focus on muscular fitness improvement through the use of resistance training. Perceived strength and muscularity have been identified as important contributors to self-esteem among young males (54, 370). Targeting the muscular fitness domain therefore represents an opportunity to engage boys who may otherwise fail to value physical activity. ATLAS aims to develop competence in a range of basic resistance training activities enabling participation in health-enhancing activity both in the short term and into the future.

There are some limitations that need to be addressed. Firstly, the lack of an economic evaluation precludes us from determining the cost-effectiveness of the intervention. Secondly, it is important to note that due to the targeted nature of the intervention, the findings may not be generalisable to different groups (e.g., females and those within other socio-economic strata) or the broader population as a whole.

5.5 Conclusion

This paper has outlined the rationale and methods for the ATLAS intervention for adolescent boys living in low-income communities. ATLAS is an innovative, school-based obesity prevention intervention targeting key energy balance-related behaviours among a sample of adolescent boys at risk of obesity and associated health problems. The intervention has a strong theoretical foundation and incorporates a number of novel strategies to increase physical activity, reduce screen-time and reduce intake of SSB's. In addition to providing evidence on the modifiability of key weight-related behaviours among adolescent boys, the ATLAS intervention will improve our understanding of the role of psychological and cognitive mechanisms of behaviour change through the assessment of a number of potential mediators. Furthermore, ATLAS will inform the development of future interventions among youth.

CHAPTER 6: OUTCOMES FROM THE ATLAS CLUSTER RANDOMISED CONTROLLED TRIAL

Preface:

This chapter presents the main study findings from the ATLAS cluster RCT. The health-related fitness and movement skill outcomes from this paper align with the *Primary aim* of this thesis. The results for boys' behavioural outcomes align with *Secondary aim 3* of this thesis.

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Abstract

Objective. To evaluate the impact of the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) intervention for adolescent boys, an obesity prevention intervention utilising smartphone technology.

Methods. ATLAS was a cluster randomised controlled trial conducted in 14 secondary schools in low-income communities in New South Wales, Australia. Participants were 361 adolescent boys (aged 12 to 14 years) considered 'at-risk' of obesity. The 20 week intervention was guided by Self-Determination Theory and Social Cognitive Theory and involved: teacher professional development, provision of fitness equipment to schools, face-to-face physical activity sessions, lunch-time student mentoring sessions, researcher-led seminars, a smartphone application and website, and parental strategies for reducing screen-time. Outcome measures included Body mass index (BMI) and waist circumference, percentage body fat, physical activity (accelerometers), screen-time, sugar sweetened beverage (SSB) intake, muscular fitness, and resistance training skill competency.

Results. Overall, there were no significant intervention effects for BMI, waist circumference, percent body fat, or physical activity. Significant intervention effects were found for screen-time (mean [SE] = -30 [10.08] min/d, $p = .03$), SSB consumption (mean [SE] = -0.6 [.26] glasses/d, $p = .01$), muscular fitness (mean [SE] = 0.9 [.49] reps, $p = .04$) and resistance training skills (mean [SE] = 5.7 [.67] units, $p < .001$).

Conclusions. A school-based intervention targeting low-income adolescent boys did not result in significant effects for body composition, perhaps due to an insufficient activity dose. However, the intervention was successful in improving muscular fitness, movement skills, and key weight-related behaviours.

6.1 Introduction

Although the global prevalence of obesity appears to have plateaued in recent years (21), the overall proportion of young people who are overweight or obese remains high, particularly among those of low socio-economic status (SES) (205). Considering the serious consequences of pediatric obesity (527), and the high likelihood of weight status tracking into adulthood (59), there is a strong rationale for targeting the health behaviours of adolescents (245, 528, 529).

It has been recommended that obesity prevention efforts should be directed toward those most susceptible, such as adolescents living in low-income communities (167). Adolescent boys of low SES are particularly predisposed to unhealthy weight gain and the global prevalence of obesity is higher among male adolescents compared to females (21). In addition, while adolescent boys are typically more active than girls (121), they are more likely to engage in high levels of recreational screen-time and consume large amounts of sugar sweetened beverages (121, 530). Yet, apart from our pilot study (67), no interventions have specifically targeted adolescent boys from low-income communities.

The challenges of modifying the health behaviours of adolescents and designing culturally appropriate interventions has prompted researchers to explore the utility of novel behaviour change techniques. Such strategies include the use of eHealth (e.g., internet-based) and mHealth (i.e., mobile phones) technologies to encourage young people to develop physical activity behavioural skills (i.e., self-monitoring and goal setting) (262, 267), and improve lifestyle behaviours (531). Mobile phone (and smartphone) ownership among young people is accelerating at a rapid rate (488, 489). Although evidence for the efficacy of mHealth interventions to improve health behaviours in young people is starting to emerge in the published literature (532, 533), it is unlikely that such interventions will provide the 'silver bullet' to the global obesity pandemic. Alternatively, they may have more utility as adjuncts to face-to-face behaviour change interventions. To the authors' knowledge, no previous study has used smartphone technology in a school-based obesity prevention program (531) and few existing smartphone 'apps' include evidence-based behaviour change techniques (534). Therefore, the primary aim of this study was to evaluate the effects of the multi-component school-based obesity prevention intervention incorporating smartphone technology, known as ATLAS (Active Teen Leaders Avoiding Screen-time). This paper reports the 8-month (immediate post-program) intervention effects.

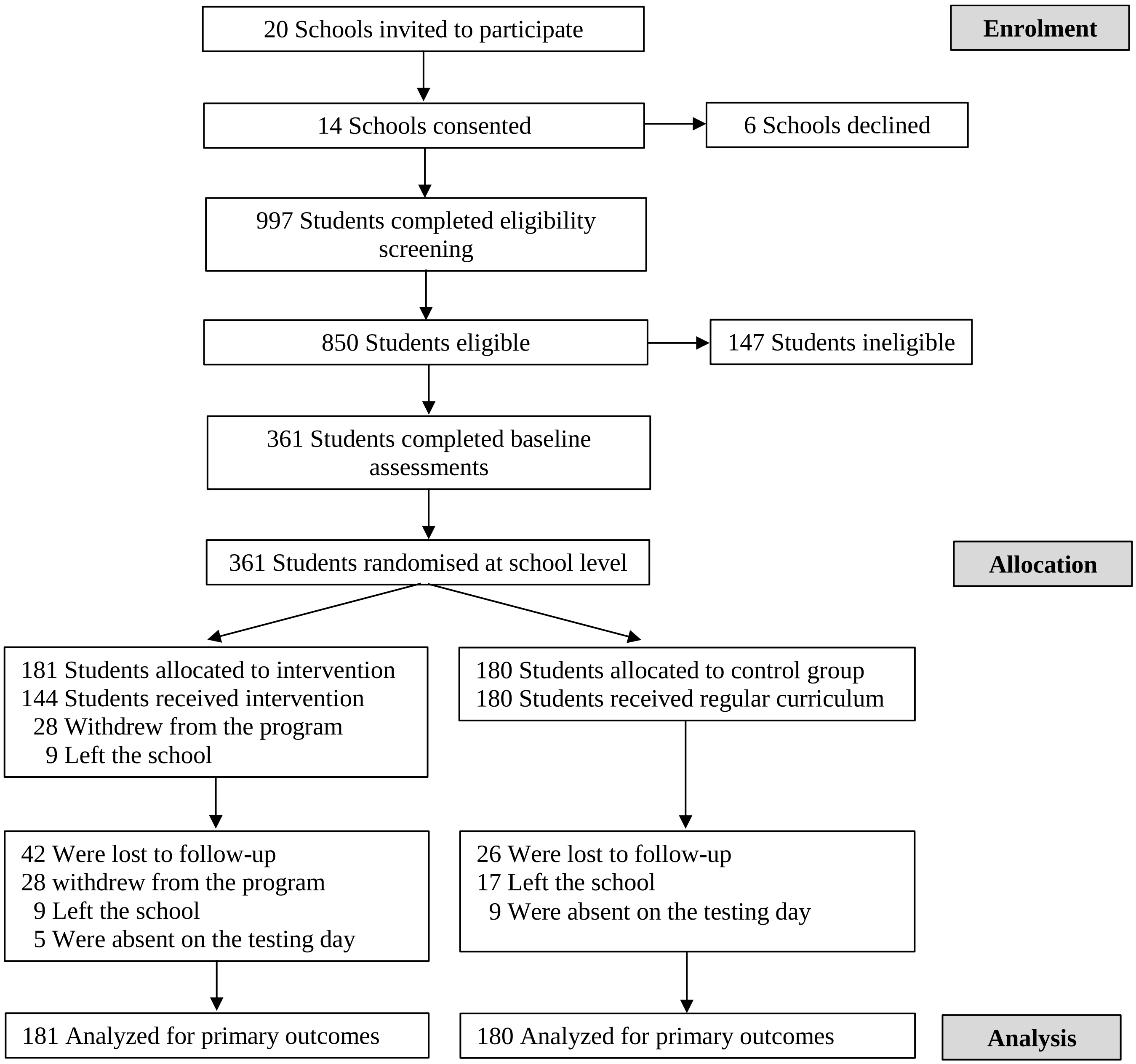

Figure 6.1 Flow of participants through the study process

6.2 Methods

6.2.1 Study design and participants

Ethics approval for this study was obtained from the University of Newcastle, Australia and the New South Wales (NSW) Department of Education and Communities. School principals, teachers, parents and study participants all provided informed written consent. The design, conduct and reporting of this trial adheres to the CONSORT statement (472). The rationale and study protocols have been reported previously (535). Briefly, ATLAS was evaluated using a cluster RCT conducted in state-funded coeducational secondary schools within low-income areas of NSW, Australia. The Socio Economic Indexes For Areas (SEIFA) of relative socioeconomic disadvantage (scale, 1 = *lowest* to 10 = *highest*) was used to identify eligible schools. Public secondary schools located in the Newcastle, Hunter and Central Coast regions of NSW with a SEIFA index of ≤ 5 (lowest 50%) were considered eligible. All male students in the first year at the study schools completed a short screening questionnaire to assess their eligibility for inclusion. Students failing to meet international physical activity or screen-time guidelines (108) were considered eligible and invited to participate.

6.2.2 Sample size and randomisation

Power calculations were conducted to determine the required sample size for detecting changes in the primary outcomes (i.e., BMI and waist circumference). Baseline post-test correlations and standard deviation estimates for BMI (r =.97, SD =1.1) and waist circumference (r =.96, SD =11.6) were taken from our pilot study and calculations assumed a school clustering effect of ICC =0.03 (67). Based on 80% power, an α of 0.05, and a potential drop-out rate of 20%, it was calculated that 350 participants (i.e., 25 from each school) would be required to detect a between-group difference in BMI of $0.4 kg.m^{-2}$. Additionally, the proposed sample size would be powered to detect a between-group difference of 1.5cm in waist circumference. Following baseline assessments, schools were paired, based on their geographic location, size and SEIFA score and randomised to either the control or intervention group. Randomisation was performed by an independent researcher using a computer-based random number producing algorithm.

6.2.3 Intervention

ATLAS was informed by the Physical Activity Leaders (PALs) pilot study (67, 69, 477) and a detailed description of the intervention is reported elsewhere (535). In summary, ATLAS is a multi-component intervention designed to prevent unhealthy weight gain through increasing physical activity, reducing screen-time and reducing SSB consumption among adolescent boys attending schools in low-income areas. Self-determination Theory (66) and Social Cognitive Theory (68) formed the theoretical basis of the program. Briefly, the intervention aimed to increase autonomous motivation for physical activity through enhancing basic psychological needs satisfaction (i.e., autonomy, competence, and relatedness) during school sport. In addition, the intervention focused on improving resistance training self-efficacy and also aimed to develop self-regulatory skills (i.e., self-monitoring and goal setting) to increase incidental physical activity. Similarly, the intervention was designed to increase participants' autonomous motivation to limit screen-time (7), by providing information regarding the consequences of screen-time and strategies for self-regulation. ATLAS was aligned with current guidelines recommending youth regularly engage in vigorous aerobic activities and physical activities to strengthen muscle and bone (108).

The intervention was delivered from December, 2012 to June, 2013 and involved a number of components which are described in Table 5.2. The smartphone app was designed to supplement the delivery of the enhanced school sport and interactive sessions, by providing participants with a medium to monitor and track their behaviours, set goals and assess their resistance training skill competency. In addition, the app provided tailored motivational and informational messages via 'push prompts'. The parental newsletters were designed to engage parents and encourage them to manage their children's recreational screen-time.

The control group participated in usual practice (i.e., regularly scheduled school sport and physical education lessons) for the duration of the intervention but will receive an equipment pack and a condensed version of the program following the 18-month assessments.

6.2.4 Assessments and measures

Trained research assistants completed baseline data collection at the study schools during November-December, 2012, at the same time of day where possible. Follow-up assessments were conducted 8-months from baseline (immediate post-intervention) and will be conducted again at 18-months from baseline (long-term follow-up). Assessors were blinded to treatment allocation at baseline but not at follow-up.

6.2.4.1 Primary outcome measures

Height was recorded using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia) and weight was measured using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo Japan). BMI was calculated using the standard equation (weight[kg]/height[m]^2). Waist circumference was measured to the nearest 0.1cm against the skin in line with the umbilicus using a non-extendible steel tape (KDSF10-02, KDS Corporation, Osaka, Japan). Weight status was established from BMI *z*-scores calculated using the 'LMS' method (WHO growth reference centiles) (491).

6.2.4.2 Secondary outcome measures

Body fat percentage was determined using the Imp™ SFB7 bioelectrical impedance analyser (493). Physical activity was assessed according to standardised protocols (494) using Actigraph™ accelerometers (model GT3X+). Analyses for weekday physical activity were performed for participants who wore their monitor for ≥600 minutes on at least three weekdays (Monday – Friday) while analyses for weekend physical activity included participants who wore their monitor for ≥600 minutes on at least one weekend day (Saturday – Sunday). Non-wear time was defined as 30 minutes of consecutive zeroes. Mean counts per minute (CPM) were calculated to provide a measure of overall activity and the cut points proposed by Evenson et al. (496) were used to categorise intensity, i.e., time spent in moderate-to-vigorous physical activity (MVPA). Hand grip dynamometry and the 90 degree push-up test (493, 497) provided a measure of upper body strength and local muscular endurance, respectively. Recreational screen-time was self-reported using a modified form of the Adolescent Sedentary Activity Questionnaire (ASAQ) (498). Two items were used to assess consumption of sugar-sweetened beverages (SSB) (121). Finally, resistance training (RT) skill competency was assessed using video analysis of the Resistance Training Skills Battery (RTSB) (8, 9). Participants performed six movement skills considered to be the foundation for more complex movements used in RT programs.

6.2.4.3 Process evaluation

A number of process measures were used to determine the reach, implementation and participant and teacher satisfaction of the ATLAS intervention. The process evaluation included: i) intervention implementation (i.e., the percentage of intended sports sessions and lunch-time mentoring sessions conducted by teachers); ii) school sport session fidelity determined using the ATLAS session observation checklist (i.e., compliance with the proposed session structure and activities, recorded by a member of the research team); iii) attendance at sessions; iv) engagement with intervention components (e.g., smartphone app, pedometers etc.); and v) program satisfaction (i.e., responses to a post-program evaluation questionnaire).

6.2.5 Statistical analysis

All analyses were conducted in December, 2013 using the SPSS for Windows, version 20.0 (2010 SPSS Inc., IBM company Armonk, NY) with alpha levels set at $p < 0.05$ and data were assessed for normality. Intervention effects for the primary and secondary outcomes were examined using linear mixed models adjusted for school clustering and participant SES and all analyses followed the intention-to-treat principle (514). Pre-specified sub-group analyses (535) for all body composition outcomes were conducted for those classified as overweight/obese (combined as a single group) at baseline. In addition, the proportional difference between treatment groups among those *improving* their weight status (i.e., moving from 'obese' to 'overweight' or from 'overweight' to 'healthy weight') or *regressing* to a poorer weight status (i.e., moving from 'healthy weight' to 'overweight' or from 'overweight' to 'obese') was explored using Pearson's χ^2 test.

6.3 Results

The flow of participants through the study is reported in Figure 6.1. Fourteen schools were recruited and 361 boys (mean age, 12.7 ±0.5 years) were assessed at baseline (Table 6.1). Follow-up assessments at 8-months were completed for 154 (85.6%) control group and 139 (76.8%) intervention group participants, representing an overall retention rate of 81.2% from baseline. Participants who did not complete follow-up assessments were more active on weekdays (p =.03) and weekends (p =.01). There were no significant differences for body composition outcomes.

Table 6.1 Baseline characteristics of study sample

Characteristics	Control (*n* = 180)	Intervention (*n* = 181)	Total (*N* = 361)
Age, mean (SD), y	12.7 (0.5)	12.7 (0.5)	12.7 (0.5)
Born in Australia, n (%)	168 (93.3)	174 (96.1)	341 (94.7)
English language spoken at home, n (%) [a]	169 (94.4)	175 (96.7)	344 (95.6)
Cultural background, n (%) [b]			
Australian	132 (73.7)	145 (80.6)	277 (77.2)
European	31 (17.3)	22 (12.2)	53 (14.8)
African	6 (3.4)	1 (0.6)	7 (1.9)
Asian	3 (1.7)	4 (2.2)	7 (1.9)
Middle eastern	2 (1.1)	0 (0)	2 (0.6)
Other	5 (2.8)	8 (4.4)	13 (3.6)
Socioeconomic position, n (%) [c]			
1-2	55 (30.9)	49 (27.1)	104 (29.0)
3-4	81 (45.5)	120 (66.3)	201 (56.0)
5-6	27 (15.2)	4 (2.2)	31 (8.6)
7-8	8 (4.5)	8 (4.4)	16 (4.5)
9-10	7 (3.9)	0 (0)	7 (1.9)
Weight, kg	53.1 (13.4)	54.0 (15.0)	53.5 (14.2)
Height, cm	160.2 (8.4)	160.9 (9.0)	160.5 (8.7)
BMI, $kg.m^{-2}$	20.5 (4.1)	20.5 (4.1)	20.5 (4.1)
Weight status, n (%)			
Underweight	5 (2.8)	2 (1.1)	7 (1.9)
Healthy weight	115 (63.9)	110 (60.8)	225 (62.3)
Overweight	38 (21.1)	39 (21.5)	77 (21.3)
Obese	22 (12.2)	30 (16.6)	52 (14.4)
Waist circumference, cm	76.5 (12.3)	76.2 (12.2)	76.3 (12.2)

Abbreviations: BMI = body mass index
[a] One participant did not report language spoken at home
[b] Two participants did not report cultural background
[c] Socioeconomic position determined by population decile using Socio-Economic Indexes For Areas of relative socioeconomic disadvantage based on residential postcode (1 = lowest, 10 = highest). Two participants did not report residential postcode

6.3.1 Changes in body composition

Changes for all outcomes are reported in Table 6.2. No intervention effects were found for the primary outcomes BMI and waist circumference, or for percent body fat. Changes in BMI (mean [SE] = -0.4 [.26] kg.m^{-2}, p =.15), waist circumference (mean [SE] = -0.5 [.95] cm, p =.57), and percent body fat (mean [SE] = -0.9 [.77] %, p =.22) for those classified as overweight/obese at baseline were all in favor of the intervention group. However, these effects were not statistically significant. Of the 19 participants that improved their weight status, 13 (68%) were in the intervention group; and of the nine participants that regressed to a more unhealthy weight status, only one (11%) was in the intervention group. A Pearson's χ^2 test indicated a significant difference in favor of intervention boys χ^2 (2) =8.08, p =.02.

6.3.2 Changes in behavioural outcomes

No significant differences were observed for overall activity (CPM) or MVPA. However, intervention boys reported less screen-time (mean [SE] = -30 [10.08] min/d, p = .03) and SSB consumption (mean [SE] = -0.6 [.26] glasses/d, p = .01), than control boys.

6.3.3 Changes in fitness and skill outcomes

There was a significant intervention effect for upper body muscular endurance in favor of the intervention group (mean [SE] = 0.9 [.49] reps, p = .04). In addition, a significant between-group difference was observed for RT skill competency in favor of intervention boys (mean [SE] = 5.7 [.67] units, p < .001).

6.3.4 Process evaluation

No adverse events or injuries were reported during the sports sessions, lunch-time leadership sessions or assessments. On average, schools conducted 79% (±15%) of intended sports sessions and 64% (±40%) of intended lunch-time sessions. Four sport session observations (two per school term) were conducted at each school. Adherence to the proposed session structure at observations one, two, three and four was 61%, 58%, 90% and 96%, respectively. Students were expected to attend at least 70% of sport sessions and at least two-thirds of lunch-time sessions. Sixty five percent of boys attended ≥ 70% of the sport sessions but only 44% of boys attended at least two-thirds of lunch-time sessions. Participant satisfaction with the ATLAS intervention was high (mean, 4.5 ±0.7; scale, 1 = *strongly disagree* to 5 = *strongly agree*). Students enjoyed the sports sessions (mean, 4.5 ±0.7) however, satisfaction with the lunch-time sessions was somewhat lower (mean, 3.7 ±1.0).

A detailed evaluation of the smartphone ‘app’ can be found elsewhere (536). Briefly, smartphone (or similar device) ownership was reported by 70% of boys and 63% reported using either the iPhone or Android version of the ATLAS ‘app’. Those students who did not have access to a smartphone could access the same features via the ATLAS website. Almost half of the group *Agreed* or *Strongly agreed* that the ‘push prompt’ messages reminded them to be more active, reduce their screen-time, and drink less sugary drinks and 44% of participants *Agreed* or *Strongly agreed* that the ATLAS app was enjoyable to use. Self-reported pedometer use was moderate with 44% of boys wearing their pedometer *sometimes* and 30% wearing their pedometer *often*. In addition, all four newsletters were sent out to 86% of parents. Teacher satisfaction with the intervention was high (mean, 4.4 ±0.5) and they reported enjoying both the pre- (mean, 5.0 ±0.0) and mid-program (mean, 4.9 ±0.4) professional development workshops.

Table 6.2 Changes in primary and secondary outcomes

Outcome[a]	Baseline	8-month	Change	*P* Value	Adjusted difference in change	*P* Value
BMI, $kg.m^{-2}$						
Intervention	20.7 (.64)	21.3 (.64)	0.60 (.09)	<.001	0.0 (.12)[e]	.84
Control	20.6 (.57)	21.2 (.57)	0.61 (.08)	<.001		
Waist circumference, cm						
Intervention	77.1 (1.89)	77.1 (1.89)	0.0 (.33)	.98	0.5 (.45)[e]	.16
Control	77.0 (1.69)	76.5 (1.69)	-0.5 (.31)	.10		
Body fat (%)						
Intervention	20.3 (1.27)	21.6 (1.28)	1.3 (.35)	<.001	0.0 (.48)	.99
Control	22.5 (1.14)	23.8 (1.14)	1.3 (.33)	<.001		
Grip strength, kg						
Intervention	22.5 (.97)	28.5 (.98)	6.0 (.32)	<.001	0.5 (.45)	.30
Control	20.4 (.87)	25.9 (.88)	5.5 (.31)	<.001		
Push-ups (repetitions)						
Intervention	9.1 (.99)	9.8 (1.0)	0.7 (.35)	.04	0.9 (.49)[e]	.04
Control	6.6 (.89)	6.5 (.89)	-0.1 (.34)	.73		
Weekday PA, counts/min[b]						
Intervention	538 (30.81)	515 (33.51)	-23 (18.08)	.21	-19 (23)	.41
Control	477 (27.18)	473 (28.58)	-3 (14.69)	.81		

Weekend PA, counts/min [c]						
Intervention	435 (47.19)	410 (54.85)	-25 (40.25)	.53	-8 (54)[e]	.57
Control	404 (42.42)	387 (47.13)	-17 (35.97	.64		
Percent MVPA (weekdays)[b]						
Intervention	8.6 (.58)	8.3 (.63)	-0.4 (.34)	.28	-0.7 (.44)	.14
Control	7.5 (.51)	7.8 (.54)	0.3 (.28)	.30		
Percent MVPA (weekends)[c]						
Intervention	6.2 (.78)	6.0 (.90)	-0.2 (.67)	.73	-0.1 (.90)[e]	.80
Control	5.8 (.70)	5.7 (.78)	-0.1 (.60)	.82		
Screen-time, min/d						
Intervention	109 (14.18)	112 (14.52)	3 (7.25)	.67	-30 (10)[e]	.03
Control	132 (12.78)	165 (12.94)	33 (7.0)	<.001		
SSB intake, glasses/d						
Intervention	3.9 (.40)	3.1 (.41)	-0.8 (.19)	<.001	-0.6 (.26)[e]	.01
Control	3.9 (.36)	3.7 (.36)	-0.1 (.18)	.44		
RT skill competency[d]						
Intervention	31.7 (.56)	40.1 (.60)	8.4 (.48)	<.001	5.7 (.67)	<.001
Control	30.7 (.53)	33.4 (.55)	2.7 (.46)	<.001		

Note. Mean (SE) are reported for all outcomes. Abbreviations: BMI = body mass index; MVPA = moderate-to-vigorous physical activity; PA = physical activity; RT = resistance training; SSB = sugar-sweetened beverages.
[a] All models were adjusted for school clustering and participant SES
[b] 240 and 120 participants wore accelerometers on weekdays at baseline and post-test, respectively
[c] 120 and 83 participants wore accelerometers on weekend days at baseline and post-test, respectively
[d] Possible values range from 0 to 56
[e] Variable transformed for analysis

6.4 Discussion

This study aimed to determine the effectiveness of the school-based ATLAS intervention for adolescent boys. No significant intervention effects were observed overall for body composition. However, for those who were overweight/obese at baseline there was a trend in favor of intervention participants for all body composition outcomes. Significant intervention effects were found for secondary outcomes including upper body muscular endurance, RT skill competency, self-reported screen-time and SSB consumption.

The intervention effects for body composition outcomes were negligible, which is similar to the findings of a recent trial involving Dutch teenagers (30). Our inclusion criteria aimed to identify boys at increased risk of obesity based on their physical activity and screen behaviours. This approach was selected to reduce the potential for weight stigmatisation, which may occur if inclusion is contingent on participants' BMI. However, it is possible that by using these broad inclusion criteria our ability to see significant improvements in anthropomorphic measures was minimised, as a number of 'healthy weight' boys with little scope for change were included in the study. Indeed, the majority of recruited boys were classified as 'healthy weight' at baseline and remained so for the duration of the intervention. Interestingly, it has been suggested that, while school-based interventions should continue to target all students, perhaps analysis of the primary outcome(s) should focus on overweight/ obese youth (537).

The findings of the present study were in contrast to those of our pilot study in which significant intervention effects for multiple measures of body composition were observed (67). This inconsistency could be due to differences in the quantity and intensity of physical activity during the enhanced sport sessions. Process data indicated that towards the end of the program, boys in the PALs study became disengaged due to the lack of variety in activities. To maintain engagement, the ATLAS sport sessions provided a greater variety of activities and also incorporated a stronger focus on movement skill development. Though program satisfaction was higher in ATLAS compared with PALs, these modifications may have resulted in lower overall activity and/or lower activity intensity during the sessions and hence smaller effects on body composition. Alternatively, as PALs participants had a higher baseline BMI, they may have had a greater propensity for change.

Although we were not powered to detect sub-group differences, changes in body composition outcomes favored intervention boys who were overweight or obese at baseline. The magnitude of these changes, though not statistically significant, may nonetheless be clinically meaningful. For example, the adjusted mean difference in body fat for overweight/ obese participants in the ATLAS intervention was 0.9%. According to Dai and colleagues (538), an increase of 1% body fat is significantly associated with unfavorable changes in total, HDL and LDL cholesterol, and triglycerides. Further, in a study of children and adolescents, Weiss and colleagues (539) reported that each 0.5 unit increase in BMI was associated with significantly increased risk of the metabolic syndrome. The adjusted mean difference in BMI for overweight/ obese subjects in our study was -0.4 $kg.m^{-2}$, which may have clinical significance. Finally, the proportional shift in weight status between study groups provides additional support for the efficacy of the intervention for overweight/obese participants.

Recent literature has identified muscular fitness as an important indicator of health status for young people (540, 541). Notably, we found significant intervention effects for upper body muscular endurance and resistance training skill competency. The intervention activities were predominantly resistance-based and as such focused on developing muscular fitness. Furthermore, the workouts and fitness challenges performed throughout the intervention were designed to be high repetition, targeting local muscular endurance rather than maximal strength specifically. Therefore, the significant improvement in muscular endurance and non-significant findings for muscular strength are not surprising. Additionally, the improvement in skill competency was expected as a core component of the sport sessions was time dedicated to RT skill development during which teachers modelled correct exercise technique and provided corrective feedback on boys' movement skill performance. Further, approximately two thirds of boys reported using the app to assess and monitor their RT technique.

Intervention boys in our study reported spending 30 minutes less per day engaged in screen-based recreation at follow-up compared with controls. Similar findings were reported in the Planet Health intervention (542), with the authors reporting an adjusted difference of 24 minutes in favor of intervention boys. The reduction in screen-time observed in ATLAS is likely to be conservative compared to other studies, as our measure of screen-time was modified to account for screen multi-tasking. Reducing screen-time was an explicit intervention target and ATLAS employed a number of strategies to encourage boys to reduce their screen-time. The relative contribution of the individual intervention components to change in screen-time is difficult to ascertain. However, the consequences of excessive screen-time and current screen-time guidelines were made explicit to boys during the researcher-led seminars and were reinforced by teachers during the face-to-face sport sessions. In addition, the majority of parents received and read the screen-time newsletters, as reported by boys. Finally, 70% of boys reported using the goal setting function of the app, which allowed users to set goals for reducing screen-time.

In addition to an effect on screen-time, intervention boys also reported significantly reducing their consumption of SSB. The adjusted mean difference was 0.6 glasses per day (approximately 150mL). A reduction in the consumption of SSB has been recommended to prevent unhealthy weight gain and the onset of metabolic disorders (111). While improvements in body composition have accompanied reductions in SSB consumption in previous studies (111, 112), these studies were of longer duration than ATLAS and also focused solely on this outcome. If the reduction in SSB consumption observed in our study is sustained, the corresponding decrease in daily energy intake may have a considerable impact on body composition over the longer term.

Although it is difficult to determine the relative contribution of individual components in multicomponent interventions, by conducting a comprehensive process evaluation we were able to gather important information on the efficacy of individual strategies. Attendance at the sport sessions was reasonable with around two-thirds of boys attending a satisfactory number of sessions, whereas attendance at the lunch-time sessions was poor. Boys reported lower satisfaction with the lunch-time sessions, which may be due to a preference to use this period for socialising. Compliance with the intended session structure was moderate at the first observation, but improved substantially over the course of the intervention. Usage of the ATLAS app for self-monitoring and goal setting was moderate. Therefore, additional strategies and features may be needed to enhance engagement in adolescent boys. It is important to note that the proportion of drop-outs that were overweight/obese was lower than it was for completers, indicating that ATLAS was successful in retaining overweight/obese boys. Finally, all teachers agreed or strongly agreed that their students benefited from involvement in ATLAS, providing a strong endorsement for the program.

Strengths of the present study include the randomised controlled design, the identification and targeting of adolescents ‘at risk’ of obesity, objective assessment of physical activity, the extensive process evaluation, and the high retention at follow-up. However there are also some limitations. While BMI is considered a suitable and stable measure of change in adiposity (543), direct measures such as dual energy x-ray absorptiometry provide a more accurate assessment of body fat. Secondly, we cannot rule out social desirability bias in our assessment of screen-time and SSB consumption. Third, we were unable to collect ATLAS app usage data which prevented a more thorough examination of the efficacy of this novel component. Fourth, similar to previous studies with adolescents (262), poor compliance to accelerometer protocols reduced the available sample size, preventing more comprehensive assessment of change in physical activity. Finally, due to the targeted nature of the intervention the results may not be generalisable to other groups (e.g., females and those from other socioeconomic strata).

There is a clear need for innovative obesity prevention programs that target adolescents ‘at risk’ of obesity. School-based interventions that utilise smartphone technology have the potential for health behaviour change, but strategies for identifying and recruiting participants and increasing the intervention dose are needed. Although the ATLAS program failed to achieve short-term changes in body composition in the overall study sample, there was a trend in favor of overweight/obese boys. In addition, there were favorable outcomes for behaviours known to be associated with adiposity and cardio-metabolic disorders. This study demonstrates that a school-based intervention targeting economically disadvantaged adolescent boys can have a favorable impact on muscular fitness, movement skills, and key weight-related behaviours. We encourage practitioners and policymakers to advocate for targeted programs in schools for young people who are disengaged in current physical education programs. Future interventions employing smartphone technology should capture objective data on app/website usage throughout the intervention period and conduct analyses examining its association with changes in intervention outcomes. Furthermore, future smartphone apps should integrate stimulating features such as social media linkage and ‘gamification’ to support ongoing engagement with this intervention component.

CHAPTER 7: USING TECHNOLOGY TO SUPPORT HEALTH BEHAVIOUR CHANGE IN ADOLESCENT BOYS: DEVELOPMENT AND IMPLEMENTATION OF THE ATLAS SMARTPHONE APPLICATION

Preface:

This chapter describes the development and implementation of a smartphone application designed to supplement program components within the ATLAS intervention. The results of this paper align with *Secondary aim 4* of this thesis.

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Lubans DR, **Smith JJ**, Skinner G, Morgan PJ. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Frontiers in Public Health*. 2014;2:1-11.

Abstract

Purpose. The primary aim is to describe the development and implementation of a smartphone application (app) designed to promote physical activity and reduce screen-time in adolescent boys 'at risk' of obesity from low-income communities.

Methods. An app was developed to support the delivery of a face-to-face school-based obesity prevention program known as the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) program. ATLAS was guided by self-determination theory and social cognitive theory and evaluated using a cluster randomised controlled trial with 361 boys (12.7± 0.5 years) in 14 secondary schools. Following the completion of the study, participants in the intervention group completed a process evaluation questionnaire and focus groups were conducted with 42 students to explore their general perceptions of the ATLAS program and their experience with the smartphone app. Barriers and challenges encountered in the development, implementation and evaluation of the app are also described.

Results. Participation in the study was not contingent on ownership of a smartphone, but 70% of participants in the intervention group reported having access to a smartphone or tablet device. Focus group participants reported an enjoyment of the program, and felt that it had provided them with new skills, techniques, and routines for the future. However, their engagement with the smartphone app was limited, due to a variety of reasons. Barriers to the implementation and evaluation of the app included limited access to smartphone devices, technical problems with the push notifications, lack of access to usage data and the challenges of maintaining participants' interest in using the app.

Conclusions. Although participants reported high levels of satisfaction with the ATLAS program in general, the smartphone app was not used extensively. Additional strategies and features may be needed to enhance engagement in adolescent boys.

7.1 Introduction

Physical inactivity has been described as a global pandemic (544). Recent estimates suggest that approximately 80% of young people internationally are not meeting the physical activity guidelines of 60 minutes of moderate-to-vigorous physical activity (MVPA) each day (14). It is of additional concern that children and adolescents are spending a large proportion of their day engaged in screen-based recreation. Both physical inactivity and high levels of screen-time are associated with a range of adverse physical and psychological health outcomes in young people, including obesity, metabolic syndrome and poor mental health (72, 143, 149). Although adolescent boys are typically more active than girls (14, 545), they report significantly higher levels of screen-time (144), making them susceptible to unhealthy weight gain and poor social and emotional wellbeing.

Schools have been identified as ideal settings for physical activity promotion and obesity prevention, as they have access to the majority of youth, appropriate facilities and qualified personnel to achieve these outcomes (546). Numerous school-based interventions delivered in the primary school setting with children have been found to be effective in promoting physical activity and preventing obesity (26, 547). In comparison, the evidence for effective school-based interventions targeting adolescents in secondary schools is very limited. Indeed, the most recent Cochrane review of obesity prevention interventions found that primary-school based interventions were twice as successful as interventions targeting adolescents (26). The challenges of achieving health behaviour change in this cohort, has prompted researchers to explore novel and engaging intervention strategies. One such approach has involved the use of eHealth technology (e.g., internet, mobile phones etc.) to encourage young people to develop physical activity behavioural skills (i.e., self-monitoring and goal setting) (262, 267, 548) and prevent the decline in physical activity typically observed during adolescence (549).

Mobile phone ownership is increasing at a rapid rate and recent data suggests that 77% of US adolescents (489) and 90% of Australian adolescents over the age of 15 own mobile phones (488). Not surprisingly, there has been a proliferation of mobile phone-based interventions using apps and short messaging service (SMS) to prompt physical activity and healthy eating in adults (550, 551). The evidence suggests that SMS-delivered interventions can have positive short-term behavioural outcomes in adults, but little is known regarding their utility for increasing activity levels in adolescents. A recent systematic review of smartphone apps for pediatric obesity prevention (534) found that very few apps included features recommended by the Expert Committee for Pediatric Obesity. The authors suggested that future apps should include comprehensive information about health behaviour change and opportunities for goal setting. Although interventions are beginning to emerge in the published literature (533), little is known regarding the efficacy and practicality of mobile phone apps to promote physical activity and reduce sedentary behaviour in young people.

Therefore, the primary objective of this paper is to describe the development and implementation of a smartphone app designed to support the delivery of the Active Teen Leaders Avoiding Screen-time (ATLAS) obesity prevention program (541). A secondary objective is to explore participants' perceptions of the program in general. ATLAS was a multi-component school-based intervention targeting adolescent boys attending schools in low-income communities, who were considered to be 'at-risk' of obesity based on their physical activity and screen-time behaviours.

7.2 Methods

7.2.1 Study design

Ethics approval for this study was obtained from the University of Newcastle, Australia and the New South Wales (NSW) Department of Education and Communities. School principals, teachers, parents and study participants all provided informed written consent. The rationale, study protocols and baseline characteristics of study participants have been reported previously (535). Briefly, ATLAS was a cluster randomised controlled trial (RCT) conducted in state-funded co-educational secondary schools within low-income communities of NSW, Australia. The Socio Economic Indexes for Areas (SEIFA) of relative socioeconomic disadvantage (scale 1= *lowest* to 10= *highest*) was used to identify eligible schools. The SEIFA index is derived from multiple indicators of socioeconomic disadvantage within an area (e.g., education, employment etc.). Public secondary schools located in the Newcastle, Hunter and Central Coast regions of NSW with a SEIFA index of ≤ 5 (lowest 50%) and an enrolment of at least 100 students in the targeted year group were considered eligible. Twenty-two eligible secondary schools were identified and 14 agreed to participate.

7.2.2 Participants

A power calculation was conducted to determine the required sample size for detecting changes in the primary outcomes (i.e., Body Mass Index [BMI] and waist circumference). Assuming a drop-out rate of 20% by the primary endpoint, it was calculated that 350 participants (i.e., 25 from each school) would be required to detect a between-group difference in BMI of $0.4 kg.m^{-2}$ and 1.5cm in waist circumference. All male students in the targeted year group at the study schools completed a short screening questionnaire to assess their eligibility for inclusion in the study. The questionnaire aimed to identify those 'at risk' of obesity based on their physical activity and screen-time behaviours. Based on their responses, students failing to meet national physical activity or sedentary behaviour guidelines (89) were considered eligible and invited to participate. Students with a medical condition that would preclude them participating in the program were also excluded. In total, 361 adolescent boys (mean age, 12.7 ± 0.5 years) in Grade 7 (first year of secondary school) consented and completed baseline assessments.

7.2.3 Intervention

ATLAS was informed by the Physical Activity Leaders (PALs) pilot study, a successful trial conducted in four secondary schools in the Hunter region, NSW (67, 69, 477). A detailed description of the ATLAS intervention is reported elsewhere (535). The multi-component intervention was designed to increase physical activity, reduce screen-time and reduce intake of sugar-sweetened beverages among adolescent boys attending schools in low-income areas. The intervention, which was delivered over 20 weeks (February-June, 2013), was underpinned by self-determination theory (SDT) (66) and social cognitive theory (SCT) (68). ATLAS focused on the promotion of lifetime (e.g., resistance training) and lifestyle (e.g., active transport) physical activities and was aligned with current physical activity guidelines, which include a recommendation to engage in muscle and bone strengthening physical activities on at least three days per week (89, 541). The intervention promoted four behavioural messages: (i) *Walk whenever you can*; (ii) *Get some vigorous physical activity on most days*; (iii) *Reduce your recreational screen-time*; and (iv) *Drink more water and less sugary drinks*. Briefly, the school-based intervention involved the following components: teacher professional development, researcher-led seminars, enhanced school sport sessions, lunch-time physical activity mentoring sessions, provision of fitness equipment to schools, pedometers for self-monitoring, parental strategies to reduce screen-time and a smartphone application (app) and website. To assist in facilitating the intervention as intended, participating teachers at the study schools attended two full-day professional development workshops (pre- and mid- program) designed and delivered by the research team. While the other intervention components have been described previously (535), a detailed description of the app is provided below:

Table 7.1 ATLAS smartphone app features, behaviour change techniques and potential mediators

Feature	Description	Behaviour change strategies	Potential mediators
1. Physical activity monitoring *(My Steps)*	This feature enabled participants to record their daily step counts measured using a pedometer and review results over a daily, weekly or monthly time scale.	▪ Prompt self-monitoring of behaviours ▪ Prompt specific goal setting	▪ Autonomous motivation for physical activity ▪ Behavioural capability ▪ Self-efficacy ▪ Self-control
2. Pre-designed fitness challenges *(My Workouts)*	This feature listed 10 pre-designed CrossFit style workouts including resistance training and aerobic exercises. Participants could enter and review results over a daily, weekly or monthly time scale.	▪ Prompt self-monitoring of behaviours ▪ Set graded tasks	▪ Self-efficacy ▪ Self-control ▪ Behavioural capability ▪ Autonomous motivation for physical activity ▪ Autonomy support
3. Assessment of resistance training skill competency *(My Technique)*	This feature enabled participants to assess their resistance training skill competency with the assistance of a peer or family member. Results could be reviewed over a daily, weekly or monthly time scale.	▪ Prompt self-monitoring of behaviours ▪ Prompt practice	▪ Behavioural capability ▪ Self-efficacy ▪ Autonomous motivation for physical activity
4. Goal setting *(My Goals)*	This feature allowed participants to set and review goals related to physical activity (steps/day), workouts (sessions/week) or screen-time (mins/day). Push notifications were automatically sent to participants to confirm if goals were achieved.	▪ Prompt specific goal setting ▪ Prompt intention formation ▪ Prompt self-monitoring of behaviours	▪ Self-efficacy ▪ Self-control ▪ Autonomous motivation for physical activity ▪ Motivation to limit screen-time ▪ Autonomy support

5. Tailored motivational messaging *(My Motivation)*	Informational and motivational messages were sent twice weekly via push notifications through the app.	▪ Information on consequences ▪ Provide information about behaviour-health link ▪ Provide general encouragement	▪ Outcome expectations ▪ Outcome expectancies ▪ Social support ▪ Autonomous motivation for physical activity ▪ Motivation to limit screen-time

Table 7.2 Mid- and post-program process evaluation questions and responses

Questions	N (%)
Mid-program questions	
I used the iPhone app	53 (48.6)
I used the Android app	14 (14.7)
I used the website	25 (25.3)
Frequency of use	
≤ 2 times	70 (58.8)
≥ 3 times	49 (41.2)
Post-program questions	
I enjoyed using the app/website:	
Strongly disagree	3 (2.8)
Disagree	13 (8.5)
Neutral	46 (43.4)
Agree	36 (34.0)
Strongly agree	12 (11.3)
The app messages reminded me to be more active, reduce my screen-time and drink less sugary drinks:	
Strongly disagree	6 (5.7)
Disagree	13 (12.4)
Neutral	35 (33.3)
Agree	38 (36.2)
Strongly agree	13 (12.4)
I used the 'My Goals' setting function on the app:	
Often	20 (19.0)
Sometimes	54 (51.4)
Rarely	15 (14.3)
Never	16 (15.2)
I used the 'My technique' function on the app:	
Often	22 (20.8)
Sometimes	45 (42.5)
Rarely	21 (19.8)
Never	18 (17.0)
I used the 'My steps' function on the app:	
Often	13 (12.4)
Sometimes	39 (37.1)
Rarely	26 (24.8)
Never	27 (25.7)
I used the 'My workouts' function on the app:	
Often	16 (15.1)
Sometimes	37 (34.9)
Rarely	25 (23.6)
Never	28 (26.4)
How often did you wear your pedometer?	
Often	34 (30.1)
Sometimes	50 (44.2)
Rarely	20 (17.7)
Never	9 (8.0)

Note. 119 and 114 participants completed the mid- and post-program evaluations

7.2.3.1 Smartphone application ('app') and website

A smartphone app was developed as a supplement to the intervention and was made available to participants on both iOS (i.e., Apple app store) and Android (i.e., Google Play) platforms at no cost to participants (Figure 7.1). A website was also developed so that the same features were available to participants without access to a smartphone or handheld device with similar capabilities. Data for both apps (i.e., iOS and Android) were stored on the device, but the iOS version could be backed up to a secondary location (i.e., iTunes or the Cloud). Consistent with the face-to-face components of the ATLAS intervention, the apps were operationalised using SDT (552) and SCT (68, 285) (Table 7.1). More specifically, the app was designed to satisfy participants' needs for autonomy and to increase their autonomous motivation for physical activity. It was also designed to enhance their self-efficacy to be physically active and increase their outcome expectations regarding the benefits of physical activity and the consequences of excessive screen-time and sugared beverage consumption. Prompting of goal setting and behavioural monitoring were also encouraged. The five functions (Figure 7.1) of the app/website are described below:

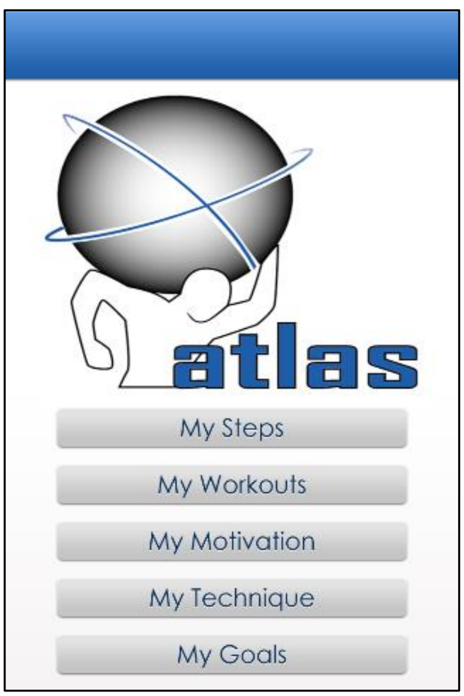

Figure 7.1 ATLAS app welcome screen

(i) Physical activity monitoring (*My Steps*) – participants were able to record their daily step counts measured using their personal pedometer which was provided by the research team. They could then review their 'date stamped' step count entries or select the graph view which allowed a visual representation (i.e., bar graph) of their entries over time. The graph view could be converted to show entries over a daily, weekly, or monthly time scale.

(ii) Pre-designed fitness challenges (*My Workouts*) – during the school sport sessions participants were introduced to CrossFit-style fitness challenges (henceforth referred to as workouts), which involved a series of resistance training (e.g., push-ups) and aerobic exercises (e.g., shuttle runs) with a predetermined number of repetitions (see Figure 7.2 for example). The workouts were also included in the app to encourage participants to complete them outside of school hours. Ten separate workouts of 'easy', 'moderate' and 'hard' rating were designed for the study and participants were encouraged to select workouts based on their perceived fitness levels. The time taken to complete the circuit was considered the result, with decreases in the time taken indicating improvements in performance. Using the app/website, students were able to select a workout, and then once completed, record their result (i.e., completion time). 'Date stamped' entries could be reviewed and entries could also be viewed in a bar graph format as described above.

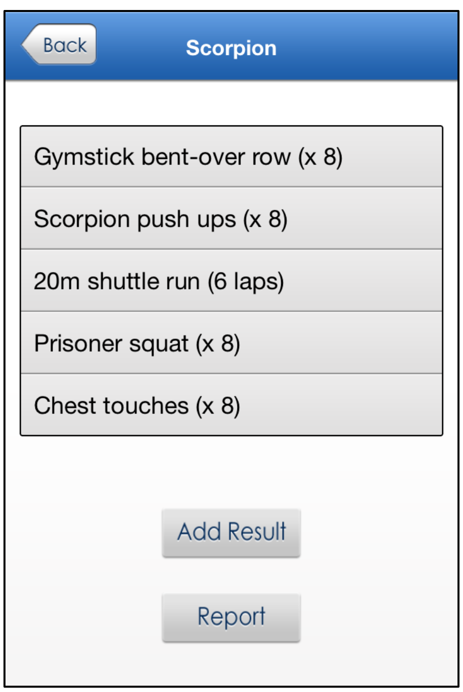

Figure 7.2 Sample challenge workout

(iii) Assessment of resistance training skill competency (*My Technique*) – The performance criteria for resistance training exercises from the Resistance Training Skills Battery (RTSB) (8, 9) were provided on the app/website. The RTSB is an assessment tool for appraising *technique* during the performance of six skills (i.e., squat, lunge, push-up, overhead press, suspended row and front support with chest touches), which are considered to be the foundation for more complex movements used in resistance training programs (5, 440, 441). The app/website allowed users to assess their own (or others) technique, with the assistance of a peer or family member, during the performance of each resistance training skill. The performance criteria for each skill that were successfully demonstrated could be selected from a list of all criteria and then submitted following the completion of the exercise. The number of performance criteria successfully demonstrated is saved as the user's score. 'Date stamped' entries could be reviewed and the graph view, using the format previously described, could also be used to track progress in correct performance of the resistance training skill over time.

(iv) Goal setting (*My Goals*) – The app/website allowed users to set and review goals related to physical activity and screen-time. This function enabled users to select either (a) the number of daily steps they would like to achieve; (b) the number of workouts per week they would like to complete; or (c) the amount of screen-time (in minutes) they would like to limit themselves to each day. The user could then select the date on which they would like the achievement of the goal to be reviewed. On the date selected by the user a *push notification* was sent asking the user to verify achievement of the goal. Previously achieved goals were retained and displayed on the screen for user review.

(v) Tailored motivational messaging (*My Motivation*) – This function was available on the app only. After the initial download of the app, users were asked to select two of four physical activity outcome expectations that were personally important to them, relating to (i) appearance (i.e., to look good), (ii) health and wellbeing (i.e., to improve my health), (iii) school performance (i.e., to do better at school) and (iv) social interaction (i.e., to spend time with friends). Based on their responses, informational and motivational messages developed in reference to SDT and SCT were sent twice weekly via *push notifications* through the app (see Figure 7.3 for example). The informational messages related to the ATLAS behavioural messages (e.g., *Exercise helps u look fit and feel good. How much exercise have u done 2day?*) and the motivational messages were based on the user's initial responses to the motivation question. (e.g., *Do u want to look good and feel gr8? Well u won't get there sitting down!*). As recommended in the literature, messages were simple and written in vernacular '*text speak'* to engage teenagers (553).

Figure 7.3 Example tailored motivational message

7.2.4 Process evaluation

Baseline and post-program assessments were conducted in November-December, 2012 and July-September, 2013, respectively. Trained research assistants completed data collection at the study schools. A process evaluation was conducted to determine participants' usage of, and satisfaction with, the ATLAS app. Evaluation questionnaires were distributed to study participants at mid- and post-program periods. The mid-program questionnaire included items on the type of app/website usage (i.e., iOS, Android, or website usage) and the frequency of use (i.e., 1= *Never* to 5= *5 or more times*). The post-program questionnaire included more detailed items regarding user enjoyment of the app/website (1 = *Strongly disagree* to 5 = *Strongly agree*) and frequency of use for each specific function (1 = *Never* to 4 = *Often*).

Participants were also asked their behavioural intentions to i) *limit recreational screen-time*, ii) *limit consumption of sugary drinks*, iii) *participate in at least 60 minutes of moderate-to-vigorous physical activity each day* and iv) *participate in muscle strengthening physical activities on 2-3 days each week* (1 = *Strongly disagree* to 5 = *Strongly agree*). To assist researchers interested in the use of smartphone apps for obesity prevention research, barriers and challenges encountered in the development, implementation and evaluation of the app are described.

7.2.5 Focus groups

A series of focus groups were conducted to gain insights into participants' experiences in and perceptions of, the ATLAS program. Consenting students took part in separate focus groups, each consisting of six participants. Each focus group included three participants who failed to meet MVPA guidelines and three participants who achieved MVPA guidelines (using baseline accelerometer data). These group meetings lasted between 42 and 58 minutes and were conducted in a separate classroom during school hours by a research team member who had not been directly involved in the delivery of the ATLAS program. The structured discussion framework was developed by the research team to facilitate discussion and reflection on the program. Specifically, the questions asked of the students were designed to explore their general perceptions of ATLAS and their experience with the ATLAS smartphone app. Views were also sought of the participants as to the perceived impact of the program on a range of attitudes and behaviours relating to physical activity and nutrition. Prompts were used as needed to explore topics in depth.

7.2.5.1 Qualitative data analysis

The focus groups were digitally recorded with the participants' consent and transcribed verbatim. A computer program (NVIVO 10) was used to assist with the organisational aspects of data analysis. Analysis was conducted by an independent qualitative researcher using a standard general inductive approach to qualitative analysis. Initially, inductively derived codes or labels were attached to the meaning units arising from the data. The developing hierarchical coding scheme was continually revised and further expanded after coding of additional transcripts. Following coding of all the transcripts, emerging themes were identified and elaborated. Due to the structured format of the discussion framework, these themes were closely aligned with the research aims. The following reports on these inductive analyses and explores the impact that the program has had on the lived experiences of the students taking part in the ATLAS program.

7.3 Results

7.3.1 Demographics

Participants were 361 adolescent males (Mean age = 12.7 ± 0.5 years) attending schools in low-income areas of NSW, Australia. The majority of boys (i.e., 95%) were born in Australia and most (i.e., 96%) reported speaking English at home. The sample was predominantly mono-cultural with 92% of boys reporting their cultural background as either Australian or European. Furthermore, 13.5% of boys indicated they were of Indigenous descent (i.e., Aboriginal or Torres Strait Islander). The sample was predominantly of low socioeconomic position with 91.4% of boys residing within areas with a SEIFA population decile ≤5 (i.e., bottom 50%). Twenty nine percent of boys resided in areas with a SEIFA population decile ≤2 (i.e., bottom 20%).

7.3.2 App/website usage

Participation in the study was not contingent on ownership of a smartphone, but 70% of participants in the intervention group reported having access to a smartphone or tablet device (including iPod Touch). At the mid-program evaluation, 49% and 15% of participants had used the iPhone and Android apps, respectively (Table 7.2). At the end of the intervention period, the majority of participants (70%) reported using the goal setting function to increase their physical activity or reduce their screen-time. Fewer participants used the app to monitor their resistance training technique (62%), pedometer steps (49%) and fitness challenge results (49%). Approximately 20% of participants did not engage with the app at all.

7.3.3 App/website satisfaction and behavioural intentions

After completing the program, almost half of the group agreed or strongly agreed that the push prompt messages reminded them to be more active, reduce their screen-time and drink less sugary drink (Table 7.2). Forty four percent of participants agreed or strongly agreed that the ATLAS app was enjoyable to use. Alternatively, 95% of participants agreed or strongly agreed that the ATLAS program overall was enjoyable. Participants' intentions to limit their recreational screen-time (mean = 3.95 ± 1.07), limit their consumption of sugary drinks (mean = 4.01 ± 0.82), participate in regular MVPA (mean = 4.16 ± 0.81), and muscle strengthening activities (mean = 4.08 ± 0.76), were high following the completion of the program.

7.3.4 Focus group results

A total of 42 male students from Year 8 participated in 7 focus groups. Each group consisted of students attending the ATLAS program from the same school. The thematic analysis revealed a range of emerging themes surrounding the participants' general perceptions of the program, key messages, and ATLAS App, as well as clusters relating to the students' perceptions and evaluations of the physical activity sessions, as well as relationships with teachers and peers. The overarching theme relating to the perceived impact of the ATLAS program contained a number of sub-themes representing the changes to behaviours, knowledge and attitudes relating to school, diet and physical activity which were felt to have followed on directly as a result of involvement in the ATLAS program.

7.3.4.1 General perceptions of ATLAS

While a number of students had some suggestions for how the program could have been improved (mainly in terms of less repetitive activities, more variety and so on, which have been covered in some detail under the heading 'Improvements and Feedback'), all expressed an enjoyment of the program, and felt that it had provided them with new skills, techniques, and routines for the future, while learning about the importance of reducing sedentary behaviour, adopting a healthy diet and limiting sugary drinks also generally having been received well by the students;

> *"I felt the ATLAS program opened a lot of opportunities in the future taught me a lot of things that I wouldn't' really do and helped me find my physical peak"*

For the majority of the students, one of the most beneficial and important aspects of the program had been the learning of "how to do things right" and adding to their repertoire of techniques and activities which they could do with friends or by themselves. Many students, who reported engaging in various out of school sports, felt that the newly acquired skills, techniques and fitness benefits arising from the program were highly transferable, such that they had gained an additional competitive edge. The particular techniques and activities most often referred to in this context were squats, lunges, and CrossFit.

Another frequently mentioned positive aspect of the ATLAS program had been the sense of achievement gained from the evidential gradual improvement in fitness throughout the duration of the program, with many commenting on the enjoyment they had gained from the regular testing of their performance against oneself and their peers;

> *"At the start of the program in the CrossFit challenges I was really, really puffed by the end but then at the end of the program I was still getting puffed by them but nowhere near as much and I could run a lot further for a lot longer"*

while yet others (albeit a minority) commented favorably on the social aspects of ATLAS;

> *"... having a training partner, having someone beside you, to slap you across the back of the head and tell you to get up and stop being lazy".*

Engaging in activities which were not usually part of the school curriculum was perceived as a special treat for some students who for instance had been doing boxing as part of their program. Not only did this present a welcome change from normal routine, but also appeared to have aided in feelings of empowerment and improved standing compared to students not involved in ATLAS.

7.3.4.2 Key messages

Students had perceived a range of different key messages being conveyed by the ATLAS program. However, the most frequently mentioned related to the importance of reducing sedentary behaviour and in particular screen-time, and reducing the consumption of sugary drinks while increasing water intake. This was closely followed by the importance of staying fit while increasing general physical activity and increasing incidental or opportunistic exercise (e.g., running to the school bus in the morning instead of walking). While many students had taken away several key messages, these four main areas accounted for over 80% of individual comments made.

Other less frequently mentioned key messages were the importance of attending to a healthy diet, with this mostly being associated with reducing overall caloric intake and fat, and the significance of learning and employing the correct technique over sheer strength. Finally, only one student had taken away from the program quite a profound message alluding to the importance of individual capacity and achievement;

> *"It's all about going at your own pace and achieving your own goals".*

7.3.4.3 ATLAS app

The reception of the ATLAS smartphone app was somewhat mixed. While approximately 80% of the students participating in the focus groups reported owning a smartphone or iPad, approximately 60% reported having downloaded the ATLAS app. Of those who had not done so, the reasons given were mostly that they had forgotten, were not aware of it, or had neglected to download it due to issues or problems with their device. Of 'non-smartphone owners', only a few students reported having used the Web app. This was exclusively accessed on home PC, and the use of it was in most instances limited to a single viewing.

Of the remaining students, over half reported short-term, once-only or very occasional use of the app, while the remainder (approximately 8 students) had used it quite frequently (i.e., 3 times/week or more). Three students particularly commented that their little usage of the app was due to being unsure how to use it.

In terms of the utility of the specific functions within the app, the CrossFit, Step Count and Goal setting functions were the most frequently used. While the feedback relating to the CrossFit function was mostly positive, being described as challenging and enjoyable, a few students had felt it had been boring and repetitive. The Step Count Function was also a high-use function, but mostly only short-term (limited by accessibility to pedometers), with some reporting simply forgetting about it. However, one student had particularly liked the graphing function to visualise his own performance while, for others, Step Count had increased their awareness of physical activity or lack thereof. Generally, the use of pedometers was erratic and short-term.

The Goal setting function had received moderate use and reports were generally good (albeit not very elaborate). Only one student had used the My Technique function, and had found it very useful. The function which certainly received the most critical feedback was Messaging, which almost exclusively had been considered a nuisance by students. Mostly, the messages had been considered too frequent, too repetitive, or received at inappropriate times (e.g., midnight) and therefore not perceived to fit in with the rhythm of their day. However, one student had found self-programmed messages very useful as reminders to engage in physical activity.

The vast majority of students taking part in the focus groups reported having successfully reached the goals which they had set for themselves at the outset of their participation in ATLAS. The most frequently mentioned of these goal accomplishments related to having achieved increased fitness levels including reaching sporting goals;

> *"My goal was just to get fitter be able to get a place in cross country which I had never done. Well, mostly I'd come 10th ... but after the ATLAS program I actually came 3rd or 4th, so I finally got into zone"*

followed by enhanced self-confidence, including higher expectations of oneself, and feelings of mental stamina;

> *"Before the ATLAS program I underestimated myself and set my goals pretty low, but during I set them a lot higher and felt I could reach them a lot more easily"*

Yet others, who reported having reached their goals, had entered the program with the expectation of becoming more physically active, improving their knowledge of health and nutrition, achieving weight loss, achieving a general improvement in their physical or mental strength, or simply, as one student put it, perform to the "best of [his] ability".

Of the seven students who reported not having reached their goals, four had not set any specific goals at the outset of the program, while two felt they may have reached their goals had the program continued, while one student, very introspectively, noted that while he had failed to reach his goal of a certain number of steps per day, he had learnt the importance of realistic and progressive goal setting.

7.3.4.4 Diet and sugary drinks

In terms of dietary changes resulting from participation in the ATLAS program, a little over half of the students reported changes to their dietary habits as a direct result of what they had learnt in the ATLAS program. This had taken the form of attempts to purchase and consume healthier foods (less junk foods), reduce amount of food eaten, eating more of the healthier foods served up at home, healthier snacking options and, most commonly, increased fruit intake. There was clear evidence that students had increased their awareness of healthy nutrition, leading to a 'think before you buy' approach and a conscious decision to improve long-term health outcomes;

> *"Yeah it has [changed my attitude to sugary drinks] because after seeing the stuff they showed us about it. It's just like terrible all the caffeine in like Monsters and all the energy drinks and that, so I'm just sticking with water now".*

Of the remainder of the students, who did not perceive any changes to their diets, most reported already adhering to healthy balanced diets, containing little junk foods, which not surprisingly appeared to stem from healthy family dietary routines. A similar pattern was observed in the student's attitude towards sugary drinks. While five students reported no changes to their consumption of sugary drinks, three of these indicated that such drinks had not been part of their diet in the first place. The remainder of students described changes to their knowledge and behaviour relating to the consumption of sugary drinks, with most having cut down their consumption, and some having either switched to sugar-free soft drinks, or cut out sugary drinks from their diet altogether and as a result increased their water consumption, with one student commenting on the positive effects it has had on his energy levels;

> *"I like to drink water and [it has] sort of helped me keep going outside, whereas before I [would] get tired and go inside and sit down but now, because I don't drink as much soft drink and that, I can sort of stay outside for a bit longer"*

7.3.4.5 Physical activity

The discussions around the students' attitude and behaviours relating to physical activity provided strong evidence of the profound impact that the program had exerted, not only on actual behaviour, but also on the cognitions accompanying the choices which the students make. The vast majority reported having replaced sedentary behaviours (mainly some form of screen-time) with physically active behaviours such as outside play or intentional fitness activities such as jogging, bike rides, chin-up's, push-up's etc. In many instances, the students talked about these changes having occurred in personal realms as well as social contexts, such that the increased physical activity had extended to friendship circles and family members as well;

> *"I used practically every afternoon be on my Xbox just playing video games and when the ATLAS program started like now I like practically out every afternoon shooting hoops with my brother and all of that, doing sport and kicking a ball and everything".*

Not surprisingly, there was strong evidence that increased motivation was one of the key factors behind their behaviour changes. This motivation appeared to stem from greater enjoyment in physical activity, a more serious approach to fitness, as well as greater knowledge and skill. Indeed, quite a few students talked about the ATLAS program having equipped them with skills and techniques to improve their sporting performance and stamina;

> *"...with surfing it's helped, like I got heaps more arm strength now or paddling power, like I'd paddle for like 2 hours and I'd be tired ... now I can paddle like the entire day and I'm fine".*

Another of the more profound impacts of the ATLAS program was changes to students' routines. While some had made just minor changes to everyday routines, such as running to school bus instead of walking, some had adopted an impressive daily fitness routine;

> *"Well, every time I used to walk home and I used to go for a jog but now I do a little bit more extra; like I'd go for a jog and come home and we've got this tree out the back and it's kind of like a chin up pole and I'd do chin ups and before I'd go to bed, I do about 50 sit ups".*

7.3.4.6 Barriers and challenges to the development, implementation and evaluation of the ATLAS app

As described previously, the ATLAS app was developed to support the delivery of a school-based obesity prevention program for adolescent boys. However, due to the timing of school terms and the conditions of funding, we were unable to conduct a usability study of the ATLAS app prior to the RCT. Consequently, the app was launched and was made available to participants before we were able to rectify minor technical glitches. More specifically, in the original version of the app, the tailored motivational messaging function did not send the push prompts to the participants' phones. The function was subsequently fixed by the technical team and participants were encouraged to update their app to access this feature, but this did not occur until 5-weeks into the intervention period.

The diversity of the ATLAS platform and device servicing (i.e., iOS, Android and web) was designed to provide greater access for users, but came at the cost of higher maintenance and data dispersion issues (Figure 7.4). The web-based application was primarily written in *Hypertext Preprocessor* and hosted in a data center in India. It included a distributed architecture model traditionally used in standard n-tier web applications, in that the client layer, business and data access layer, and data layer all reside in different locations. Platform decisions were solely based on the two most dominant market shares at the time of development. As shown in Figure 7.4, each platform has it merits and drawbacks, but both use local device storage; the iOS version can also be backed up to a secondary location such as iTunes or the Cloud. This created problems for the evaluation of the ATLAS app as we did not have access to user data to determine the utility and usage of the five different functions (i.e., *My Steps*, *My Workouts*, *My Technique*, *My Goals* and *My Motivation*).

7.4 Discussion

The primary objective was to describe the development and implementation of the ATLAS smartphone app designed to promote physical activity and reduce screen-time in adolescent boys from low-income communities who are at risk for obesity. Although we were unable to collect objective usage data, the majority of participants reported having access to a smartphone device and utilised the ATLAS app functions to some extent. The focus group findings indicated that the participants benefited from the ATLAS program in general, but did not engage extensively with the smartphone app. Lack of engagement may in part be due to the technical glitches experienced by the research team.

Figure 7.4 Original ATLAS infrastructure architecture

To our knowledge, ATLAS is the first smartphone app designed to supplement an obesity prevention program for adolescent boys. The app included five major features, guided by behavioural theory to promote physical activity and reduce sedentary behaviour and the consumption of sugary drinks. A unique aspect of the ATLAS smartphone app was that it included push prompt messages (e.g., to set goals), based on information entered by participants. After completing the program, almost half of the participants agreed or strongly agreed that the push prompt messages reminded them to be more active, reduce their screen-time and drink less sugary drinks. Interestingly, the messaging was considered a nuisance by many students in the focus groups. However, it is possible that messaging still had its desired effect, as participants' intentions to adhere to the ATLAS behavioural messages was high at the completion of the study. The content of the push prompt messages used in the ATLAS intervention was guided by the Nutrition and Enjoyable Activity for Teen Girls intervention (262, 267, 475). Similarly, the format and style of messages was guided by formative work conducted with adolescents (553), which found that young people desired SMS that were i) informative providing relevant new information), ii) simple (limited to small words and phrases), and iii) sociable (could be shared easily with friends). The optimal messaging format for promoting health behaviour in young people is not known and additional formative research may help to create messages that are meaningful and long lasting.

Due to the structure of the ATLAS architecture we were not able to determine the degree to which participants engaged with the app or if they continued to use the app after the completion of the study. It is possible that the novelty of the app wore off quickly, as participants may have found more attractive mobile apps to use. In adults, self-monitoring behaviours diminish over the duration of an intervention (554). While there is evidence to suggest that behavioural skills, such as goal setting and self-monitoring are important for adolescents' physical activity levels (460, 461, 548, 555), evidence for their sustained impact is limited. It is plausible to suggest that adolescents also find it challenging to adhere to physical activity self-monitoring protocols. Research exploring the ways that young people use apps to access health information and monitor their health behaviours is limited. A number of questions emerged from our findings. What are the apps most commonly used by adolescents? What are the features of these apps? How many apps do young people have on their phones? Do push prompts encourage young people to engage with specific apps? What other strategies can be used to enhance goal setting and self-monitoring in adolescents? Young people have notoriously short attention spans (556, 557) and can be a challenging group to keep engaged. ‘Gamification’ or ‘social media linkage’ might provide some entertainment value and encourage prolonged use of the app in future versions. These questions could be explored in future research including analyses examining app usage and its association with behaviour change along with qualitative research to explore adolescent perceptions and beliefs around these issues.

In the current study, participants were provided with pedometers to self-monitor their physical activity. A recent systematic review concluded that pedometers could be used to increase physical activity in young people and highlighted the importance of individually tailored goals (558). Although these strategies were employed in the ATLAS intervention, only 30% of participants wore their pedometers regularly. In a previous study, Scott and colleagues (559) found that many young people did not enjoy wearing objective monitoring devices such as pedometers and accelerometers and it is possible that participants in the current study were reluctant to wear the devices for self-monitoring purposes. While not feasible in the current study, apps that take advantage of a phone’s inbuilt accelerometer (e.g., ‘Moves’) may have more utility for promoting self-monitoring in young people. These apps do not require the user to wear an additional activity monitor or regularly enter values, but the user must carry their phone, which can also be considered a limitation. However, phones are not always carried during physical activity and can be ‘worn’ in many places. Furthermore, evidence for the validity and reliability of smartphone apps to measure physical activity is only starting to emerge in the literature and acceleration values from phones may not always provide a reliable estimate of a person’s physical activity.

Over two thirds of participants in the intervention group reported access to a smartphone or tablet. Although access is not equivalent to ownership, there is a growing trend in the ownership of smartphone devices in youth populations (489). To cater for participants who did not have access to a smartphone, a website was developed. While the initial multi-versions of ATLAS were suitable for testing and evaluation in the intervention, the challenges of maintaining all three versions for use in future studies and for dissemination to schools was not considered to be feasible. Therefore, at the completion of the study it was decided that the ATLAS app would evolve into a single Web Services based architecture. The research team is currently working on a revised ATLAS app including native mobile applications written for both iOS and Android devices. This model will allow the ATLAS app to be serviced on multiple mobile devices and computing platforms due to it becoming effectively a web based mobile application. Through the use of custom developed web services, coupled with a centralised data source (Figure 7.5) we will have significantly more control and access to the application data for research and analysis purposes. With the new architecture, users of all types of smartphones, including Apple, Android, Windows, and Blackberry will be able to consume the service.

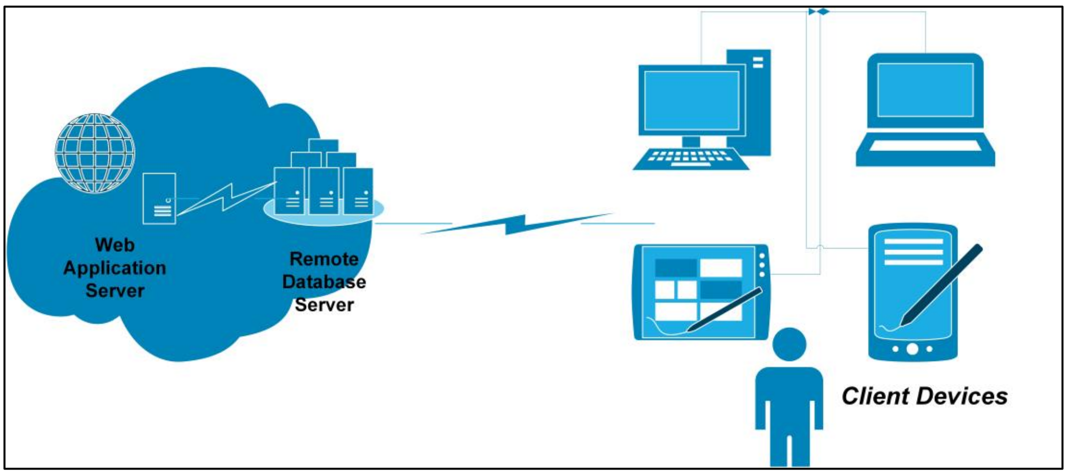

Figure 7.5 Proposed ATLAS data storage arrangements

ATLAS is the first obesity prevention program targeting adolescent boys to be supplemented with a purpose built smartphone app guided by SDT and SCT. Despite these strengths, there are some limitations to the current study. First, it is not possible to determine the unique contribution of the app to behaviour change, as it was one component of a multi-component school-based intervention. Second, due to the original software architecture we were not able to access participants' usage data. Alternatively, participants self-reported their use of the app features, which introduces self-report bias. Third, our study was conducted in a sample of adolescent boys attending schools in low-income communities and therefore our findings cannot be generalised to other populations. Finally, the timing of the school-based intervention prevented us from conducting a usability study before implementation and minor technical problems were experienced.

7.5 Conclusion

In this study we have described the development and implementation of a smartphone app designed to supplement a school-based obesity prevention program for adolescent boys. The majority of participants reported having access to a smartphone or tablet and many engaged with the ATLAS app features. Participants reported moderate satisfaction with the app, but were more positive of the intervention in general. Findings from our focus groups suggest that additional training on how to use the app may be necessary to improve in future studies. In addition, the technical glitches experienced by the research team highlight the importance of allowing sufficient time to conduct a usability study before conducting a full-scale RCT.

Although eHealth interventions hold promise for behaviour change in youth, it is unlikely that they will provide the ‘silver bullet’ to the global physical activity pandemic. Physical activity is a complex behaviour that can take place in a wide variety of settings and is influenced by various psychological, social and environmental factors. Future studies are encouraged to explore the utility of technology-based intervention strategies, such as smartphone apps, to determine if they are appropriate stand-alone strategies or adjuncts to face-to-face behaviour change interventions.

CHAPTER 8: IMPROVING ADOLESCENT BOYS' HEALTH-RELATED FITNESS: MEDIATING EFFECTS OF RESISTANCE TRAINING SKILL COMPETENCY

Preface:

This chapter presents the results of a study investigating the mediating effects of resistance training skill competency on health-related fitness and physical activity among boys participating in the ATLAS cluster RCT. The results of this paper align with *Secondary aim 5* of this thesis.

The contents of this chapter have been accepted for publication in the *Journal of Sports Sciences*.

Citation:

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Abstract

Purpose. The purpose of this study was to examine the mediating effect of resistance training skill competency on percent body fat, muscular fitness and physical activity among a sample of adolescent boys participating in a school-based obesity prevention intervention.

Methods. Participants were 361 adolescent boys taking part in the ATLAS cluster RCT; a school-based program targeting the health behaviours of economically disadvantaged adolescent males considered 'at-risk' of obesity. Body fat percentage (bioelectrical impedance), muscular fitness (hand grip dynamometry and push-ups), physical activity (accelerometry), and resistance training skill competency were assessed at baseline and at post-intervention (i.e., 8-months). Three separate multi-level mediation models were analysed to investigate the potential mediating effects of resistance training skill competency on each of the study outcomes using a product-of-coefficients test. Analyses followed the intention-to-treat principle.

Results. The intervention had a significant impact on boys' resistance training skill competency, and improvements in skill competency significantly mediated the effect of the intervention on percent body fat and the combined muscular fitness score. No significant mediated effects were found for physical activity.

Conclusion. Improving resistance training skill competency may be an effective strategy for achieving improvements in body composition and muscular fitness in adolescent boys.

8.1 Introduction

Physical inactivity has been described as a global pandemic (15). International guidelines recommend children and adolescents engage in at least 60 minutes of moderate-to-vigorous physical activity (MVPA) each day, consisting of aerobic activities and activities to strengthen muscle and bone (108). However, recent global estimates show that 80% of adolescents fail to meet this guideline (14). Considering the current and future economic burden associated with physical inactivity, identifying evidence-based strategies to engage young people in health-enhancing physical activity is clearly warranted. Adolescence is a critical developmental window for establishing healthy behavioural habits that may track into adulthood (23), yet this is also a period during which significant declines in physical activity occur (22). To promote engagement in a variety of physical activities during adolescence, a more thorough understanding of the mechanisms underpinning physical activity participation is required.

As demonstrated in a recent systematic review (58), perceived movement skill competence (hereafter referred to as perceived competence) is a consistent psychological correlate of physical activity in adolescent populations. However, perceived competence is situated within the context of an individual's actual competence in various forms of movement. Stodden et al., (65) posit that developing actual motor competence provides a foundation for the development of an individual's perceived competence, health-related fitness, physical activity behaviours, and a healthy weight status. During the transition to middle childhood (i.e., 6-9 years of age), children develop the cognitive capacity to more accurately assess their competence in various movement contexts, and this assessment will increasingly influence, either positively or negatively, their motivation to engage in physical activity (65). Consequently, in addition to improving perceived competence, a focus on improving actual movement skills may be crucial to increase motivation in various types of physical activity among adolescents.

Much of the literature regarding movement skill competence has focused on proficiency in fundamental movement skills , a set of skills considered the 'building blocks' for the more complex motor patterns required for successful sports performance (61). While there is evidence for the importance of fundamental movement skill proficiency for physical activity and health-related fitness (61), fundamental movement skills may be a better predictor of organised (i.e., competitive sports) rather than non-organised (i.e., individual fitness activities) physical activities (560). Given participation rates for organised sports decline during adolescence (561), competence in motor patterns related to ‘lifelong’ physical activities (e.g., resistance training, cycling, swimming, yoga etc.) may be required to engage adolescents in ongoing physical activity.

Resistance training refers to a method of conditioning using a variety of resistive loads to achieve improvements in health, muscular fitness, and physical performance (37, 562) This type of activity may be a convenient substitute for (as well as an adjunct to) organised sport as it can be performed alone, at little or no cost, and with minimal equipment if preferred. Importantly, the motor coordination patterns required to be successful in this form of activity may be easier to learn than the specialised motor patterns required for success in many sports. Therefore, this form of activity may be an appropriate substitute for youth that have failed to achieve the level of fundamental movement skill proficiency inherently demanded for successful sports performance (563). Additionally, resistance training may be a desirable activity option for sufficiently skilled adolescents that have decided to discontinue participation in organised sport, and for overweight and obese youth who may avoid aerobic-based physical activities

Despite the benefits of resistance training for young people (37), and its potential as an alternative to organised sport, little research has focused on resistance training-related movement skills and their association with physical activity and health-related fitness. Recently, Lubans and colleagues (8) designed a skill assessment battery for evaluating resistance training movement skills - the Resistance Training Skills Battery. The six movements included in this assessment battery (i.e., squat, lunge, push up, overhead press, front support with chest touches, and suspended row) encompass all the major muscle groups and are considered the foundation for more complex movements used in resistance training programs. The importance of resistance training skill competency for health-related fitness and physical activity has not been empirically examined. However, cross-sectional evidence among a small sample of adolescents has demonstrated that resistance training skill competency is associated with muscular fitness (8). Further exploration of these associations using experimental data is warranted. Therefore, the aim of the present study is to examine the potential mediating effects of resistance training skill competency on body composition, muscular fitness and physical activity among a sample of adolescent boys participating in a school-based obesity prevention intervention (564, 565).

8.2 Methods

8.2.1 Study design and participants

Participants were 361 adolescent boys (mean age, 12.7 ± 0.5 years) involved in the Active Teen Leaders Avoiding Screen-time (ATLAS) cluster randomised controlled trial ; a school-based obesity prevention trial conducted in 14 secondary schools in low-income areas of New South Wales, Australia. Ethics approval for the study was obtained from the human research ethics committees of the University of Newcastle and the New South Wales Department of Education and Communities. School principals, teachers, parents and study participants all provided informed written consent prior to enrolment in the study. A detailed description of the methodology can be found elsewhere (564).

8.2.2 Power calculation

Prior to recruitment, a power calculation was conducted to determine the required sample size to detect meaningful changes in the primary outcomes (i.e., body mass index [BMI] and waist circumference) of the ATLAS study. Based on 80% power, an α level of 0.05, an expected drop-out rate of 20%, and a school clustering effect of ICC = 0.03; it was calculated that 350 participants (i.e., 25 per school) would be required to detect a between-group difference in BMI and waist circumference of 0.4 $kg.m^{-2}$ and 1.5 cm, respectively. In addition, the study was adequately powered to detect small to medium-sized mediation effects using a product-of-coefficients test (566).

8.2.3 Intervention

The ATLAS intervention was a multi-component, school-based program aimed at improving body composition, muscular fitness and weight-related behaviours (i.e., screen-time, physical activity and sugared beverage consumption) among adolescent boys attending schools in low-income communities. The intervention was underpinned by Self-Determination Theory (66) and Social Cognitive Theory (68). Specifically, the intervention aimed to improve competence, autonomy, and relatedness needs satisfaction during school sport in order to enhance self-determined motivation for physical activity. In addition, the intervention aimed to increase boys' perceived competence and self-efficacy for resistance training exercises through the development of resistance training movement skills. The intervention included researcher-led seminars for students, provision of fitness equipment to schools, a smartphone application and website, pedometers for self-monitoring, parental strategies for reducing screen-time (i.e., newsletters), lunch-time physical activity mentoring sessions, and face-to-face activity sessions run by teachers during the timetabled school sport period. Intervention strategies were aligned with key behavior change techniques. For example, the smartphone application component of the program included strategies for self-monitoring and goal setting and also provided information on the link between health and weight-related behaviours via push prompts (536). Participating teachers delivered the intervention following a pre-program professional learning workshop conducted by members of the research team. During the school sport sessions, students participated in a range of activities including resistance training circuits, high-intensity fitness challenges, strength and aerobic-based games, and modified ball games. The program focused on improving muscular fitness and students completed both elastic band (i.e., Gymstick™) and body weight (e.g., push-ups) resistance exercises. Finally, a core component of the activity sessions was time dedicated to resistance training movement skill development, during which teachers explained and modelled correct exercise technique and provided corrective feedback to students during their performances. A more detailed description of the intervention, including the resistance training-based school sport sessions, has been reported previously (564).

8.2.4 Measures

Assessments were conducted by trained research assistants at baseline (November – December, 2012) and 8-months later after the conclusion of the program (July – September, 2013). Demographic information including age, country of birth, cultural background, and language spoken at home was collected via a questionnaire. The Socio Economic Indexes For Areas (SEIFA) Index of Relative Socioeconomic Disadvantage (scale, 1 = *lowest* to 10 = *highest*) (567) was used to determine participant SES. Individual SES was coded as the population decile corresponding to the participant's residential postcode. For interpretation, a value of ≤ 5 indicates the bottom 50% of the socioeconomic distribution.

8.2.4.1 Height and body mass

Height was recorded to the nearest 0.1 cm using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia). Weight was measured to the nearest 0.1kg without shoes, in light clothing using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo, Japan). BMI was calculated using the standard equation (weight [kg] / height [m]2) and weight status was determined using BMI z-scores calculated using the 'LMS' method (WHO growth reference centiles) (491).

8.2.4.2 Body composition

Body fat percentage was assessed using the Imp SFB7 bioelectrical impedance analyser (ImpediMed, Ltd., Eight Mile Plains, Queensland, Australia). The Imp SFB7 is a multi-frequency, tetra polar bioelectrical impedance spectroscopy device and has acceptable test-retest reliability in adolescents (493).

8.2.4.3 Muscular fitness

The 90-degree push-up test was used as a measure of upper body muscular endurance. Push-ups were performed in time with a metronome, set at 40 beats per minute, allowing one push-up every three seconds. Testing procedures were explained prior to the test. Participants lowered their body in a controlled manner until a 90-degree angle was formed at the elbow then pushed back up. The test concluded when participants either failed to maintain the movement with adequate form in time with the metronome, failed to lower themselves to the required depth on three non-consecutive repetitions, or upon volitional failure. Participants did not receive verbal encouragement during the conduct of the test. This test has acceptable test-retest reliability in adolescents (493). Upper body muscular strength was assessed using a handgrip dynamometer (SMEDLEY'S dynamometer TTM, Tokyo, Japan). After adjusting the grip-span to suit the hand size of the participant, boys were asked to squeeze the dynamometer continuously as hard as possible for three seconds with the elbow in full extension down by the side of the body. The test was performed three times each for the left and right hands, alternating hands after each trial, and the participants score was calculated as the mean of all trials. To provide a measure of muscular fitness encompassing both maximal strength and local muscular endurance, a muscular fitness score was calculated (173, 323). The muscular fitness score was calculated using the results of the two muscular fitness tests. To adjust for differences in body size, hand grip strength was first expressed relative to body weight. The individual scores were then standardised as follows: (value-mean/SD). The muscular fitness score was calculated as the sum of the two standardised scores.

8.2.4.4 Physical activity

Physical activity was assessed using Actigraph™ accelerometers (model GT3X+). Participants wore their monitors for seven consecutive days, during waking hours except while bathing and swimming. Data were collected and stored in 5-second epochs. Valid wear time was defined as a minimum of three weekdays with at least 8 hours (i.e., 480 minutes) of total wear time recorded, and non-wear time was defined as 30 minutes of consecutive zeroes. Activity counts were categorised into sedentary, light, moderate, and vigorous intensity using the cut points proposed by

Evenson et al. (496). The time (i.e., mean daily minutes) spent in moderate and vigorous intensity activity was summed to produce a measure of moderate-to-vigorous physical activity (MVPA).

8.2.4.5 Resistance training skill competency

Resistance training skill competency was assessed using video analysis of the Resistance Training Skills Battery (8). Following a demonstration by the assessor, participants performed two sets of four repetitions of each exercise in the order listed (i.e., squat, push up, lunge, overhead press, front support with chest touches, and suspended row) with a rest period of up to 15 seconds between sets. Participants did not receive skill specific feedback during their performance. Each skill consists of four or five performance criteria and is scored by adding the total number of performance criteria successfully demonstrated across the two sets. Consequently, the highest possible score for each skill is 8 or 10 depending on the number of performance criteria. Each of the six skill scores are summed to produce a composite score, termed the Resistance Training Skill Quotient (RTSQ), with a possible range of 0 – 56. The Resistance Training Skills Battery has satisfactory test-retest reliability in adolescents (Typical error of RTSQ [95%CI] = 2.5 [2.1 to 3.0]) (8).

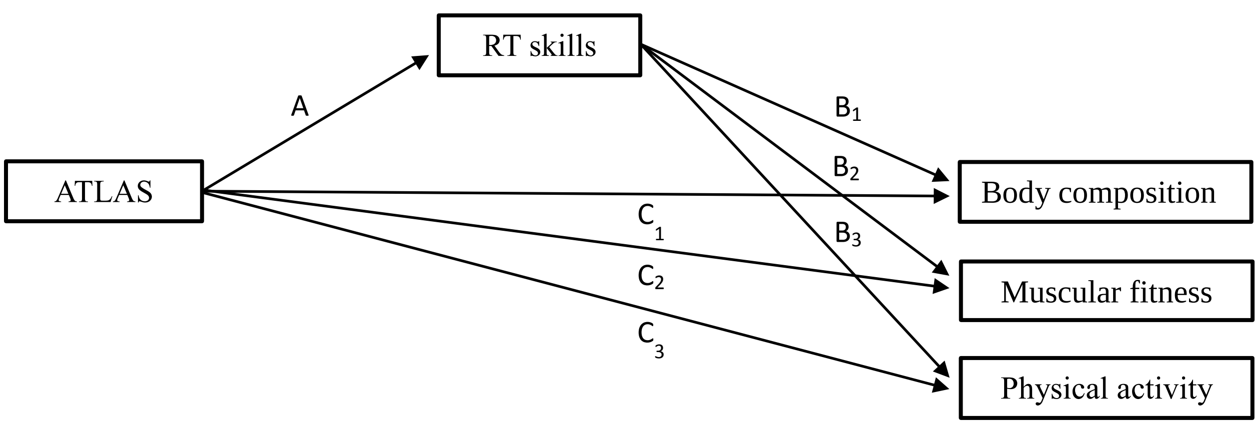

Figure 8.1 Hypothesised mediation models

8.2.4.6 Statistical analyses

For all analyses, statistical significance was set at $P < 0.05$. Cross-sectional associations between study variables at baseline were examined using Pearson's bivariate correlations in SPSS version 20.0 for Windows (2010, SPSS Inc., IBM company Armonk, NY). Mediation analyses followed the intention-to-treat principle, with missing data for percent body fat and muscular fitness imputed using the expectation maximisation method (568). Due to the large amount of missing data for MVPA, no imputation was performed for this outcome. Mediation analyses were conducted using a product of coefficients test (569) in MPlus, version 7.11 for Windows (Muthén & Muthén, Los Angeles, CA). Multi-level linear regression analysis was used to: (i) calculate the regression coefficient for the effect of the intervention on the hypothesised mediator (Pathway A); (ii) determine the association between the mediator variable and the outcome variable at post-intervention, independent of group assignment and baseline values (Pathway B); and (iii) estimate the total (Pathway C) and direct (Pathway C') intervention effects for each study outcome. The direct effect (C') represents the intervention effect controlling for the mediator, or the effect of the intervention on the outcome not explained by the mediated effect. The product of the A and B coefficients was then computed to determine the mediated effect (Pathway AB) and the 'RMediation' package (570) was used to compute the confidence intervals of the mediated effect. Confidence intervals that do not cross zero indicate statistical significance. Three separate single mediator models were tested (Figure 1), one for each outcome (i.e., MVPA, muscular fitness and percent body fat). All models were adjusted for baseline values, participant SES, and school-level clustering. Subgroup analyses were also conducted, with the models repeated separately for boys classified as overweight or obese (combined into a single group) at baseline.

Table 8.1 Baseline characteristics of study sample

Characteristics	Control (*n* = 180)	ATLAS (*n* = 181)	Total (*N* = 361)
Age, y	12.7 (0.5)	12.7 (0.5)	12.7 (0.5)
Born in Australia	168 (93.3)	174 (96.1)	341 (94.7)
English language spoken at home [a]	169 (94.4)	175 (96.7)	344 (95.6)
Cultural background [b]			
Australian	132 (73.7)	145 (80.6)	277 (77.2)
European	31 (17.3)	22 (12.2)	53 (14.8)
African	6 (3.4)	1 (0.6)	7 (1.9)
Asian	3 (1.7)	4 (2.2)	7 (1.9)
Middle eastern	2 (1.1)	0 (0)	2 (0.6)
Other	5 (2.8)	8 (4.4)	13 (3.6)
Socioeconomic position			
1-2	55 (30.9)	49 (27.1)	104 (29.0)
3-4	81 (45.5)	120 (66.3)	201 (56.0)
5-6	27 (15.2)	4 (2.2)	31 (8.6)
7-8	8 (4.5)	8 (4.4)	16 (4.5)
9-10	7 (3.9)	0 (0)	7 (1.9)
Weight status			
Underweight	5 (2.8)	2 (1.1)	7 (1.9)
Healthy weight	115 (63.9)	110 (60.8)	225 (62.3)
Overweight	38 (21.1)	39 (21.5)	77 (21.3)
Obese	22 (12.2)	30 (16.6)	52 (14.4)

Note. Data for age are presented as mean (SD). All other data are presented as or *n* (%).

ATLAS = active teen leaders avoiding screen-time

[a] one participants did not report language spoken at home.

[b] two participants did not report cultural background.

8.3 Results

In total, 361 boys (mean age, 12.7 ±0.5 years) were assessed at baseline. As shown in Table 8.1, the majority of boys were born in Australia (95%), identified their cultural background as Australian (77%) and spoke English at home (96%). In addition, 85% of boys resided in areas with a SEIFA score less than 5 indicating that the majority were of low-to-middle SES. Further, approximately a third of boys were classified as overweight or obese. Post-intervention assessments for the primary outcomes at 8-months were completed for 293 boys, representing an overall retention rate of 81%. The 8-month study outcomes have been reported previously (565). Briefly, there were no significant intervention effects for body composition, physical activity or grip strength. However, significant group-by-time effects were observed for screen-time (mean = -30 ± 10 mins/d; $P = .03$), push-ups (mean = 0.9 ± 0.5 repetitions; $P = .04$), and sugar-sweetened beverage consumption (mean = -0.6 ± 0.3 glass/d; $P = .01$).

The number of participants with complete data for resistance training skill competency and each outcome was $n = 253$ (70%) for percent body fat, $n = 248$ (69%) for muscular fitness, and $n = 130$ (36%) for MVPA. Baseline and post-test values for study outcomes can be seen in Table 8.2. Pearson's bivariate correlations indicated that resistance training skill competency was significantly associated in the expected direction with percent body fat ($r = -.28$, $P < .001$), muscular fitness ($r = .43$, $P < .001$) and MVPA ($r = .16$, $P = .01$) at baseline.

8.3.1 Intervention effects (Pathway C)

Results for the action theory test (A), conceptual theory test (B), direct effect (C'), and mediated effect (AB) can be found in Table 8.3. Analyses were first conducted only among those with complete data for the mediator and the outcome, then among the entire sample with missing data imputed. Comparisons of the regression coefficients showed that the magnitude of the effects were similar between analyses, providing additional support for the use of the expectation maximisation approach. Values reported hereafter are unstandardised regression coefficients from analyses with imputation for missing data (except for the physical activity outcome). Among the overall sample, the intervention did not significantly improve MVPA (B [SE] = -1.53 [5.58], $P = .78$) or percent body fat (B [SE] = -.62 [.39], $P = .11$). Conversely, the effect of the intervention on muscular fitness approached significance (B [SE] = .18 [.10], $P = .07$). Among the overweight/obese subgroup, the intervention effect was statistically significant for percent body fat (B [SE] = -1.52 [.56], $P = .006$) and muscular fitness (B [SE] = 0.27 [.12], $P = .03$). However, there were also no significant effects for MVPA (B [SE] = -1.5 [8.2], $P = .85$).

8.3.2 Action theory test (Pathway A)

Significant intervention effects were observed for resistance training skill competency in both the overall sample (B [SE] = 4.6 [.5], P <.001) and among the overweight/obese subgroup (B [SE] = 4.3 [1.0], P <.001).

8.3.3 Conceptual theory tests (Pathway B)

Following adjustment for individual SES, school, group allocation, and baseline values, resistance training skill competency at post-intervention was significantly associated with percent body fat (B [SE] = -.21 [.05], P < .001) and muscular fitness (B [SE] = .04 [.02], P = .02) among the overall sample. Resistance training skill competency was not significantly associated with MVPA (B [SE] = .10 [.40], P = .81) at post-intervention. Among overweight/obese boys, the association with resistance training skills approached significance for percent body fat, but was not significant for muscular fitness or MVPA.

8.3.4 Mediation tests (Pathway AB)

Among the overall sample, the mediated effect was statistically significant for percent body fat (B [SE] = -.95 [.26]; 95% CI = -1.49 to -.47) and muscular fitness (B [SE] = .16 [.07]; 95%CI = .03 to .31). Conversely, the mediated effect was not significant for MVPA (B [SE] = .50 [2.1]; 95%CI = -3.6 to 4.6). Among the overweight/obese subgroup, the mediated effect approached significance for percent body fat, but was not significant for MVPA or muscular fitness.

Table 8.2 Changes in study outcomes

Outcome	Baseline, Mean (SD)	8-month, Mean (SD)	Change, Mean (SD)
Body fat, (%)			
Intervention	20.1 (8.5)	21.5 (7.5)	1.4 (3.7)
Control	22.3 (8.3)	23.7 (8.1)	1.4 (3.4)
Muscular fitness score [a]			
Intervention	.36 (1.85)	.42 (1.69)	.07 (.93)
Control	-.37 (1.64)	-.34 (1.63)	.01 (.72)
MVPA, minutes [b]			
Intervention	67 (18)	63 (20)	-4 (18)
Control	60 (18)	62 (23)	2 (21)
RT skill competency [c]			
Intervention	30.8 (5.7)	38.3 (5.5)	7.5 (5.1)
Control	29.8 (5.9)	33.2 (5.4)	3.4 (5.0)

Note. Values may differ from those reported in the published outcomes paper due to the use of a different method for imputing missing data.

MVPA, moderate-to-vigorous physical activity; RT, resistance training

[a] Sum of standardised values for the hand grip strength and push-up tests

[b] *n* = 56 intervention group and *n* = 74 control group participants provided valid accelerometer data at both baseline and post-test

[c] Possible values range from 0 to 56.

Table 8.3 Action theory test, conceptual theory test and significance of the mediated effect of resistance training skill competency on study outcomes

Study outcome	Action theory test		Conceptual theory test		Direct effect		Indirect effect	
	A (SE)	*P*	B (SE)	*P*	C' (SE)	*P*	AB (SE)	95% CI
Overall sample								
Body fat (%)	4.6 (0.5)	< 0.001	-0.21 (0.05)	< 0.001	0.34 (0.38)	0.368	-0.95 (0.26)	-1.49 to -0.47
Muscular fitness [a]	-	-	0.04 (0.02)	0.022	0.03 (0.10)	0.722	0.16 (0.07)	0.03 to 0.31
MVPA (mins/d) [b]	-	-	0.10 (0.40)	0.812	-2.30 (5.34)	0.667	0.50 (2.10)	-3.6 to 4.6
Overweight/obese subsample								
Body fat (%)	4.3 (1.0)	< 0.001	-0.15 (0.09)	0.097	-0.68 (0.63)	0.281	-0.67 (0.44)	-1.62 to 0.12
Muscular fitness [a]	-	-	0.01 (0.02)	0.532	0.23 (0.12)	0.050	0.04 (0.07)	-0.10 to 0.19
MVPA (mins/d) [c]	-	-	0.97 (0.69)	0.164	-6.50 (8.56)	0.448	4.23 (3.24)	-1.7 to 11.1

Note. Values reported are unstandardised regression coefficients.

MVPA = moderate-to-vigorous physical activity

[a] Sum of standardised values for the hand grip strength and push-up tests

[b] *n* = 130 participants in the overall sample provided complete data for resistance training skill competency and MVPA

[c] *n* = 43 participants in the overweight/obese subsample provided complete data for resistance training skill competency and MVPA

8.4 Discussion

The aim of the present study was to examine the potential mediating effects of resistance training skill competency on changes in percent body fat, muscular fitness and physical activity among boys participating in the ATLAS intervention. To the authors' knowledge this is the first study to investigate the link between resistance training movement skills and health outcomes. Resistance training skill competency was found to be a statistically significant mediator of percent body fat and muscular fitness. Conversely, no significant mediated effects were observed for physical activity.

Although school-based health behaviour interventions often target theoretical mediators, analyses of the mechanisms of change in these studies are rarely performed (289). Consequently, our current understanding of 'what works' in behavioural interventions is largely based on inference, rather than on empirical evidence. Our findings therefore, address a notable gap in the literature. Due to the novelty of our hypothesised mediator, comparisons with other studies are problematic. However, previous research has found that fundamental movement skill proficiency during youth is related to physical activity, cardiorespiratory fitness, and body composition (61). Additionally, significant associations between motor competence and muscular fitness among children and adolescents have been reported (571, 572), albeit in cross-sectional studies. During our initial evaluation of the Resistance Training Skills Battery (8), we found that resistance training skill competency was significantly associated with muscular fitness in a sample of 12-16 year old adolescents, with the overall skill score independently explaining 39% of the variance. However, due to the cross-sectional nature of the study causation could not be determined. The results of the present study extend our previous findings, demonstrating a potential causal relationship between resistance training skill competency and both muscular fitness and body composition in adolescent males.

There are a number of possible explanations for these findings. Firstly, it is likely that improvements in resistance training skill competency enabled more effective exercise performance during the school sport sessions. For example, performing exercises with correct technique and through the full range of motion may have resulted in a greater training stimulus, facilitating larger gains in muscular fitness. Further, although training-induced gains in muscular fitness during early adolescence are partly due to neural adaptations (37), it is possible that boys with greater skill competency achieved the level of training intensity sufficient to trigger increases in lean mass, which could also explain the mediated effect for body composition. Alternatively, the use of proper exercise technique may have resulted in greater energy expenditure during the school sport sessions, influencing boys' body composition through the effect on energy balance. Secondly, the ATLAS program was designed to satisfy boys' basic psychological need for competence by providing them with opportunities to develop their resistance training movement skills. The Trans-Contextual Model (282) posits that autonomous motivation for physical activity in one context (e.g., school sport) can translate into motivation for physical activity in other contexts (e.g., leisure-time). Therefore, in line with the tenets of Self-Determination Theory (66), participants may have experienced greater autonomous motivation to engage in resistance training activities during their leisure-time. Finally, it is possible that improvement in resistance training skills was a proxy for program adherence, meaning that improvement in skill competency was simply capturing participation and engagement with the ATLAS program.

As hypothesised, the ATLAS intervention improved boys' resistance training skill competency. The mean improvement in the overall skill score among intervention boys - above and beyond that of the control group - was 4.1 units, corresponding to a moderate effect size (d = .71). Although this is the first intervention to assess resistance training skill competency, previous interventions have been successful in improving fundamental movement skills among children (573). Furthermore, a meta-analysis of resistance training studies demonstrated that this training modality is effective for improving sports-related motor skills among children and adolescents (47). Unlike improvements in muscular fitness, which will deteriorate quickly upon the cessation of training (37), a learned movement pattern is more permanent (574), and there is emerging evidence that interventions aimed at improving fundamental movement skills result in sustained changes in this outcome (48, 573). This is in contrast to physical activity and fitness outcomes which may be less stable over time (48). Importantly, these data suggest that the basic skills required to be physically active will be retained once they are learned, thereby enabling effective movement performance throughout the lifespan. Considering the potential for resistance training to become a lifelong physical activity, improving competence in related movement skills is a valuable intervention outcome. Learning the requisite movement skills to be successful in this form of activity could remove a considerable barrier to future participation.

Despite significant mediation effects for muscular fitness and body composition, resistance training skills did not appear to be a mediator of physical activity. The conceptual model proposed by Stodden et al. (65) posits that motor competence influences body composition through health-related fitness and physical activity. However, the null findings for physical activity may be due to the challenges of using accelerometers to measure physical activity in adolescents. As only 36% of boys provided complete data for resistance training skill competency and MVPA, our statistical power was substantially reduced. In addition, although accelerometry is considered a high quality measure of physical activity, these devices are best suited for detecting ambulatory movement (e.g., running). The ATLAS intervention was focused on developing competence in resistance training, which typically involves non-ambulatory movements that may not be detected by accelerometers (e.g., body weight squat). Previous research has shown that providing incentives contingent on the provision of valid data, and keeping a physical activity log are effective strategies for improving compliance with accelerometry among high school-aged students (575). Although these strategies were used in the present study, they did not appear to be effective at improving compliance. As evidence for the validity of new monitoring devices (e.g., wrist-worn personal activity trackers) becomes available, researchers should consider using these devices as they may be more acceptable to adolescents and hence may improve participant compliance with monitoring protocols.

Despite statistically significant intervention effects for muscular fitness and percent body fat among overweight/obese boys, no significant mediated effects were observed among this subgroup. Although the threshold for statistical significance was not reached, the mediated effect for percent body fat was in the hypothesised direction and accounted for 49.6% of the intervention effect. Considering that ATLAS targeted a number of weight-related behaviours (i.e., physical activity, screen-time, and sugared beverage intake), it may be that the effect of the intervention on body fat for overweight/obese boys was also due to changes in these behaviours.

The findings of this study have implications for the assessment and evaluation of youth exercise programs. While fitness testing has traditionally been the preferred method for evaluating training progress, we suggest that resistance training movement skill development may be an equally valuable outcome, particularly among novice trainers. This may be of considerable importance considering the influence of maturation on responses to training (37). Individuals with limited improvement in fitness following an exercise program may remain motivated if they experience tangible improvements in skill competency. Conversely, if success is based solely on fitness outcomes, these individuals may become disheartened and discontinue participation. According to the model proposed by Stodden et al., (65), youth with low motor competence are likely to become trapped in a continuous cycle of disengagement from physical activity, leading to a future of poor health outcomes. Importantly, resistance training may be a suitable activity for overweight/obese youth who often display low levels of motor competence and struggle physically with the aerobic activities they are typically prescribed (37). As demonstrated, improving resistance training skill competency is an achievable intervention outcome for overweight/obese youth. However, further research is needed to determine the mediating mechanisms behind changes in fitness and body composition among this subgroup

The strengths of our study include the experimental design, objective assessment of skill competency, and use of robust multi-level mediation techniques. Unfortunately, the limitations associated with physical activity measurement may have hampered our ability to properly examine the association between resistance training skill competency and physical activity. Finally, as the study sample were adolescent males from schools in low-income communities, care should be taken in generalising study findings to other groups.

8.5 Conclusions

Previous research has shown that properly designed and supervised resistance training programs are a safe and effective way of improving muscular fitness and decreasing adiposity among young people (37). However, to date, little research has focused on the role of movement skills in achieving the health outcomes commonly sought from this mode of exercise. To the authors' knowledge, ATLAS is the first intervention to explicitly target resistance training movement skill development in the school setting. Moreover, this is the first study to empirically examine the mediating role of resistance training movement skills for health-related outcomes. This study has identified a feasible and efficacious approach for achieving improvements in body composition and muscular fitness among adolescent males. Future research should explore the contribution of motivational factors in the association between movement skill development and changes in health-related fitness, using Self-Determination Theory (66) as a framework. Furthermore, there is a rationale for investigating skill competency related to other lifelong activities (e.g., Yoga), and their relationships with physiological and psychosocial health outcomes. Finally, replication of these findings in other population groups (i.e., young females) is warranted.

CHAPTER 9: DISCUSSION

9.1 Overview

The previous chapters of this thesis have described each of the included studies in detail and have explained, compared and discussed their findings within the context of the existing literature. Therefore, the purpose of this chapter is to synthesise the key findings, outline the main strengths and limitations of this research, and discuss the implications of this body of work. In addition, an overview of the key research gaps addressed by this thesis is provided. As outlined in Chapter 1, the primary aim of this thesis was to:

1. Evaluate the effects of the ATLAS cluster randomised controlled trial (RCT) on health-related fitness and resistance training (RT) movement skill competency among adolescent boys attending schools in low-income communities (Chapters 5 and 6).

The primary hypothesis of this thesis was that, following the delivery of the ATLAS intervention, adolescent boys randomised to the intervention group will demonstrate favourable changes in: (1) body composition; (2) muscular fitness; and (3) RT movement skill competency, compared with a control group participating in usual practice.

The secondary aims of this thesis were to:

1. Systematically review the evidence base regarding the health-benefits of muscular fitness for children and adolescents (Chapter 3);
2. Develop and evaluate a test battery for assessing adolescents' RT movement skill competency (Chapter 4);
3. Evaluate the effectiveness of the ATLAS intervention on adolescent boys' physical activity, screen-time, and sugar-sweetened beverage (SSB) consumption (Chapters 5 and 6);
4. Describe the development and implementation of a smartphone application designed to promote physical activity and reduce screen-time among adolescent boys (Chapter 7); and
5. Examine the potential mediating effects of RT movement skill competency on health-related fitness and physical activity (Chapter 8).

As demonstrated by the aims above, the primary focus of this thesis was the development and evaluation of the ATLAS school-based intervention. Secondary to this main focus were two related research topics: (i) the health benefits of muscular fitness for children and adolescents; and (ii) the assessment of RT movement skill competency among adolescents. Therefore, the following discussion is structured into two main sections, which correspond to these two foci. The first section consists of the evaluation of the ATLAS cluster RCT (*Primary aim* and *Secondary aims 3 – 5*), and includes a discussion of the intervention outcomes and the process measures. The second section comprises the benefits of muscular fitness for children and adolescents (*Secondary aim 1*) and the assessment of RT movement skill competency among school-age youth (*Secondary aim 2*). Within each of these sections, an overview of findings is presented, followed by a discussion of the main strengths and limitations of the research. In addition, the implications of the findings for future research and practice are presented.

9.2 Research gaps addressed by this thesis

To provide a meaningful contribution to the current evidence base, this body of work addressed a number of limitations of previous research. From the review of the literature, the following research gaps were identified:

- Previous school-based physical activity and obesity prevention interventions have typically been more successful for younger children compared with adolescents (26, 28). Adolescent obesity prevention programs have reported mixed success (26). However, there are relatively few school-based interventions that have targeted adolescents (26).

- Despite the popularity of school-based approaches for improving physical activity and fitness and preventing obesity, previous school-based intervention research has been limited by poor methodological quality including the use of inadequate study designs, subjective outcome measures, small sample sizes, and short follow-up durations (26, 29).

- Despite recommendations that intervention studies examine the mechanisms of change within their trials (290), few previous studies have conducted statistical mediation analyses (289) resulting in limited empirical evidence regarding the most effective strategies for improving health-related outcomes among youth.

- Previous intervention studies have found sex to be a moderator of intervention effects (30, 31), suggesting that certain intervention strategies may be more appropriate for either boys or girls. Among the few single-sex programs that have been evaluated among adolescents, almost all have targeted females (26). Consequently, there is little evidence regarding the effectiveness of single-sex, gender-targeted programs on health outcomes among adolescent males.

- Despite the recognised benefits of RT for youth (37), few school-based interventions have included RT within their programs (29). As a result, there is little evidence regarding the feasibility, acceptability, and effectiveness of this mode of exercise when delivered in the school setting.

- Although recommendations to perform 'muscle and bone strengthening' physical activities appear in national (89) and international (108) youth physical activity guidelines, there has not yet been a comprehensive and systematic evaluation of the associations between muscular fitness and health outcomes among children and adolescents.

- Despite international recommendations that youth RT programs incorporate a focus on movement skill development (37), there is currently no available assessment tool for quantifying RT skill competency among school-aged youth. Further, there is a limited understanding of the potential benefits of developing movement competence in this mode of exercise.

9.3 Evaluation of the ATLAS cluster RCT

The following section corresponds to Chapters 5 – 8 of this thesis and encompasses the *Primary aim* and *Secondary aims 3 – 5*.This section is divided into two main subsections discussing: (i) the ATLAS intervention outcomes; and (ii) the findings of the process measures included within the ATLAS study.

9.3.1 Intervention outcomes

9.3.1.1 Body composition outcomes

In Chapter 6, the eight-month (i.e., immediate post-intervention) outcomes from the ATLAS cluster RCT (535, 565) were presented. As reported, the ATLAS intervention did not result in improvements in the primary outcomes of BMI and waist circumference, or body fat percentage among the overall sample. Pre-specified sub-group analyses, conducted among boys classified as overweight or obese at baseline, showed a trend in favour of the intervention group for all three body composition variables. However, the between-group differences for these outcomes were not statistically significant. Based on these findings, *Primary hypothesis 1* of this thesis was not supported.

9.3.1.2 Muscular fitness and movement skill outcomes

A significant group-by-time effect was observed for local muscular endurance (i.e., push-up repetitions). However, despite the between-group difference for maximal strength (i.e., hand grip dynamometry) favouring intervention boys, this was not statistically significant. There was also a large and highly significant intervention effect for boys' RT movement skill competency. Based on these findings, *Primary hypothesis 2* was partially supported *and Primary hypothesis 3* was supported.

9.3.1.3 Behavioural outcomes

ATLAS resulted in a significant between-group difference of approximately 30 minutes of recreational screen-time per day. Boys in the intervention group did not report a reduction in total screen-time. Rather, they maintained their screen-time over the study period while boys in the control group reported a significant increase in total screen-time. In addition, intervention boys reported consuming significantly fewer SSBs at post-test compared with boys in the control group. In contrast to screen-time, a significant reduction in SSB intake was reported by intervention boys, resulting in a difference of approximately 150mL per day (i.e., 0.6 glass) between the two groups. No intervention effects were found for accelerometer measured total physical activity (i.e., counts per minute) or moderate-to-vigorous physical activity (MVPA).

9.3.1.4 Mediation analysis

In Chapter 8, the results of a study investigating the potential mediating effects of RT movement skill competency on study outcomes were presented (576) (*Secondary aim 5*). Although there was no overall intervention effect for body fat percentage, RT skill competency was found to be a significant mediator of change in body fat. In addition, RT skill competency significantly mediated the effect of the intervention on muscular fitness. No mediated effects were found for MVPA. Consequently, two out of three hypothesised mediation pathways were supported by the data.

9.3.2 Strengths and limitations

As mentioned previously, much of the past school-based intervention research has been limited by inadequate study designs, including the use of uncontrolled or quasi-experimental trial designs (26). Adolescents undergo considerable physiological changes as a result of normal growth and development (577). Therefore, when conducting research among this population, the use of a control or comparison group is essential for disentangling the unique effects of an intervention from changes that would be expected to occur naturally. This may be of particular importance in the assessment of changes in health-related fitness, which can vary considerably with age and maturational status (578-580). Although quasi-experimental studies have a comparison group, the potential for systematic differences between groups in unmeasured variables raises concerns over internal validity (581). Moreover, selection bias inherent within these trials due to the lack of randomisation may result in artificially inflated intervention effects (26). ATLAS utilised a cluster RCT design, the gold standard study design for school-based intervention research (258). Further, appropriate adjustment for the effects of school-level clustering was made for all outcome analyses.

An additional strength of the ATLAS study was the use of accelerometry for the assessment of physical activity. Many previous school-based interventions have relied on self-report measures of physical activity (26), which are highly prone to recall and social desirability bias and typically overestimate total physical activity (582). Although pedometers provide an objective assessment of youth physical activity, these devices are limited by their inability to evaluate time spent in activities of varying intensity (582). The capacity for accelerometry to provide objective data on both the duration and intensity of physical activity, makes this a preferable method for field-based physical activity assessment (583).

In addition to objective measurement of physical activity, the ATLAS study also included objective assessment of RT movement skill competency. To the author's knowledge, this is the first study to include RT skill competency as an outcome in a school-based physical activity program. As presented in Chapter 4 of this thesis, the process-based assessment tool for measuring RT skills (i.e., the RTSB) demonstrated acceptable test-retest reliability and construct validity (8). Furthermore, the RTSB has also demonstrated satisfactory inter-rater reliability (9). The findings presented in Chapter 4 provide credibility to the results for RT movement skill competency reported elsewhere.

Finally, as previously discussed, few intervention studies conduct statistical mediation analyses to determine the mechanisms underlying changes in study outcomes (289). The development of movement competence in RT exercises was an important objective of the ATLAS intervention, and explicit intervention strategies were utilised to achieve improvements in RT movement skill competency. Robust multi-level mediation analysis was then used to explore the causal associations between developing RT movement skill competency and improving body composition, muscular fitness and physical activity. This is the first study to explore the possible mediating effects of objectively assessed RT movement skill competency. The use of mediation analysis to explore these associations addresses a recognised limitation of past research (289, 290).

Although there were a number of strengths of the ATLAS study, it is also important to acknowledge some limitations. BMI is considered a suitable measure for assessing change in adiposity (543), and is a simple and reliable method for assessing adiposity outside of a laboratory setting (1). However, BMI does not differentiate fat mass from lean mass, and may therefore be insensitive for detecting changes in body fat (584). This may be a concern for trials utilising RT, as increases in (or even maintenance of) lean mass may potentially mask intervention effects for body composition, resulting in greater risk of Type II error. Due to the limitations of BMI, alternative measures of adiposity such as skinfold thickness and Dual Energy X-ray Absorptiometry (DEXA) may be more suitable for evaluating the effects of obesity prevention interventions (30). However, precise skinfold assessment requires considerable training and experience. Further, this type of assessment could cause anxiety among adolescents, particularly those that are overweight or obese. In addition, there are obvious logistical and financial limitations to using DEXA, particularly in larger trials and those conducted in school settings.

An additional consideration regarding body composition assessment in the present study relates to the age of the study sample. Although randomisation should have accounted for any systematic differences between groups in terms of maturational status, maturation was not assessed and was therefore not able to be included as a covariate in the outcome analyses. Previous research has shown that the mean age of peak height velocity (i.e., the pubertal growth spurt) among adolescent males is approximately 13 years (585). The sample in the present study were, on average, 12.7 years old at the time of baseline data collection, placing them at an age in which drastic changes in both somatic height (i.e., 10.3cm per year) and body composition occur (586). It is possible that this rapid growth and development confounded any attempt to isolate intervention effects for body composition from the large changes naturally associated with this developmental stage.

In the ATLAS study, three separate measures of body composition were utilised (i.e., BMI, waist circumference, and bioelectrical impedance analysis [% body fat]). This may have increased the potential risk of Type I error. However, the use of multiple measures helped to address the limitations of individual measures and enabled the confirmation of study findings. For example, in the main analysis there was agreement between all body composition measures, providing support for the conclusion that the intervention did not have an effect on body composition overall. Considering that RT was a core physical activity within the ATLAS intervention, the findings for

BMI could have been confounded by changes in boys' lean body mass. However, the results for percent body fat confirmed the lack of an effect, also showing no difference in change between groups. In the sub-group analysis for overweight/obese boys, the between-group difference in change for all body composition measures favoured intervention boys, supporting the conclusion of a trend toward positive effects for the intervention group. Therefore, although feasibility constraints precluded the use of the most desirable body composition measures, the use of multiple measures enabled certain measurement limitations to be mitigated.

Another study limitation was the use of subjective self-report methods to assess screen-time and SSB intake. Although these measures are commonly used in intervention research to assess changes in these behaviours (587, 588), it is possible that the positive intervention effects for these outcomes were influenced by social desirability bias. Recall bias and social desirability remain significant challenges to the accurate assessment of dietary and sedentary behaviours by self-report (589, 590). However, there are few suitable alternatives for assessing these outcomes. We aimed to address a limitation of past research by modifying the Adolescent Sedentary Activity Questionnaire (ASAQ) to address the issue of recreational screen-time multi-tasking. It has been reported that up to a quarter of adolescents' screen-time is spent using multiple devices concurrently (98). Although this has been known for some time (499), the current ASAQ still uses the sum of time reported using individual screen devices to calculate total screen-time (498). Consequently, the ASAQ may produce inflated estimates of total screen-time, as time spent multi-tasking is not accounted for. From an obesity prevention perspective, it is likely to be of little consequence whether young people are using one, two or three devices at once. However, an accurate assessment of the total time spent engaged in these sedentary behaviours is critical. The modified ASAQ measured the total time spent sitting using screens (of any kind) for the purpose of entertainment. Although this prevents a more detailed examination of the changes in different types of screen-time (e.g., TV, video gaming, or PC use), this method is expected to provide a more accurate assessment of *total* screen-time. When comparing study findings, it should therefore be recognised that our estimate of screen-time is likely to be more conservative than that of studies using the traditional ASAQ, or other instruments with a similar approach for calculating total screen-time.

Although the objective assessment of physical activity is a strength of the ATLAS study, the use of this method was also problematic. Consistent with other research among adolescents (46, 267), compliance with physical activity monitoring was poor, particularly on weekend days. Consequently, the reduced sample size hampered our ability to appropriately examine the effect of the intervention on physical activity. Participant compliance has previously been identified as a significant limitation of accelerometer-based physical activity measurement (575, 591). In addition to problems with compliance, it should also be noted that accelerometers are best for detecting ambulatory movement (e.g., running) (583). The ATLAS study aimed to build competence in RT and encouraged boys to participate in this mode of exercise during their leisure-time. RT includes many non-ambulatory movements (e.g., push-ups, body-weight squats), which may not be adequately detected using accelerometers (583).

Another measurement limitation in the ATLAS study pertained to the use of hand grip dynamometry for assessing change in muscular strength. Hand grip dynamometry has been identified as the most valid (211) and reliable (213) field-based test for assessing muscular strength. Consequently, performance on this fitness test can be considered a suitable marker of absolute strength among youth. Furthermore, this test is easily administered and offers little risk of injury to participants. This particular fitness test may have utility for exploring associations between muscular strength and health-related outcomes in cross-sectional and longitudinal research. However, due to the specificity of muscular adaptations in response to training (592), hand grip strength may be a poor measure for assessing change in muscular strength in experimental studies. This may be particularly true for programs like ATLAS, which focus on compound movements (e.g., squat, lunge, and push-up), and target the large muscle groups of the body rather than the forearm flexors and extensors, specifically. The body-weight and elastic tubing RT exercises used in the ATLAS activity sessions may not have provided a sufficient training stimulus to improve hand grip strength. However, this does not necessarily mean that improvements in maximal strength in other body regions (e.g., lower body strength) were not achieved. Future intervention studies need to weigh the validity of their selected muscular fitness tests against their sensitivity to detect the changes in fitness that would be expected from participation in the program. For example, although the timed push-up test is not considered the most valid or reliable test of local muscular endurance (211, 213), this test was suitable for detecting changes in this fitness component within the ATLAS study, as it closely reflected one of the core exercises used during the physical activity sessions.

A final limitation of the present study is that the results may not be generalisable to other groups. For example, the ATLAS study sample were adolescent males from a single year group, considered at increased risk of obesity based on their physical activity and screen-time behaviours. Furthermore, all participants attended schools in low-income communities. Although there is a clear justification for targeting this group, care should be taken in the comparison of study findings, particularly in cases where there are obvious differences in sample characteristics (i.e., studies among females or adolescents from other socioeconomic strata).

9.3.3 Implications for research and practice

9.3.3.1 Enhancing trial efficacy

As noted previously, the ATLAS intervention had no effect on body composition among the overall sample. This was a surprising finding considering the large intervention effects for body composition observed in the PALs pilot study (67). This outcome is, however, consistent with the findings of reviews and meta-analyses examining the effectiveness of previous obesity prevention interventions among adolescents (26, 28). Comparing results with the PALs study may provide the most useful insights into the underlying reasons for the null findings, as both PALs and ATLAS utilised essentially the same intervention framework, yet resulted in substantially different outcomes for body composition. One potential explanation for the inconsistency in findings has to do with differences between the study samples. The mean baseline BMI of the PALs sample was approximately 1.6 units higher than that of the ATLAS sample (i.e., 22.1 vs 20.5 $kg.m^{-2}$). It may be that boys in the PALs study simply had greater scope to improve their body composition due to a higher average BMI.

While this explanation is plausible, it is also important to explore alternative explanations. A calculation of the average weekly physical activity dose intended for each intervention (i.e., no. of sessions per week x session duration / no. of weeks) suggests that PALs provided, on average, 18 additional minutes of physical activity per week (i.e., 96 mins vs 114 mins). This difference is explained by the greater number of lunch-time sessions provided in the PALs intervention. The decision to reduce the number of lunch-time activity sessions in ATLAS was based on attempts to reduce the teacher and participant burden. Anecdotal evidence from students and teachers suggested that PALs participants were less satisfied with the lunch-time sessions due to a preference for using this time to socialise with friends. Process data from ATLAS suggests similar feelings among participating boys, with satisfaction ratings for the lunch-time sessions (3.7 ± 1.0 [scale of 1 to 5]) lower than those for the school sport sessions (4.5 ± 1.0 [scale of 1 to 5]). Further, only 44% of ATLAS participants attended an acceptable number of lunch-time sessions (i.e., at least two thirds). It is possible the resulting difference in accumulated physical activity from the lunch-time sessions contributed to the differences between PALs and ATLAS for body composition outcomes.

It is also possible there were differences in the average intensity of the physical activity sessions between the PALs pilot study and ATLAS cluster RCT. As outlined in Chapter 6, feedback from teachers and participants in the PALs study suggested that boys wanted more variety in activities during the sport sessions. Based on this feedback, and considering that ATLAS was being delivered for 20 weeks (compared with 10 weeks in PALs), it was determined that a greater range of activities would be needed to sustain participant engagement in the program. It is possible that these changes, although resulting in greater participant satisfaction with the ATLAS program (i.e., 4.5 ± 0.7 vs 4.0 ± 0.9 [scale of 1 to 5]), also resulted in lower activity intensity during the school sport sessions.

Logically, a greater quantity and higher intensity of physical activity will be more beneficial for achieving improvements in body composition. Indeed, there is evidence that the dose of physical activity in school-based interventions is an important determinant of trial efficacy (49). Therefore, future studies may need to consider strategies to increase the physical activity dose. Despite evidence of lower satisfaction with the lunch-time sessions, this period may still have utility for increasing students' overall physical activity during school hours. Researchers may need to consider ways of increasing adherence and participant enjoyment during these sessions, perhaps by encouraging participants to invite their friends, or by allowing more student choice in regards to the selection of activities. Indeed, SDT posits that perceived autonomy (i.e., choice) is an important determinant of motivation for a given activity (66).

In addition to increasing the number of physical activity opportunities, efforts may also need to be made to increase the average intensity of physical activity sessions. Previous research has demonstrated the importance of physical activity intensity for a number of health-related outcomes (80, 593). However, considering that higher exercise intensity may decrease program adherence (594), an appropriate balance may need to be found between exercise intensity and program enjoyment. Enjoyment has been found to mediate intervention effects for physical activity in previous studies (595) and a recent meta-analysis showed intrinsic motivation to be the motivational regulation most strongly associated with physical activity (279). Therefore, it is important that exercise intensity is not increased at the cost of participant enjoyment.

Finally, more attention may need to be given to the promotion of physical activity within the home environment. Support for physical activity from parents and family members has been consistently identified as a correlate of physical activity among adolescents (70). Further, in their Cochrane review of school-based physical activity interventions (29), Dobbins and colleagues note that "parental involvement could be an integral part of school-based interventions" (p.26). Rather than encouraging ‘general’ physical activity at home, researchers should consider strategies to promote physical activity during specific time periods. There is evidence that differences in physical activity between high and low active youth are greatest during the after-school period (596), suggesting that this ‘critical window’ is particularly significant for accumulating sufficient physical activity. Consequently, this period may be a useful focus for future health promotion interventions.

In addition to insufficient physical activity, the null findings for body composition may have been due to a lack of emphasis on alternative dietary outcomes. The decision to target SSB intake as the only dietary outcome was partly due to the results of the PALs study, which showed a reduction in SSB consumption among intervention boys, but no effect on the consumption of fruit and vegetables (67). There is evidence to suggest that reducing SSB intake alone can improve body composition among youth (109). Yet, reductions in reported SSB consumption in ATLAS were not accompanied by improvements in body composition. Social desirability bias may have led to an inflated estimate of change in SSB intake. Alternatively, the changes in SSB consumption may not have been large enough, or have occurred over a long enough period, to contribute to a change in body composition. There are a number of other discretionary foods, which could have also been targeted, such as energy-dense snacks and junk food (e.g., take-away fast food). Like SSBs, adolescents may have enough personal control over their consumption of these foods to enable reductions in intake through individual-level intervention strategies. Future obesity prevention interventions should consider targeting consumption of these discretionary foods. Conversely, future studies may need to incorporate more intensive family-based strategies aimed at engaging parents to improve their children’s diets. Engaging parents to support changes in their children’s dietary and sedentary behaviours was recommended by the authors of the most recent Cochrane review of youth obesity prevention interventions (26).

While there were no intervention effects for body composition among the entire sample in ATLAS, the effects for all three body composition variables among overweight and obese boys favoured the intervention group. Although the adjusted difference in change between groups was not statistically significant, it must be noted that the study was not powered to detect sub-group effects. Nonetheless, the magnitude of change in these outcomes might be clinically meaningful. Further, the fact that all three body composition variables indicated the same trend provides evidence of a positive effect for this ‘at risk’ sub-group. The limited capacity for change in BMI among ‘healthy weight’ youth is an issue with implications for the evaluation of future obesity prevention interventions. In their discussion of the HEALTHY school-based diabetes prevention trial (537), Marcus and colleagues suggest that, although school-based trials should continue to target all students, the primary outcome analysis should perhaps be focused on those most at risk (i.e., initially overweight/obese youth). Overweight and obese youth have the greatest need for intervention and the greatest capacity to respond to it. Therefore, there may be a need to examine more closely the effects of interventions on this sub-group. As noted by Marcus and colleagues (537), recruiting students for school-based trials on the basis of weight status may lead to weight stigmatisation. Therefore, when using school-based approaches, both overweight and non-overweight students should continue to be targeted. However, considering that meaningful intervention effects for youth at the greatest risk of poor health outcomes may be passing undetected, it would appear that there is a rationale for future obesity prevention interventions to ensure that they are adequately powered to detect effects among the overweight/obese sub-group.

9.3.3.2 Measurement of study outcomes

Considering the benefits of participating in muscle strengthening physical activities (37), and increased research interest in the promotion of this mode of exercise (55), new measurement methods may be needed to more effectively assess youth participation in these activities. As noted previously, accelerometry may be problematic for evaluating participation in this form of exercise, as these devices are best at detecting ambulatory movements common to aerobic physical activity (e.g., walking, jogging) (583). Recent studies among adolescents have utilised simple self-report methods to assess participation in RT-based activities (12, 254). Yet, this subjective approach raises many of the same concerns for validity and reliability as for other self-report measures of physical activity (582). For example, studies that simply measure the ‘number of days’ or even the ‘duration’ of muscle strengthening physical activity may not account for the large inter-individual variations in activity intensity, and also fail to capture the type of RT exercise (e.g., single joint isolation or multi-joint compound movements). Recall bias may be less of an issue for self-reporting ‘muscle and bone strengthening’ activities compared with other physical activities, as these activities are likely to occur as part of planned exercise. Furthermore, compared with aerobic activity, there are comparatively fewer incidental activities that can be specifically considered ‘muscle and bone strengthening’.

It is likely that social desirability bias might be a problem for assessing RT participation in intervention studies, particularly if this is the mode of exercise being encouraged by researchers and/or teachers within their programs. Objective measures that can accurately assess participation in non-ambulatory activities such as RT, may help to address the limitations of self-report measures. Recently, next generation activity monitors that integrate accelerometer data with data from other sensors (i.e., galvanic skin response, skin temperature, and heat flux) have emerged (597, 598). Although further validation of these devices will be required, they may be more effective at assessing the complete spectrum of physical activity, including 'muscle and bone strengthening' activities such as RT. Future research targeting youth participation in RT should recognise and aim to address the current limitations of physical activity measurement for this type of activity.

Another measurement limitation with implications for future research is poor compliance with accelerometer protocols. Previous research has shown that providing incentives contingent on the provision of valid data, and keeping a physical activity log are effective strategies for improving compliance with accelerometry among high school-aged students (575). In ATLAS, students were offered a $10 gift voucher at each assessment period, provided they complied with physical activity monitoring protocols (i.e., ≥ 4 days with at least 10 hours of valid wear time). Further, students were provided with a physical activity log sheet and were instructed to complete the log each day. However, these strategies did not appear to significantly improve compliance, highlighting the challenges of physical activity assessment among this population. Anecdotal evidence suggests that adolescents did not like wearing the waist-worn accelerometers, due to discomfort and disapproval from peers. Wrist worn accelerometers may be more acceptable to adolescents, as they may be more comfortable and are potentially more discreet due to their 'watch-'or 'bracelet-like' appearance. Considering the recent increase in access to wearable personal activity monitors (e.g., Fitbit, Jawbone UP, Nike+ Fuelband and Polar Loop) (599), there is scope for researchers to test the validity of such devices. Although the validity of physical activity monitoring devices should remain a priority, consideration should also be given to the acceptability of these devices among study participants, as this may maximise compliance and minimise bias resulting from missing data.

9.3.3.3 Delivery of resistance training within schools

Importantly, the ATLAS study demonstrated that a feasible, and potentially scalable and sustainable school-based program can elicit significant improvements in adolescent boys' RT movement skill competency and muscular fitness. Furthermore, statistical mediation analysis showed that improvements in body fat and muscular fitness were partially mediated by improvements in RT skill competency. This study provides evidence that movement skill development is an effective strategy for improving muscular fitness and body composition. This program was delivered by teachers using existing school facilities and a relatively inexpensive equipment pack. Considering extensive evidence of the benefits of muscular fitness for school-aged youth (3, 13), there is a strong rationale for the delivery of muscle strengthening physical activities within the school setting. This argument is further bolstered by the inclusion of ‘muscle and bone strengthening’ physical activities within current Australian (89) and international (108) physical activity guidelines for youth.

No adverse events or injuries were reported during the school sport sessions. Therefore, consistent with previous evidence (40), RT can be considered safe for young adolescents. According to a recent international position statement on youth RT, this type of exercise should only be delivered by appropriately qualified personnel (i.e., those with a recognised strength and conditioning accreditation) (37). PE teachers conduct routine fitness testing within schools and are also likely to have had a background in the delivery of health-related fitness activities through both their undergraduate training and professional experience. This study demonstrates that, with a small amount of professional learning, teachers can safely and effectively deliver RT in the school setting. This finding provides support for the argument that schools should provide opportunities for their students to engage in ‘muscle and bone strengthening’ physical activities. Although it is not recommended that PE teachers deliver heavy ‘free-weight’ RT activities (e.g., power lifting) without an appropriate qualification, these teachers should be able to deliver low-risk body-weight/ elastic tubing RT to students, assuming they are provided with appropriate professional learning to inform them of the key safety and technique considerations. Furthermore, as demonstrated by the findings of the mediation analysis, a focus on RT movement skill development may be an effective approach for improving muscular fitness and body composition within school-based RT programs. Therefore, teachers should provide adequate instruction on RT movement skills, and provide appropriate feedback on students’ performances. The RTSB may be a useful instrument to support this objective within practical settings.

9.3.4 Process evaluation

9.3.4.1 Overview of findings

Process data from the ATLAS cluster RCT were presented in Chapters 6 and 7. School and student recruitment goals were met prior to the commencement of the intervention. At eight-month post-test, 154 (86%) control group and 139 (77%) intervention group boys completed assessments, representing an overall retention rate of 81%. Of the 68 boys lost to follow-up, 26 (38%) had transferred schools. On average, schools delivered 79% ± 15% of intended school sport sessions and 64% ± 40% of the intended lunch-time sessions. Common reasons for failing to deliver the school sport sessions included conflict with school sporting carnivals and exams, and inclement weather. As suggested by the larger standard deviation, there was greater heterogeneity between schools for the delivery of the lunch-time sessions. Implementation fidelity was assessed through four sport session observations at each school. Adherence to the proposed session structure improved over the course of the intervention. At the beginning of the program, boys were informed that they were expected to attend at least 70% of the school sport sessions and at least two-thirds of the lunch-time sessions that were delivered. At the conclusion of the program, 65% and 44% of boys had attended a satisfactory number of school sport and lunch-time sessions, respectively. Responses to the post-program evaluation questionnaire indicated that boys highly enjoyed the ATLAS program overall and the school sport sessions, whereas satisfaction with the lunch-time sessions was moderate. Teacher satisfaction with the intervention overall was high and teachers reported enjoying both the pre- and mid-program professional learning workshops. Finally, all teachers either 'agreed' or 'strongly agreed' that their students benefited from participating in the program.

9.3.4.2 Smartphone app process evaluation

An investigation of the development and implementation of the ATLAS smartphone app was presented in Chapter 7 (536). Approximately 70% of boys reported owning a smartphone or similar device capable of downloading and running applications (e.g., iPod touch). Unfortunately, due to technical limitations stemming from the design of the ATLAS app, objective usage data was not collected. Consequently, the process data regarding app usage is based on self-report. Close to two thirds of study participants reported using the app on either the Apple or Android platforms. Usage of the different functions of the app varied; with the highest proportion of usage found for the goal-setting function (70%) and the lowest found for monitoring of pedometer steps and fitness challenge results (49% for both). Approximately one in five boys did not engage with the app at all. Satisfaction with the app was moderate with 44% of boys 'agreeing' or 'strongly agreeing' that the app was enjoyable to use. Focus group findings suggested that boys typically did not engage extensively with the app component of the program.

9.3.5 Strengths and limitations

A strength of the present study was the use of an eligibility screening questionnaire to identify and target adolescents 'at risk' of obesity and related comorbidities. Although screening students on the basis of BMI or weight status may be the most direct method for assessing obesity risk, this approach has the potential to lead to the stigmatisation of overweight and obese youth. Therefore, this is not an appropriate screening method for school-based intervention research. In the ATLAS study, all male students in the targeted year group at the study schools completed a brief two-item eligibility screening questionnaire to assess their adherence to current youth physical activity and screen-time guidelines (89). Boys failing to meet current recommendations for physical activity or recreational screen-time were invited to participate. Although most students were considered eligible using this method, the recruited sample showed a baseline overweight/obesity prevalence of 36%, which is considerably higher than the population prevalence for low-SES boys of the same age (121). Therefore, this approach does appear to have been successful for recruiting an 'at risk' study sample.

Another clear strength of ATLAS was the extensive process evaluation. Waters and colleagues have recommended that, to enable translation of successful trials, future youth obesity prevention programs should collect process data; including data on appropriateness, implementation, feasibility, acceptability, and potential harms (26). A template for reporting adverse events was provided to teachers in the program handbook, and no adverse events or injuries were recorded over the duration of the intervention or during the assessments. Chapters 5 and 6 presented the findings of the process evaluation, which included data on feasibility (i.e., achievement of school/student recruitment goals), implementation (i.e., number of intended sessions conducted and compliance with the proposed session structure), and acceptability (i.e., participant retention, attendance at sessions, and teacher and student satisfaction). This extensive process evaluation provides additional insight into the potential for this trial to be disseminated more broadly, and recognises the need for data on 'external validity' to be reported in efficacy trials (26, 600, 601) .

In addition to a high overall retention rate, an important finding from the ATLAS study was the high retention of overweight/obese boys. Concerns have been raised previously that school-based interventions may be less effective for the most 'at risk' youth (67), and past studies (including PALs) have shown significantly higher BMI's among study drop-outs compared with completers (267, 542, 602). Although not statistically significant, drop-outs in the ATLAS study tended to have a lower BMI than boys retained in the program. This finding may reflect the suitability of our participant recruitment procedure and/or the appropriateness of the selected physical activities for overweight youth (i.e., RT). Significant differences in key variables between completers and drop-outs were only found for physical activity. Study drop-outs demonstrated significantly higher baseline physical activity levels compared with completers, further supporting that ATLAS was successful in retaining the most 'at risk' boys.

Limitations regarding the process evaluation were the lack of objective usage data for the smartphone component and the lack of an economic evaluation of the intervention. For the former, objective data would have enabled a better assessment of the ways in which boys engaged with the app and of which functions were most commonly utilised. For the latter, a cost-effectiveness analysis would provide further evidence on the potential of the intervention to be disseminated more broadly. However, it should be noted that the primary intervention component (i.e., the face-to-face activity sessions) were delivered by teachers during school hours. As this comprised part of the teachers' normal duties, no additional cost was associated with this component of the program. Consequently, ATLAS has the potential to be cost effective. However, it is acknowledged that data to support this claim are not available and other associated costs (e.g., equipment, resources, and the app development) need to be taken into account.

9.3.6 Implications for research and practice

The identification and targeting of 'at risk' youth is an important consideration within school-based intervention research. Indeed, it has previously been recommended that school-based interventions be evaluated among those most 'at risk' (469, 470). As previous school-based approaches, particularly whole-school approaches, may have been less successful for the most 'at risk' students (28, 603), there is a need for strategies to ensure that students most in need of intervention are being appropriately targeted. A previous school-based trial targeting male adolescents used aerobic fitness test scores (i.e., from the multi-stage fitness test) to identify eligible participants (36). Using this approach, the study recruited a sample with a large baseline prevalence of combined overweight/obesity (i.e., 48%) (36). Considering the influence of fat-mass on performance in the multi-stage fitness test (340), it is not surprising the eligible study sample included such a high proportion of overweight and obese boys. However, it is noteworthy that many initially healthy weight adolescents will become overweight in later life (604), due largely to weight-related behaviours (e.g., increased screen-time and SSB consumption) that may become increasingly entrenched as youth get older (104). For example, in a longitudinal study of Canadians aged 7-18 years at baseline, it was found that 85% of adults classified as overweight or obese had been a healthy weight during their youth (104). For obesity specifically, 70% of the obese adults had been a healthy weight during their youth (104). As these data suggest, youth weight status is only one risk factor for future obesity. Consequently, there is a rationale for identifying 'at risk' youth on the basis of behavioural risk factors (e.g., physical activity and screen-time). The eligibility screening method used in ATLAS was aligned with current physical activity and screen-time recommendations and was relatively easy to administer, taking approximately 10 minutes to explain and complete. Therefore, it can be considered a feasible approach for use in future research.

Importantly, this approach may be less likely to result in weight stigmatisation compared with screening methods using weight-status or student fitness test results as criteria for inclusion.

The feasibility of disseminating multi-component interventions more broadly is an important, yet often overlooked, aspect of intervention design (600). Indeed, it could be argued that highly efficacious programs are of little value to population health if they demonstrate a limited capacity for more widespread implementation. Therefore, while efficacy testing remains an essential part of the research process, the potential for translation should be considered paramount in the design of school-based interventions (600). Furthermore, it has been argued that external validity should be measured alongside efficacy regardless of the trial's primary aim (i.e., efficacy or effectiveness) (600, 601). The ATLAS intervention has identified a promising approach for the delivery of evidence-based physical activity programs in schools. The school sport period was selected on the basis of feasibility, sustainability, and the potential for research translation. For example, New South Wales (NSW) public secondary schools are mandated by the state education authority to provide 80-120 minutes of planned physical activity each week. Therefore, schools must allocate time for physical activity, in addition to that occurring as part of the PE curriculum. The delivery of school sport is part of the existing role of teachers. Moreover, students are both available and expected to participate in physical activity during this regularly scheduled period. Consequently, there is scope for schools state-wide to adopt and deliver efficacious physical activity programs during this allocated period, as there would likely be minimal disruption to normal routines and staffing arrangements. Furthermore, programs could be adopted long-term and be delivered routinely within schools as a regular activity option for students. Importantly, it has previously been identified that unsustainable and resource intensive interventions need to be replaced with interventions that are embedded within existing practice and operating systems (26). The ATLAS intervention represents an attempt to address this need.

Importantly, relative to traditional RT delivered in a gym or other dedicated training area, the ATLAS program requires minimal space and equipment, and can therefore be implemented relatively easily, assuming teachers have the requisite knowledge and skills to program and confidently supervise the RT sessions. In NSW, all public school teachers are required to participate in ongoing professional learning as part of a mandated professional accreditation process. The ATLAS professional learning days were endorsed by the organisation responsible for overseeing this accreditation process (i.e., the NSW Institute of Teachers). Therefore, in addition to training teachers in the safe and effective delivery of the ATLAS program, the professional learning component also fulfils a need of schools and teachers to complete such training. Finding ways to complement existing routines, and offering tangible incentives to schools and teachers may assist in the uptake of evidence-based physical activity programs. Indeed, the provision of professional learning opportunities for teachers was a key recommendation for future research within the most recent Cochrane review of youth obesity prevention interventions (26).

In Australian public schools, sport is often delivered on a term-by-term basis (i.e., approximately every 10 weeks). Consequently, students often participate in one term of school sport before being offered a new sport choice for the following school term. The ATLAS program ran for two school terms (i.e., 20 weeks). Feedback from teachers indicated that boys withdrawing from the program often wanted to try a new sport option in the second school term with friends that were not participating in ATLAS. Considering the effectiveness of the 10-week PALs pilot study (67, 69), and feedback that study drop-outs wanted to try a new sport option in the second half of the ATLAS study, it may be that the current intervention program would work best in a 10-week format (i.e., one school term). This may be the most feasible approach for future implementation, as a 10-week program would be consistent with the expectations of students and the current organisation of school sport in many public secondary schools. Additional evaluation of a shortened version of ATLAS would be required to determine whether the significant effects found in the 20-week trial can be replicated, or whether there are any differential effects for other outcomes. Furthermore, the identified limitations of the current study should be addressed in any future trial.

9.4 Muscular fitness and RT skill competency among school-aged youth

The following section corresponds to Chapters 3 and 4 of this thesis and encompasses *Secondary aims 1 and 2*.

9.4.1 Systematic review of the benefits of muscular fitness for children and adolescents

9.4.1.1 Overview of findings

In Chapter 2, it was identified that a comprehensive and systematic evaluation of the associations between muscular fitness and health outcomes among children and adolescents has not yet been conducted. To address this gap, Chapter 3 presented the findings of a systematic review and meta-analysis of studies examining these associations (541) (*Secondary aim 1*). Strong evidence was found for an association in the expected direction between muscular fitness and adiposity, cardiovascular disease risk, self-esteem, and bone health. The evidence for an association between muscular fitness and musculoskeletal pain and cognitive ability was found to be inconsistent/uncertain. As demonstrated by the pooled effect sizes for adiposity (i.e., $r = .25$) and self-esteem (i.e., $r = .39$), the associations were generally low-to-moderate in magnitude.

9.4.2 Strengths and limitations

There were a number of strengths of this systematic review. First, the comprehensive literature search was designed to capture cross-sectional, longitudinal and experimental studies examining the range of potential benefits of muscular fitness. Of the previous reviews that have been published on this topic, one was a narrative review (3), and the other only included prospective studies examining the associations between fitness and cardiovascular and metabolic health outcomes (13). Furthermore, both of these studies focused on health-related fitness more broadly rather than muscular fitness specifically (3, 13). Although prospective studies can provide better evidence on the associations between muscular fitness and health outcomes, it is important to review cross-sectional evidence as these studies may help to generate hypotheses and direct future research (132). There were a large number of studies included within the current review, covering a range of potential health benefits. Furthermore, risk of bias was acknowledged in the quantitative synthesis, strengthening the credibility of review findings. Finally, the included meta-analyses tested for the effects of publication bias, and the pooled effect sizes were adjusted using Duval and Tweedie's *trim and fill* procedure (313). Despite clear evidence of its existence, many authors fail to address publication bias in systematic reviews (605). Although the *trim and fill* method is not without its criticisms (606), the adjustment of the effect sizes using this method did not materially alter the study findings. Further, it can be considered prudent to present a conservative estimate of the pooled effect rather than to potentially overestimate the effect in cases where publication bias is suspected.

Despite the clear strengths of the present study, there were some limitations. The breadth of outcomes examined by this review prevented a more detailed investigation of the moderators of the observed associations. For example, included studies sometimes reported associations separately by age group or sex. Although the moderating effect of age and sex may be of interest to researchers and paediatric health professionals, this was beyond the scope of the present review. Another limitation of the current study was the lack of investigation into the injury prevention benefits of muscular fitness for youth populations. Although this outcome is of obvious importance from a population health perspective, the review was deigned to be generalisable to the wider youth population. Consequently, studies of young athletes were excluded during the screening process. The injury prevention benefits of RT have previously been reviewed in detail (40), and there is good evidence to suggest that this method of training can reduce the risk of sports-related injuries. However, it is acknowledged that the influence of muscular fitness on injury risk, outside of other neuromuscular changes occurring through RT participation (e.g., improvements in balance or movement biomechanics), remains unclear.

Finally, it should be noted the findings presented in the systematic review represent the pooling of results from studies using a variety of different muscular fitness tests, which may measure different components of muscular fitness (i.e., maximal strength, power, and local muscular endurance). In the present review, findings from the most valid muscular fitness tests were prioritised in studies where the results of multiple tests were reported. However, it is likely the association between muscular fitness and health markers may differ depending on the muscular fitness test/component being examined (607). There is relatively little research investigating the criterion validity of commonly used muscular fitness tests, and a lack of consensus on the most appropriate criterion measures for each muscular fitness component (607). Therefore, there is scope for future research to further investigate the associations between specific muscular fitness tests/components and health outcomes among youth populations.

9.4.3 Implications for research and practice

This review identified a number of limitations of the field, which should be addressed by future research. An important finding was that there are few longitudinal and experimental studies that have examined the associations between muscular fitness and health among youth. For example, of the 110 studies included in this review only 20 (18%) and 4 (4%) studies used longitudinal and experimental study designs, respectively. Consequently, there was little causal evidence available for many of the associations being examined. This was more of a problem for certain health outcomes than others. For example, there was sufficient evidence to support a causal association between muscular fitness and adiposity, as reported by an earlier review (13). Further, the present review supports a causal association between muscular fitness and CVD risk factors. Conversely, apart from one small intervention study, there were no longitudinal or experimental studies investigating the link between muscular fitness and psychological and cognitive health outcomes. As a result, the causal links between muscular fitness and these outcomes remain speculative. There is a clear need for more high quality longitudinal and experimental research to further elucidate the potential causal associations between muscular fitness and the health outcomes included in this review, particularly for psychological and cognitive health outcomes. Indeed, further longitudinal and experimental evidence was recommended within a recently published paper titled ‘Top 10 research questions related to musculoskeletal fitness testing in children and adolescents’ (607).

In addition to the lack of causal evidence, few studies provided standardised coefficients (e.g., regression or correlation coefficients), preventing more comprehensive meta-analyses of the associations being examined. Future studies exploring these associations are encouraged to report standardised coefficients to allow simpler comparisons between studies, and to enable more thorough meta-analyses of the association between muscular fitness and health benefits. Furthermore, there is a need for intervention studies targeting improvements in muscular fitness and other health outcomes, to examine the mechanisms of change within their studies. These interventions typically report time and group effects, but rarely examine the associations between changes in muscular fitness and changes in other study outcomes. Considering that experimental evidence can provide the strongest support for these associations, there is a rationale for ancillary analyses to be included within future experimental research on this topic.

Perhaps the most significant implication of this systematic review is that it provides strong support for the inclusion of muscle strengthening physical activities within youth physical activity and fitness programs. Based on the evidence presented, the recent inclusion of ‘muscle and bone strengthening’ activities within youth physical activity guidelines (89) is justified. Importantly, this review presented emerging evidence suggesting that the beneficial effects of muscular fitness may be independent of CRF. This finding has clear implications for practice, as it suggests that youth would benefit most from participation in a range of physical activities that improve both cardiorespiratory and muscular fitness. Specifically, there may be significant risk reductions for clustered metabolic risk through participation in both aerobic and muscle strengthening physical activities, particularly for those with initially low levels of fitness (53). Considering the staggering rise in inactivity-related chronic disease observed in recent decades (608), youth participation in physical activities that improve both cardiorespiratory and muscular fitness may produce substantial future population health benefits. Therefore, practitioners should endorse and deliver a range of physical activities that target multiple health-related fitness components.

9.4.4 Development and evaluation of the Resistance Training Skills Battery for adolescents

9.4.4.1 Overview of findings

Chapter 4 described the development and evaluation of the Resistance Training Skills Battery (RTSB) (8) (*Secondary aim 2*), a process-based instrument designed to evaluate adolescents’ proficiency in six core RT movements (i.e., squat, lunge, push-up, overhead press, front support with chest touches, and suspended row). The RTSB was developed in consultation with practising experts in the fields of movement skill development and paediatric RT. These experts considered the RTSB to be a safe, developmentally appropriate, and feasible assessment tool for use in both research and applied settings. Following the instrument development phase, the construct validity and test-retest reliability of the RTSB was evaluated among a convenience sample of adolescent boys and girls in grades 7-10 from one secondary school in NSW, Australia. The test-retest reliability analysis demonstrated that the RTSB can be used reliably to rank adolescents on their overall RT skill competency. Furthermore, it was determined the instrument has the necessary sensitivity to detect small but meaningful changes in RT movement skills. Finally, as the combined skill score (i.e., the RTSQ), was found to be an independent predictor of muscular fitness, the RTSB was considered to demonstrate acceptable construct validity.

9.4.5 Strengths and limitations

A strength of this study was the consultation with experts during the development phase of the RTSB. These experts provided valuable feedback, which aided in the refinement of the final instrument. The recognition of a need for such a testing battery, and expert acceptance of the final version of the RTSB, provides strong support for face validity. A second strength was the use of a single research assistant to conduct the video analysis during the reliability testing phase of the study. Although the inter-rater reliability of the RTSB has since been demonstrated (9), the use of a single rater limited the potential for systematic measurement bias arising from inter-rater variation. Although the methods utilised in this study are sound, it should be noted the convenience sample used to test the reliability and construct validity of the RTSB was small and rather homogenous, and is therefore not representative of the wider adolescent population. Consequently, further testing of the instrument among different adolescent populations may be required. Analysis of the reliability of the RTSB among different populations of assessors (e.g., PE teachers) is also warranted.

9.4.6 Implications for research and practice

The findings presented in Chapter 4 suggest that the RTSB can be used reliably to rank adolescents based on their overall RT movement skill competency. Further, the RTSB was found to have sufficient sensitivity to detect small but meaningful changes in RT skills. Therefore, this instrument can be considered useful for the assessment of movement skill competency in school- and community-based RT programs. This instrument may have utility for use in both research and applied settings, and could be used for a number of purposes. For example, the RTSB could be used to: (i) diagnose youth with poor movement competence; (ii) provide important process-based feedback to novice trainers; and (iii) evaluate the effects of youth RT programs or interventions on movement skill competency. Considering the mediating effects of RT skill competency found in the ATLAS study (assessed using this instrument), there is support for the use of the RTSB among practitioners to further promote a focus on the development of movement skills. The development of RT movement skill competency during adolescence may enable lifelong participation in this health-enhancing activity.

9.5 Concluding remarks

The health inequities prevalent within low-income communities require targeted intervention strategies. However, there is considerable difficulty in engaging ‘at risk’ youth within these areas. Targeting the school setting is an attractive and potentially effective strategy, but evidence of the effectiveness of school-based interventions for improving adolescent health outcomes remains inconsistent. Designing interventions to suit the needs and preferences of specific groups (e.g., males or females) may be an effective strategy to enhance intervention effects, and delivering health-enhancing RT activities to adolescent males represents one such approach. However, there is currently little empirical evidence evaluating the effectiveness of targeted single-sex programs. Therefore, further testing among adolescent populations is needed. This thesis has identified an efficacious, feasible, and potentially sustainable approach to improving muscular fitness, movement skills and key weight-related behaviours among low-income adolescent males within the school setting. However, consistent with prior research, this thesis has reinforced the challenges of addressing youth obesity. Valuable lessons continue to be learnt through the delivery of high quality intervention trials. With continued research, the most efficacious and sustainable approaches to improving adolescent health and wellbeing may be elucidated, and the desired impacts on population health then realised.

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APPENDICES

Appendix 1: Ethics approval (University of Newcastle)

HUMAN RESEARCH ETHICS COMMITTEE

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Notification of Expedited Approval

To Chief Investigator or Project Supervisor:	**Associate Professor David Lubans**
Cc Co-investigators / Research Students:	**Professor Philip Morgan** **Professor Ronald Plotnikoff** **Doctor Kerry Dally** **Mr Jordan Smith**
Re Protocol:	**Increasing physical activity and improving social and emotional wellbeing in adolescent boys**
Date:	**04-Jul-2012**
Reference No:	**H-2012-0162**
Date of Initial Approval:	**03-Jul-2012**

Thank you for your **Response to Conditional Approval** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under **Expedited** review by the Chair/Deputy Chair.

I am pleased to advise that the decision on your submission is **Approved** effective **03-Jul-2012**.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. *If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.*

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request. Your approval number is **H-2012-0162**.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants You may then proceed with the research.

Conditions of Approval

This approval has been granted subject to you complying with the requirements for *Monitoring of Progress*, *Reporting of Adverse Events*, and *Variations to the Approved Protocol* as detailed below.

PLEASE NOTE:
In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.

- ***Monitoring of Progress***

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

- ***Reporting of Adverse Events***

1. It is the responsibility of the person **first named on this Approval Advice** to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
    - Causing death, life threatening or serious disability.
    - Causing or prolonging hospitalisation.
    - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
    - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
    - Any other event which might affect the continued ethical acceptability of the project.
5. Reports of adverse events must include:
    - Participant's study identification number;
    - date of birth;
    - date of entry into the study;
    - treatment arm (if applicable);
    - date of event;
    - details of event;
    - the investigator's opinion as to whether the event is related to the research procedures; and
    - action taken in response to the event.
6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- ***Variations to approved protocol***

If you wish to change, or deviate from, the approved protocol, you will need to submit an *Application for Variation to Approved Human Research.* Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. **Variations must be approved by the (HREC) before they are implemented** except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

Best wishes for a successful project.

Professor Allyson Holbrook
Chair, Human Research Ethics Committee

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Human Research Ethics Administration

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Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref

Appendix 2: Ethics approval (Department of Education and Communities)

NSW GOVERNMENT | Education & Communities

Assistant Professor David Lubans
Faculty of Education & Arts School of Education
University Drive
CALLAGHAN NSW 2308

DOC 12/321041

Dear Assistant Professor Lubans

SERAP Number **2012121**

I refer to your application to conduct a research project in New South Wales government schools entitled *Increasing physical activity and improving social and emotional well-being in adolescent boys*. I am pleased to inform you that your application has been approved. You may now contact the Principals of the nominated schools to seek their participation. **You should include a copy of this letter with the documents you send to schools.**

This approval will remain valid until 04/07/2013.

The following researchers or research assistants have fulfilled the Working with Children screening requirements to interact with or observe children for the purposes of this research for the period indicated:

Name	Approval expires
David Revalds Lubans	08/06/2013
Jordan james paul Smith	20/04/2013
Sarah Anne Costigan	19/04/2013
Tara louise Finn	19/06/2013
Lee Ann Upton	05/04/2013

I draw your attention to the following requirements for all researchers in New South Wales government schools:

- School Principals have the right to withdraw the school from the study at any time. The approval of the Principal for the specific method of gathering information for the school must also be sought.
- The privacy of the school and the students is to be protected.
- The participation of teachers and students must be voluntary and must be at the school's convenience.
- Any proposal to publish the outcomes of the study should be discussed with the Research Approvals Officer before publication proceeds.

When your study is completed please forward your report marked to Manager, Schooling Research, Department of Education and Training, Locked Bag 53, Darlinghurst, NSW 2010.

You may also be asked to present on the findings of your research.

Yours sincerely

Bill Tomlin
Acting Senior Manager
Student Engagement and Program Evaluation
6 September 2012

Student Engagement and Program Evaluation Bureau NSW Department of Education and Communities
Level 3, 1 Oxford Street, Darlinghurst NSW 2010 – Locked Bag 53, Darlinghurst NSW 1300 Telephone: 02 9244 5619– Fax: 02 9266 8233 – Email: serap@det.nsw.edu.au

Appendix 3: Parent/ student information and consent form

A/Prof David Lubans
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Faculty of Education and Arts
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Email:

Research Project: Increasing physical activity and improving social and emotional wellbeing in adolescent boys

STUDENT & PARENT INFORMATION STATEMENT

Dear student and parent,

Your school is invited to participate in the research project identified above which is being conducted by A/Prof David Lubans, Prof Philip Morgan, Prof Ron Plotnikoff, Dr Kerry Dally and Mr Jordan Smith from the University of Newcastle. This research is funded through the Australian Research Council. This project is part of the research studies of Mr Jordan Smith who is supervised by A/Prof David Lubans, Prof Philip Morgan, Prof Ron Plotnikoff.

Why is this research being done?

Physical activity declines sharply during adolescence and data from the 2010 NSW Schools Physical Activity and Nutrition Survey revealed that 40% of adolescents are not accumulating sufficient activity to accrue the associated health benefits. Physical activity is important for adolescents' physical, social and emotional well-being. The aim of this study is to evaluate the impact of a school-based program to increase physical activity and improve psychological wellbeing among adolescent boys.

Who can participate in this research?

Male students in grade 7 (1st year of secondary school) at your child's school who have been identified as eligible through a screening questionnaire, will be eligible to participate in this study. We aim to recruit 24 students from each school. Parents will be invited to participate in the program by supporting behavioural messages at home.

What choice do you have?

The school principal has agreed to your school being involved in the study. However participation in the study is entirely you and your parent's choice. If you agree to participate you can choose to withdraw from the study at any time and will be free to discontinue participation in the assessments at any time. If you choose to withdraw from the program, you will be provided with alternative physical activity during normal school sport lesson time. A decision not to participate or discontinuation of involvement in the study will not jeopardise your relationship with the University of Newcastle or the school. Withdrawal from this task will not result in any disciplinary action, nor will it affect your academic grades, given that this is a purely voluntary research task.

What is involved in this study?

Schools who agree to participate will be ***randomly allocated*** to either a study program recipient group or a wait list control group. Schools allocated to the wait list control will not receive the study program during the study period. However, program materials will be made available to these schools following completion of the study. Consenting students will participate in a physical activity program, which will be based at school. The program will run for two full school terms (terms 1 and 2, 2013) and will aim to improve the physical activity behaviours and psychological wellbeing of participants. Students in **BOTH** groups will complete evaluation measures on three occasions during the study period (baseline, 9-months and 18-months). Students who do not consent to participate will not be involved in any component of the study. The program components and evaluation measures are listed below in Table 1.

Table 1: Program components and evaluation strategies

Program components ***(Wait list control schools will receive the program components in 2014).***	***Evaluation of program*** ***(Measures will be completed by all participants in BOTH program recipient schools and wait-list control schools).***
i) Interactive seminars: Boys will attend interactive seminars delivered by members of the research team. Interactive seminars will address key physical activity and nutrition behaviours and leadership principles. **ii) Enhanced school sport sessions:** School Sport sessions will be delivered by teachers and involve an information component (10-15 minutes) and a physical activity session (75-80 minutes). The information component will include physical activity and nutrition recommendations. Teacher-directed physical activity sessions will include resistance training using elastic tubing devices, boxing style fitness activities and small team games. **iii) Lunch-time physical activity sessions:** Boys will participate in self-directed physical activity sessions involving elastic tubing resistance training. Sessions will be supervised by teachers but organised and run by boys. Boys will be required to recruit and instruct Grade 7 students on how to safely use the elastic tubing resistance training devices. **iv) Physical activity and nutrition handbooks:** Boys will be provided with physical activity and nutrition handbooks. Handbooks will include information and home challenges designed to promote physical activity and healthy eating for parents and boys **v) Parental strategies to reduce sedentary behaviours:** Parents and boys will be provided with a variety of strategies to reduce adolescents' screen time. For example, identifying alternatives to screen behaviours, monitoring of screen behaviour, enforcement of screen time rules and implementation of home challenges to reduce screen time. **vi) On-going professional support**: Members of the research team will observe three school sport sessions at each school over the study period and provide feedback and on-going professional development for teachers.	The following measures will be taken 3 times (baseline, 9-months and 18-months): • *Body composition and health-related fitness:* height, weight, waist circumference will be measured and body fat percentage will be assessed using bioelectrical impedance. Muscular fitness will be assessed using a hand grip dynamometer, sit up test and push-up test. • *Subjective well-being and self-esteem:* well-being will be measured using questionnaires. • *Physical activity:* will be measured over a seven day period using accelerometers. • *Resistance training skill proficiency:* will be assessed by video analysis of the performance of 6 key movements (squat, shoulder press, front support with chest touches, push up, lunge and suspended row). • *Screen time, sleep time and sleepiness:* will be measured using brief questionnaires. • *Dietary behaviours:* key dietary behaviours will be assessed using a nutrition behaviour questionnaire. • *Beliefs about physical activity and screen time:* students' beliefs about physical activity and screen time will be assessed using a questionnaire.

What are the risks and benefits of participating?

The evaluation measures will be carried out by trained research assistants. The enhanced school sport sessions will be developed by the research team and delivered by a suitable member of the school's teaching staff. Based on previous studies, students will have no greater chance of injury by participating in these programs in comparison to other sports and physical activities. In the event of an injury occurring, the student will immediately be asked to stop participation, and normal school procedures for the management of injury will be followed. The student will not return to participation in the program's physical activities until clearance has been received from a suitable practitioner. The program will provide students with an opportunity to increase their knowledge and skills and improve attitudes toward physical activity and nutrition. Students will also benefit from participation in a variety of enjoyable exercise activities and as part of the program's delivery. If your involvement in completing any of the surveys or activities in the program make you feel uncomfortable or cause you distress then you can contact the researchers (contact details at the end of this letter) and you will be able to discuss your concerns confidentially.

How will the information collected be used?

The data collected from this study will be used for journal publications and conference presentations and to inform future practice for the design of valuable, evidence-based school sport programs.

How will privacy be protected?

Any personal information provided by students and parents will be confidential to the researchers. The results of the study will be published in general terms and will not allow the identification of individual students or schools. Once the data has been collected, de-identified using participant codes and entered into an electronic data file, questionnaires and other data collection sheets will be destroyed. Video footage of the resistance training skill tests will be de-identified using participant codes. Participants will be given the opportunity to view their footage and have it deleted upon request. The electronic data files will be retained for at least 5 years but no individual will be identifiable in the data files or published reports.

What do you need to do to participate?

If you are willing to participate in this study, you and your parent(s) will need to complete the accompanying consent forms (Parent and Student) and return them to the school's office or your roll-class teacher as soon as possible.

Further information

Following the completion of the study, the school will be sent a report describing the findings of the study. Results will also be sent via post to study participants and their parents. Individual results will not be given to students. If you would like further information please do not hesitate to contact A/Prof David Lubans. Thank you for considering this invitation.

A/Prof David Lubans	Mr Jordan Smith
Faculty of Education & Arts School of Education University of Newcastle Phone: (02) 4921 2049 David.Lubans@newcastle.edu.au	Faculty of Education & Arts School of Education University of Newcastle Phone: (02) 4921 6299 jordan.smith@uon.edu.au

This project has been approved by the University's and NSW DET Ethics committees, Approval numbers H-2012-0162 SERAP 2012121. Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

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Research Project: Increasing physical activity and improving social and emotional wellbeing in adolescent boys

PARENT CONSENT FORM

Chief Investigators: A/Prof David Lubans, Prof Philip Morgan, Prof Ron Plotnikoff, Dr Kerry Dally and Mr Jordan Smith

I have been given information about the project identified above and have discussed it with my child. We understand that if I consent to my child's involvement, he/she will participate in the study entitled: *Increasing physical activity and improving social and emotional wellbeing in adolescent boys.* We understand that my child's school will be randomly allocated to one of two interventions:

(i) *The study program recipient group:* where student participants will receive a 6-month physical activity program.

OR

(ii) *The wait-list control group:* where student participants will not receive the physical activity program during the study period. However, program materials will be made available following the study's completion.

We understand that my child will complete the following program evaluation measures: weight, height, body composition and waist circumference, physical activity, screen time and dietary behaviours, self-esteem and subjective wellbeing, sleep time and daytime sleepiness, muscular fitness and cardiovascular fitness and video analysis of resistance training skill proficiency.

We have had an opportunity to ask A/Prof Lubans questions about the research. I have discussed this project with my child and we understand that their participation in this research is voluntary and that he/she is free to withdraw from the research project at any time. His/her refusal to participate or withdrawal of consent will not affect his/her relationship with the University of Newcastle or the school. Withdrawal from this task will not result in any disciplinary action against my child, nor will it affect his/her academic grades, given that this is a purely voluntary research task.

Please discuss the project together and ensure that you are both happy to participate before signing the consent form. By signing below I am indicating consent for my child to participate in this research project conducted by A/Prof David Lubans, as it has been described to us in the Information Statement, a copy of which I have retained.

Student name: ____

Parent/guardian name: ____

Signature: ______________________________ **Date:** _______________________

Child's signature: ________________________ **Date:** _______________________

Child's mobile number (if applicable): _________________________ (this will be used to send a reminder to wear the physical activity monitoring device).

For the receipt of monthly newsletters providing updated information about the program your child has been participating in, please provide your contact details:

Postal address: ____

Email address: __________________________________ **Phone:** _______________________

Please sign the completed consent letter and return to the school's office or your child's roll call teacher

This project has been approved by the University's and NSW DET Ethics committees, Approval numbers H-2012-0162 SERAP 2012121. Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

Appendix 4: Student eligibility screening questionnaire

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Project Title: *ATLAS Project*

Eligibility Screening Questionnaire

Student Name: ______________________________

School: _____________________________________

ID: _______________________

To protect your privacy this cover sheet will be removed and destroyed once you have been allocated a study number.

PARTICIPANT SCREENING QUESTIONNAIRE:

Please answer the following questions as honestly as possible by circling **one response** per question.

1) During a **typical school day** how much time do you spend watching TV or DVDs, playing video games or using the computer for entertainment?

Less than 2 hours per day **Approx 2 hours per day** **More than 2 hours per day**

2) Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. **Physical activity** can be done in sports, playing with friends, or walking to school. Some examples of **physical activity** are running, brisk walking, rollerblading, biking, dancing, skateboarding, swimming, soccer, basketball, football and surfing.

Add up all the time you spend in physical activity each day (don't include your PE class).

Over a typical or usual week, on how many days are you physically active for a total of at least 1 hour? (Circle one response)

0 days **1** **2** **3** **4** **5** **6** **7 days**

Appendix 5: Anthropometric and fitness measures recording sheet

Assessment Recording Sheet

Assessment (circle): **Baseline** **9 months** **18 months**

Date: ______________ School: ______________________________________

Name: ____ ID: __________

Mobile No. ___________________________________

Checklist (COMPLETE IN THE FOLLOWING ORDER):

1) Survey Monkey Survey Completed **Yes / No**

Assessment	**1st Recording**	**2nd Recording**	**3rd Recording**
Hand Strength (Left)			
Hand Strength (Right)			
Height (cm x 0.01=m)			
Weight (kg)			
Waist Circumference (cm)			
Sit ups (score)			
Push-up test (repetitions)			
Resistance Training Skill Proficiency Video Analysis	Squat		
	Push Up		
	Lunge		
	Overhead Press		
	Front Support Chest Touches		
	Suspended Row		

BIA (%)	**FM (%)** __________	**FM (%)** __________

Appendix 6: Accelerometer information sheet and activity log

INFORMATION SHEET
PHYSICAL ACTIVITY MONITOR

Thank you for your involvement in the ATLAS project conducted by the University of Newcastle. You have been asked to wear a physical activity monitor for one week to assist with this research. Please find below an explanation of your monitor. Please do not hesitate to call Tara Finn on (02) 49216299 if you have any questions.

What does the physical activity monitor do?
When worn, the monitor records all movement by duration and intensity. The monitor can detect how much time is spent participating in activities of varying intensities (e.g. sitting, walking, running).

How long should the monitor be worn for?
We would like you to wear the monitor for 7 days (including week and weekend days) for all waking hours. It is important that you behave normally and do not try to do more activity than usual simply because you are wearing the device.

How is the monitor to be positioned when being worn?
- The monitor is to be positioned on the front of the hip - directly in line with the knee. The monitor can be worn under clothing to keep discreet.
- Make sure the monitor is NOT upside down - the sticker on the top of the monitor should be facing upwards i.e. pointing towards the sky.
- The elastic belt should fit firmly but not feel uncomfortable.

When to take the monitor OFF.
The monitor should be taken off when you go to bed at night, or if there is a chance that the monitor could get wet (e.g. swimming, showering). **THE MONITORS ARE NOT WATER PROOF.**

Why do I need to complete the daily activity log?
The activity log (see over page) tells us important information about when you wore the monitor and why it was taken off (e.g. for a shower). To complete the log:
- Each day shade in the hours when you were wearing the monitor. Hours which are NOT shaded in indicate the monitor was not worn (e.g. when sleeping or showering).
- Note any specific time periods that the monitor was taken off and why (e.g. 3.30-4.30pm on Wednesday – Swimming).
- Indicate on the log if you participated in any of the following activities and for how long (these activities are not easily detected by the monitor so it's important that they are recorded on the log):
  * Riding a bike
  * Jumping on a trampoline
  * Riding a scooter

What do I do at the end of the 7 days?
Your will need to return the monitor to school after 7 days. The due date for returning this monitor has been recorded at the top of the log sheet (next page). It is VERY IMPORTANT that the monitor is returned to school on its due date.

The monitors are expensive, so please take care of them. It is quite a sturdy piece of equipment, but will be damaged if thrown or forcefully dropped. You should not lose the monitor if worn during all waking hours because it is securely fitted to a belt.

ACTIVITY MONITOR LOG SHEET

Name ………………………………………. **Monitor ID Number** ……………......………….............

School …………………………………….. **Date to be returned to school** ………………………..

INSTRUCTIONS:

1. Please shade in the hours during which the activity monitor was WORN
2. When the monitor was NOT WORN please indicate what you were doing and how long the monitor was not worn for (e.g. showering – 30 min).
3. Please indicate any time spent swimming, riding a bike or scooter, or playing on a trampoline.

See the example on the left hand side of the page for how to complete the log.

EXAMPLE:

	Time	Monday
Morning Hours	12-1	Sleep
	1-2	Sleep
	2-3	Sleep
	3-4	Sleep
	4-5	Sleep
	5-6	Sleep
	6-7	Sleep
	7-8	**PUT ON**
	8-9	**BIKE RIDING (30 min)**
	9-10	
	10-11	
	11-12	
Afternoon / Night hours	12-1	
	1-2	
	2-3	
	3-4	**TAKEN OFF SWIM (40 min)**
	4-5	**TAKEN OFF SHOWER (20 min)**
	5-6	**PUT ON**
	6-7	
	7-8	
	8-9	
	9-10	**TAKEN OFF BED**
	10-11	Sleep
	11-12	Sleep

		Day of the week						
	Time							
Morning Hours	12-1							
	1-2							
	2-3							
	3-4							
	4-5							
	5-6							
	6-7							
	7-8							
	8-9							
	9-10							
	10-11							
	11-12							
Afternoon / Night hours	12-1							
	1-2							
	2-3							
	3-4							
	4-5							
	5-6							
	6-7							
	7-8							
	8-9							
	9-10							
	10-11							
	11-12							

Appendix 7: ATLAS study questionnaire

Thank you for being involved in this study with the University of Newcastle. We would like you to answer all the questions outlined in this questionnaire. Each section asks questions about your beliefs and behaviours related to Sedentary behaviour, Physical Activity, Sleepiness and Nutrition.

This is not a test. There are no right or wrong answers.

Cover Information

1. What is your first name?

2. What is your last name?

3. What is your ID Number?

SCREEN TIME

4. Recreational screen time refers to the time you spend sitting while watching television or DVD's, playing electronic games (e.g. Xbox, PlayStation), using your iPhone/iPad or computer for anything other than homework (e.g., Facebook, Twitter, games etc.). Please answer all questions below:

Think about a normal school week, and write down how long you spend in recreational screen time before and after school each day:

Monday

	Monday Hours
How long do you spend in Recreational screen time?	

5. Tuesday

	Tuesday Hours
How long do you spend in Recreational screen time?	

6. Wednesday

	Wednesday Hours
How long do you spend in Recreational screen time?	

7. Thursday

	Thursday Hours
How long do you spend in Recreational screen time?	

8. Friday

	Friday Hours
How long do you spend in Recreational screen time?	

WEEKEND SCREEN TIME

9. Think about a normal weekend and write down how long you spend in recreational screen time for that weekend:

Saturday

	Saturday Hours
How long do you spend in Recreational screen time?	

10. Sunday

	Sunday Hours
How long do you spend in Recreational screen time?	

FEELINGS SCALE

11. Below are 8 statements with which you may agree or disagree. Using the 1 – 7 scale below, indicate your agreement with each item by selecting that response for each statement.

	Strongly disagree	Disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Agree	Strongly Agree
I lead a purposeful and meaningful life	○	○	○	○	○	○	○
My social relationships are supportive and rewarding	○	○	○	○	○	○	○
I am engaged and interested in my daily activities	○	○	○	○	○	○	○
I actively contribute to the happiness and well-being of others	○	○	○	○	○	○	○
I am competent and capable in the activities that are important to me	○	○	○	○	○	○	○
I am a good person and live a good life	○	○	○	○	○	○	○
I am optimistic about my future	○	○	○	○	○	○	○
People respect me	○	○	○	○	○	○	○

SUGARED DRINK CONSUMPTION

Instructions: Carefully read each of the questions below and answer by selecting one response per question.

12. How many glasses of softdrink or cordial do you have each day? (All types)

- ◯ None
- ◯ 1 per day
- ◯ 2 per day
- ◯ 3 per day
- ◯ 4 per day
- ◯ 5 per day
- ◯ 6 per day
- ◯ 7 or more per day

13. How many fruit-juice based drinks do you have each day? Eg – Orange juice or Popper

- ◯ None
- ◯ 1 per day
- ◯ 2 per day
- ◯ 3 per day
- ◯ 4 per day
- ◯ 5 per day
- ◯ 6 per day
- ◯ 7 or more per day

AGGRESSION SCALE

14. For each question, indicate how many times in the last 7 days you did any of the following:

	0	1	2	3	4	5	6+
I teased students to make them angry	◯	◯	◯	◯	◯	◯	◯
I got angry very easily with someone	◯	◯	◯	◯	◯	◯	◯
I fought back when someone hit me first	◯	◯	◯	◯	◯	◯	◯
I said things about other kids to make other students laugh	◯	◯	◯	◯	◯	◯	◯
I encouraged other students to fight	◯	◯	◯	◯	◯	◯	◯
I pushed or shoved other students	◯	◯	◯	◯	◯	◯	◯
I was angry most of the day	◯	◯	◯	◯	◯	◯	◯
I got into a physical fight because I was angry	◯	◯	◯	◯	◯	◯	◯
I slapped or kicked someone	◯	◯	◯	◯	◯	◯	◯
I called other students bad names	◯	◯	◯	◯	◯	◯	◯
I threatened to hurt or to hit someone	◯	◯	◯	◯	◯	◯	◯

MOTIVATION TO LIMIT SCREEN TIME

15. Please indicate how true each statement is for you by selecting ONE RESPONSE per statement

	Not at all true 0.	1.	2.	Somewhat true 3.	4.	5.	Very True 6.
I try to limit my screen time because I believe that too much screen time is bad for my health	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because my parent(s) will get angry with me if I don't	◯	◯	◯	◯	◯	◯	◯
I don't see why I should try to limit my screen-time	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because it allows me to do other things that I enjoy	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because I feel guilty if I spend too much time in front of a screen	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen time because I believe it is important	◯	◯	◯	◯	◯	◯	◯
I can't see why I should bother limiting my screen-time	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because my parent(s) pressure me to do so	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because it gives me time to do other things that are important to me	◯	◯	◯	◯	◯	◯	◯
I don't see the point of limiting my screen-time	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because I don't want other people to think that I am lazy	◯	◯	◯	◯	◯	◯	◯
I try to limit my screen-time because I feel it is important	◯	◯	◯	◯	◯	◯	◯
I don't see any reason why I should limit my screen-time	◯	◯	◯	◯	◯	◯	◯

SCREEN TIME RULES

16. The following questions relate to rules around recreational screen time in your home. Recreational screen time refers to the time you spend sitting while watching television or DVD's, playing electronic games (e.g. Xbox, PlayStation), using your iPhone/iPad or computer for anything other than homework (e.g., Facebook, Twitter, games etc.). Please answer all questions below by circling ONE RESPONSE per question

In your home do your parents/caregivers have the following rules about screen use?

	Yes	No	Sometimes
No recreational screen-time before homework	◯	◯	◯
No recreational screen-time while doing homework	◯	◯	◯
Less than 2 hours of recreational screen-time per day	◯	◯	◯
No recreational screen-time during daylight hours	◯	◯	◯
No electronic screen devices (i.e. iPhones, iPads, laptops, TVs etc) in the bedroom after bedtime	◯	◯	◯
No internet without permission	◯	◯	◯

DAYTIME SLEEPINESS

Instructions: Carefully read each of the questions below and answer by selecting one response per question.

17. Daytime Sleepiness

	Never	Seldom	Sometimes	Frequently	Always
How often do you fall asleep or get drowsy during class periods?	◯	◯	◯	◯	◯
How often do you have trouble getting out of bed in the morning?	◯	◯	◯	◯	◯
How often do you think that you need more sleep?	◯	◯	◯	◯	◯

STRATEGIES FOR BEING PHYSCIALLY ACTIVE

This section asks questions about your beliefs and behaviours related to REGULAR PHYSICAL ACTIVITY.

Physical activity is any bodily movement that increases your breathing and heart rate. REGULAR physical activity involves participating in a total of 60 MINUTES of at least MODERATE INTENSITY activity on ALL OR MOST days of the week. Examples of at least moderate intensity activities includes brisk walking, bike riding, skateboarding, dancing, running, playing netball or soccer, swimming laps or training for sport etc.

The following questions are about strategies you have used in the PAST THREE MONTHS to participate in REGULAR PHYSICAL ACTIVITY.

18. In the past THREE MONTHS how often...

	Never	Rarely	Sometimes	Often	Always
…did you do things to make physical activity more enjoyable (eg. be physically active with friends or while listening to an i-pod)?	◯	◯	◯	◯	◯
…did you participate in a variety of physical activities/sports to avoid boredom with the same types of physical activity?	◯	◯	◯	◯	◯
…did you set yourself physical activity goals (eg. trying a more difficult mountain bike trail or gradually increasing how far you jog)?	◯	◯	◯	◯	◯
…did you organise to be physically active with a friend or family member?	◯	◯	◯	◯	◯
…did you make an effort to look for nearby settings where you could be physically active (eg. the beach or bush trails)?	◯	◯	◯	◯	◯
…did you keep track of how much physical activity you did (eg. by using a timer, pedometer or speedometer when you exercised, or by keeping a logbook)?	◯	◯	◯	◯	◯

VIDEO GAMING

19. Video Gaming

The following questions refer to your experiences with video gaming on either a computer or game console (Xbox 360, PS3 etc). Please answer by selecting ONE RESPONSE per question.

	Yes	No	Sometimes
Over time, have you been spending much more time thinking about playing video games, learning about video-game playing, or planning the next opportunity to play?	○	○	○
Do you need to spend more and more time and/or money on video games in order to feel the same amount of excitement?	○	○	○
Have you tried to play video games less often or for shorter periods of time, but are unsuccessful?	○	○	○
Do you become restless or irritable when attempting to cut down or stop playing video games?	○	○	○
Have you played video games as a way of escaping from problems or bad feelings?	○	○	○
Have you ever lied to family or friends about how much you play video games?	○	○	○
Have you ever stolen a video game from a store or a friend, or have you ever stolen money in order to buy a video game?	○	○	○
Do you sometimes skip household chores in order to spend more time playing video games?	○	○	○
Do you sometimes skip doing homework in order to spend more time playing video games?	○	○	○
Have you ever done poorly on a school assignment or test because you spent too much time playing video games?	○	○	○
Have you ever needed friends or family to give you extra money because you spent too much money on video-game equipment, software, or game/Internet fees?	○	○	○

PHYSICAL SELF-DESCRIPTION

This is a chance to look at yourself. IT IS NOT A TEST. There are no right or wrong answers. Be sure that your answers show how you feel about yourself.

20. Read each statement carefully and select ONE option to indicate how true or false you feel each statement is about you.

	False	Mostly false	More false than true	More true than false	Mostly true	True
I am a physically strong person	◯	◯	◯	◯	◯	◯
I have a lot of power in my body	◯	◯	◯	◯	◯	◯
I am stronger than most people my age	◯	◯	◯	◯	◯	◯
I am weak and have no muscles	◯	◯	◯	◯	◯	◯
I would do well in a test of strength	◯	◯	◯	◯	◯	◯
I am good at lifting heavy objects	◯	◯	◯	◯	◯	◯

EXPERIENCES IN SCHOOL SPORT

For each statement, please select the response that best describes your experiences in school sport

21. During school sport....

	Not at all true 1.	2.	3.	Somewhat True 4.	5.	6.	Very True 7.
I can decide which activities I want to practice in school sport	◯	◯	◯	◯	◯	◯	◯
I think I am pretty good at school sport activities	◯	◯	◯	◯	◯	◯	◯
I feel I am pursuing goals that are my own	◯	◯	◯	◯	◯	◯	◯
I feel understood in school sport	◯	◯	◯	◯	◯	◯	◯
I have a say regarding what skills I want to practice	◯	◯	◯	◯	◯	◯	◯
I am satisfied with my performance	◯	◯	◯	◯	◯	◯	◯
I choose to participate in school sport according to my own free will	◯	◯	◯	◯	◯	◯	◯
In school sport I feel listened to	◯	◯	◯	◯	◯	◯	◯
I feel some freedom in choosing what I do in school sport	◯	◯	◯	◯	◯	◯	◯
In school sport I feel supported	◯	◯	◯	◯	◯	◯	◯
I feel pretty competent in school sport	◯	◯	◯	◯	◯	◯	◯
I feel I participate in school sport gladly	◯	◯	◯	◯	◯	◯	◯
I have some choice in what activities I do in school sport	◯	◯	◯	◯	◯	◯	◯
I am pretty skilled in school sport	◯	◯	◯	◯	◯	◯	◯
I really have a sense of wanting to take part in school sport	◯	◯	◯	◯	◯	◯	◯
In school sport I feel safe	◯	◯	◯	◯	◯	◯	◯
I feel that I do school sport because I want to	◯	◯	◯	◯	◯	◯	◯
In school sport I feel valued	◯	◯	◯	◯	◯	◯	◯
I feel I am doing what I want to be doing in school sport	◯	◯	◯	◯	◯	◯	◯

PARTICIPATION IN SCHOOL SPORT

Please indicate how much you agree with each of the following statements.

22. I take part in school sport...

	Not at all true 1.	2.	3.	Somewhat True 4.	5.	6.	Very True 7.
Because school sport is fun	◯	◯	◯	◯	◯	◯	◯
Because I want to learn sport skills	◯	◯	◯	◯	◯	◯	◯
Because I'll get in to trouble if I don't	◯	◯	◯	◯	◯	◯	◯
Because it is important for me to do well in school sport	◯	◯	◯	◯	◯	◯	◯
But I don't really know why	◯	◯	◯	◯	◯	◯	◯
Because school sport is exciting	◯	◯	◯	◯	◯	◯	◯
Because I want the teacher to think I am a good student	◯	◯	◯	◯	◯	◯	◯
But I don't see why I should do school sport	◯	◯	◯	◯	◯	◯	◯
Because that's what I am supposed to do	◯	◯	◯	◯	◯	◯	◯
Because I would feel bad if I didn't	◯	◯	◯	◯	◯	◯	◯
Because I want to improve in school sport	◯	◯	◯	◯	◯	◯	◯
Because I enjoy learning new skills	◯	◯	◯	◯	◯	◯	◯
But I think I am wasting my time in school sport	◯	◯	◯	◯	◯	◯	◯
Because of the enjoyment I feel when learning new skills	◯	◯	◯	◯	◯	◯	◯
Because I want the other students to think I am skilful	◯	◯	◯	◯	◯	◯	◯
But I don't see what I get out of school sport	◯	◯	◯	◯	◯	◯	◯
So that the teacher doesn't shout at me	◯	◯	◯	◯	◯	◯	◯
Because that's the rule	◯	◯	◯	◯	◯	◯	◯
Because I can learn skills which I could use in other areas of my life	◯	◯	◯	◯	◯	◯	◯
Because it bothers me when I don't take part	◯	◯	◯	◯	◯	◯	◯

Appendix 8: Student mid-program evaluation questionnaire

ATLAS Mid-Program Evaluation

Thank you for taking part in the ATLAS program. Please complete the following questions and let us know what you think about the program.

1) Have you used any of the following?

	Yes	No
a. ATLAS iPhone App	Y	N
b. ATLAS Android App	Y	N
c. ATLAS website	Y	N

2) How often have you used the ATLAS Apps:

- ☐ Never
- ☐ Once
- ☐ Twice
- ☐ Three times
- ☐ Four times
- ☐ 5 or more times

3) How often do you use your ATLAS pedometer:

- ☐ Never
- ☐ Once
- ☐ Twice
- ☐ Three times
- ☐ Four times
- ☐ 5 or more times

PLEASE TURN OVER AND COMPLETE THE SECOND PAGE

4) ATLAS school sport sessions:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I have enjoyed participating in the ATLAS school sport sessions, e.g. boxing circuits, Gymstick workouts.	SD	D	N	A	SA
b. My participation in ATLAS has encouraged me to be more active at home.	SD	D	N	A	SA

5) Strength training skills and fitness:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. My participation in ATLAS has helped to improve my strength training skills and technique.	SD	D	N	A	SA
b. My participation in ATLAS has helped to improve my fitness.	SD	D	N	A	SA

6) What have you liked about the ATLAS program?

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7) Do you have any suggestions to improve the ATLAS program?

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Thank you for completing this survey ☺

Appendix 9: Student end of program evaluation questionnaire

Name: ___________________________

School:__________________________

ATLAS
End-program evaluation

Thank you for taking part in the ATLAS study. We would like to know what you thought of the program and would be grateful if you could complete the following questionnaire.

Please be honest in your reply. All responses will be treated in confidence.

During the program

1) Overall:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The ATLAS program was enjoyable.	SD	D	N	A	SA
b. The ATLAS program provided me with useful information about ***screen-time.***	SD	D	N	A	SA
c. The ATLAS program provided me with useful information about ***physical activity and fitness***.	SD	D	N	A	SA
d. The ATLAS program provided me with useful information about ***sugared drinks.***	SD	D	N	A	SA

2) ATLAS school sport sessions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed participating in the ATLAS school sport sessions (e.g. boxing activities, Gymstick workouts etc)	SD	D	N	A	SA
b. I enjoyed the sport session delivered by the fitness professional	SD	D	N	A	SA
c. I enjoyed participating in fitness testing (e.g. push up test)	SD	D	N	A	SA

3) **Strength training skills and fitness:**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. My participation in ATLAS has helped to improve my strength training skills and technique.	SD	D	N	A	SA
b. My participation in ATLAS has helped to improve my fitness.	SD	D	N	A	SA

4) **PowerPoint Presentations:**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The PowerPoint presentations delivered by University staff provided me with useful information about physical activity, strength training, sugared drinks, screen-time and fitness.	SD	D	N	A	SA

5) **ATLAS pedometer:**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Wearing my pedometer made me think about how much physical activity I was doing.	SD	D	N	A	SA

	Often	Sometimes	Rarely	Never
b. How often did you wear your pedometer?	O	S	R	N

6) ATLAS Newsletters:	Yes	No	Sometimes
a. My parents/caregivers read the ATLAS newsletters.	Y	N	S
b. I read the ATLAS newsletters.	Y	N	S

7) The ATLAS messages:

Which of the messages were most important to you? Please rank in order from 1 (***most important***) to 4 (***least important***).

Walk whenever you can	
Reduce your recreational screen-time	
Get some vigorous physical activity on most days	
Drink more water and less sugary drinks	

8) ATLAS lunch-time sessions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed participating in the ATLAS lunch-time sessions (i.e. training year 7 boys)	SD	D	N	A	SA

b. Why / why not? ____

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9) **ATLAS app / website:**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed using the ATLAS app and/or website	SD	D	N	A	SA
b. The messages sent through the app reminded me to be more active, reduce my screen-time and drink less sugary drinks	SD	D	N	A	SA

	Often	Sometimes	Rarely	Never
c. I used the goal setting function to help increase my physical activity and reduce my screen-time.	O	S	R	N
d. I used the ‘my technique’ function to help improve my resistance training skills and technique	O	S	R	N
e. I used the app / website to log my steps and monitor my physical activity levels	O	S	R	N
f. I used the app / website to record and monitor my fitness challenge results	O	S	R	N

10) In the future I plan to:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Limit my recreational screen-time.	SD	D	N	A	SA
b. Limit my consumption of sugary drinks.	SD	D	N	A	SA
c. Do at least 60 minutes of moderate to vigorous physical activity each day	SD	D	N	A	SA
d. Participate in muscle strengthening physical activities (e.g. resistance training).	SD	D	N	A	SA

11) Which part of the ATLAS program did you enjoy the most (please tick one only):

- ☐ Sport sessions
- ☐ PowerPoint presentations
- ☐ Smartphone App / Website
- ☐ Receiving and using my pedometer
- ☐ Lunch-time training sessions
- ☐ Fitness testing
- ☐ Other (please specify):____

12) Were there any parts of the ATLAS program you DID NOT enjoy (please list):

____

____

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____

13) **Do you have any suggestions to <u>improve</u> the ATLAS program?**

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Thank you for completing this survey ☺

Appendix 10: Teacher end of program evaluation questionnaire

Name: ___________________________

School:__________________________

ATLAS

End-program teacher evaluation

Thank you for delivering the ATLAS study at your school. We would like to know what you thought of the program and would be grateful if you could complete the following questionnaire. Please be honest in your reply

During the program

1) Overall:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed delivering the ATLAS program.	SD	D	N	A	SA
b. The students enjoyed participating in the ATLAS program	SD	D	N	A	SA
c. The students benefited from participating in the ATLAS program	SD	D	N	A	SA

2) Sport sessions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed delivering the ATLAS sport sessions	SD	D	N	A	SA
b. The students enjoyed participating in the sport sessions.	SD	D	N	A	SA
c. The students were sufficiently active during the sport sessions.	SD	D	N	A	SA

3) **ATLAS lunch-time sessions**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I enjoyed delivering the ATLAS lunch-time sessions	SD	D	N	A	SA

b. Why / why not? ____

____

____

c. The ATLAS students enjoyed participating in the lunch-time sessions (i.e. training the year 7 boys)	SD	D	N	A	SA
d. The year 7 students enjoyed participating in the lunch-time sessions	SD	D	N	A	SA

4) **University support and SAAFE teaching principals**	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Observing the first ATLAS session delivered by a university staff member (David, Phil, or Jordan) helped me understand how to deliver the ATLAS program and apply the SAAFE principals	SD	D	N	A	SA
b. Observing the session delivered by the fitness professional (Steve Henderson) helped me understand the SAAFE principals	SD	D	N	A	SA
c. The session delivered by the fitness professional gave me some new ideas for activities	SD	D	N	A	SA
d. I intend to apply the SAAFE principals during my PE and sport lessons in the future	SD	D	N	A	SA
e. The university staff provided adequate support to help me deliver the ATLAS program	SD	D	N	A	SA

5) ATLAS resources	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The resources and equipment provided were sufficient to deliver the ATLAS program (e.g. Gymsticks, boxing pads, activity cards etc)	SD	D	N	A	SA
b. The ATLAS teacher handbook was useful and assisted me in delivering the ATLAS program	SD	D	N	A	SA

During the sport sessions I used…	Often	Sometimes	Rarely	Never
c. Gymsticks	O	S	R	N
d. Hanging gym handles	O	S	R	N
e. Boxing pads / gloves	O	S	R	N
f. Activity cards	O	S	R	N
g. Equipment from my own school	O	S	R	N
h. I used the teacher handbook to plan my sessions	O	S	R	N

6) What did you enjoy most about delivering the ATLAS program at your school

7) What were the biggest challenges in delivering the ATLAS program at your school

8) Do you have any suggestions to <u>improve</u> the ATLAS program?

Thank you for completing this survey ☺

Appendix 11: Teacher handbook

ATLAS

ACTIVE TEEN LEADERS AVOIDING SCREEN-TIME

atlas
active teen leaders avoiding screen-time

TEACHER HANDBOOK

THE UNIVERSITY OF NEWCASTLE AUSTRALIA
PRIORITY RESEARCH CENTRE FOR PHYSICAL ACTIVITY AND NUTRITION

HMRI
Hunter Medical Research Institute
READY FOR THE NEXT 10 YEARS

Australian Government
Australian Research Council

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Table of Contents

Introduction to the ATLAS Program

Welcome to the Active Teen Leaders Avoiding Screen-time (ATLAS) program, a research project of the University of Newcastle. ATLAS is an innovative school-based program aimed at increasing physical activity and reducing screen-time to improve the health and well-being of adolescent boys from low-income communities.

ATLAS behavioural messages

The research team have created 4 simple messages designed to guide students toward a healthier lifestyle (see below). These messages, targeting both physical activity and diet, are based on behaviours known to have a strong relationship with health. The messages will be made explicit to students at the start of the program and should be consistently reinforced throughout the duration of the program (see ATLAS school sport sessions on page 5). Below is an example of how you might adapt a message to engage your students:

"You shouldn't spend any more than 2 hours a day watching TV or surfing the internet. Constantly overdoing it on screens can result in low fitness, sleep problems and poor grades. Consider what's more important to you, another episode of Family Guy or being fit and strong!"

The ATLAS messages are:

1. Walk whenever you can
2. Get some vigorous physical activity on most days
3. Reduce your recreational screen-time
4. Drink more water and less sugary drinks

Teacher roles and responsibilities

The table below outlines your roles and responsibilities as an ATLAS champion:

Task	When?	Completed
Attend two workshops at the university	Dec 2012	Y
	Apr 2013	
Organise data collection at schools on 3 occasions	Dec 2012	Y
	July 2013	
	Apr 2014	
Deliver 10 weeks of school sport	Term 1, 2013	
Deliver 10 weeks of school sport	Term 2, 2013	
Observe 1 school sport session delivered by a member of the research team	Term 1, 2013	
Facilitate 6 lunch time sessions (run by students)	Term 2, 2013	

NOTE: A $150 voucher will be given to one teacher involved in organising students for each of the three data collection periods.

ATLAS school sport sessions

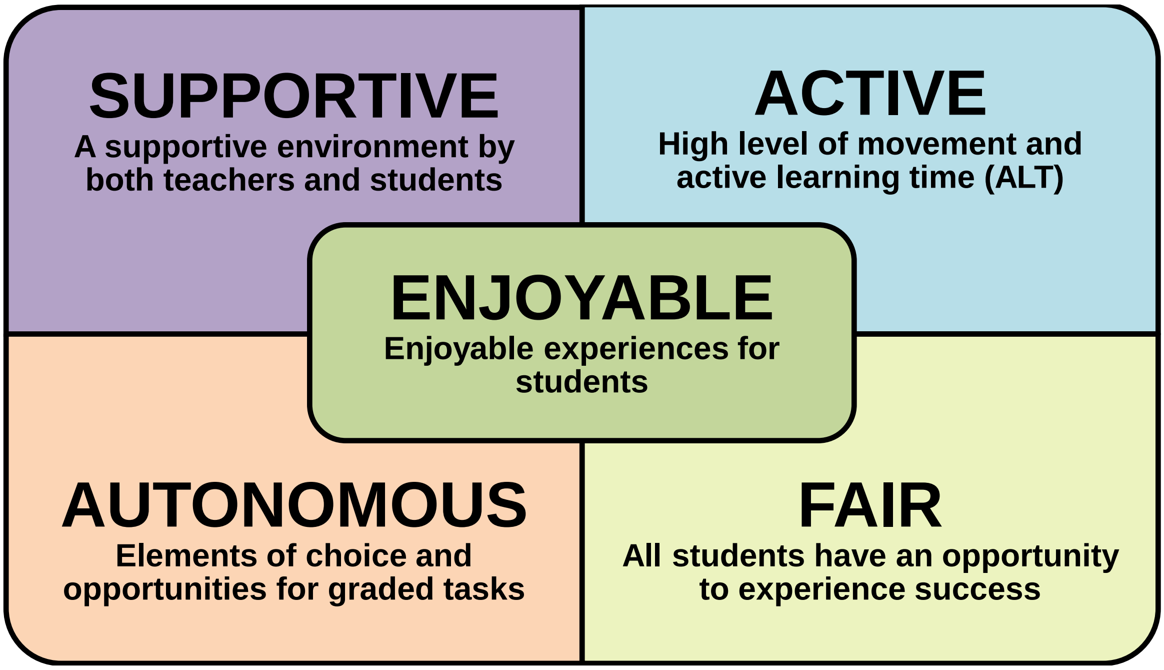
Your school sport sessions should follow the format below:

	EXPLANATION	TIME TAKEN
WARM UP	• General warm-up involving movement based games and dynamic stretching	3-5 mins
RT SKILL DEVELOPMENT	• Circuit or workout consisting of Gymstick and body weight exercises • Opportunities for student choice (e.g. exercises, music etc). • Moderate intensity exercise • Emphasis on skill development and improving technique	20 – 30 mins
FITNESS CHALLENGE	• Short, high intensity workout • Pre-designed workout completed for ‘time’ (stopwatch/timer required) • Performed in pairs. Partner counts reps, monitors technique and provides encouragement • Results recorded	10 mins
GAMES	• Select one strength-based challenge, one aerobic-based challenge and one modified ball game • Ensure there is a mix of individual, partner and team-based activities • Ensure there is **at least one** activity that involves physical contact	20-30 mins
COOL DOWN	• Static stretching • Discuss ATLAS behavioural messages • Reinforce key skill components or concepts	5 mins

NOTE: Timings will vary depending on the length of your sport period.

The SAAFE principles

The research team has come up with some easy to follow principles that should guide your instruction during the delivery of the program.



SUPPORTIVE:
- Recognise all students efforts
- Acknowledge supportive behaviour (weekly award for the ATLAS ‘motivator’)
- Give personal feedback (private rather than public)

ACTIVE:
- Circuits, small-sided games (avoid elimination games) and ‘fitness infusion’
- Maximise available equipment and monitor in-class PA
- Teacher participation boosts motivation to be active

AUTONOMOUS
- Provide student choice at least 3 times during a session (e.g., group size, music, exercises)
- Opportunities for student leadership (e.g., setting up equipment, running warm-ups)
- Make the tasks relevant (e.g., reinforce the importance of muscular fitness)

FAIR
- Modify tasks to suit ability levels
- Evenly match students during competitive tasks
- Regularly swap partners to provide all students the opportunity to experience success

ENJOYABLE
- Start and finish with an enjoyable activity
- Don’t use exercise as punishment
- Provide a variety of engaging activities (avoid boring and repetitive tasks)

Student leadership

One of the novel components of the ATLAS program is the promotion of student leadership. This is where the '*L*' in ATLAS comes from! The ATLAS program aims to engage students in physical activity mentoring. This will allow them to develop leadership skills, gain confidence, and will enhance the relevance of physical activity in their own lives.

During **term two** of the program students will have the opportunity to become an ATLAS leader. As the teacher you will be asked to facilitate and supervise 6 lunchtime training sessions (20 minute duration). Students that elect to be involved will do the following:

- Recruit year 7 boys
- Organise a workout (design the session, set up and pack up equipment)
- Lead a training session (explain the exercises and provide feedback)

ATLAS accreditation

Students that have met the requirements below will be awarded a certificate of accreditation at the end of the program. This could be awarded a school assembly.

To be eligible for ATLAS accreditation students must:

1. Attend **at least 70%** of school sport sessions (e.g.14 from 20 sessions)
2. Attend **4 or more** lunchtime leadership sessions
3. Set and achieve **at least 3** goals related to physical activity, screen-time or fitness (students will provide evidence to the teacher)

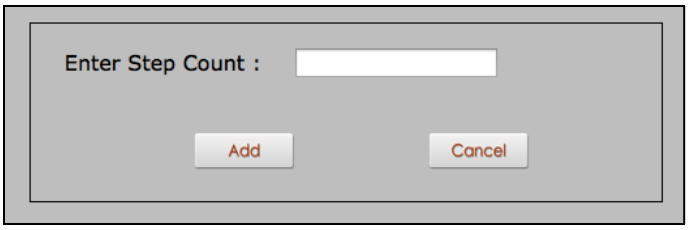
ATLAS smartphone app and website

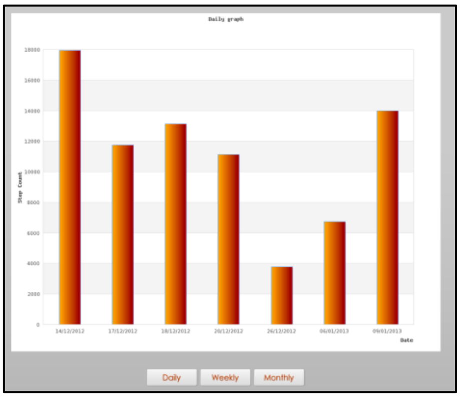
To support the ATLAS program the research team has developed a smartphone application. This ‘app’ is available on both iOS and Android platforms. For students without access to a smartphone, a website with the same functionality is available at www.atlasboys.com

The ATLAS app has the following functions:

- ## My Steps

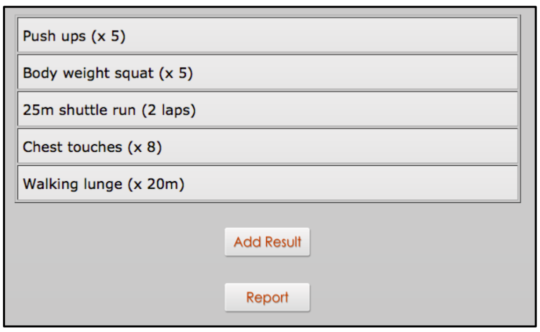
Pedometers are a great way to monitor physical activity. This function allows students to record their step counts, either during a sport session or for the whole day. They can record and store step counts and even review their step counts using the graph view

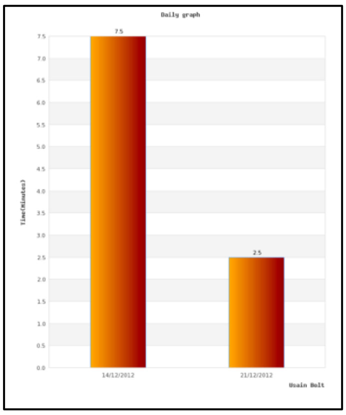




- ## My workouts

This function allows students to complete a number of predesigned workouts. The exercises and number of repetitions are listed and the student can record and store their results (time taken). Once again students are able to review their progress using the graph view, giving them a way to view their improvements. Students should record their results from the fitness challenge during the sports sessions here.



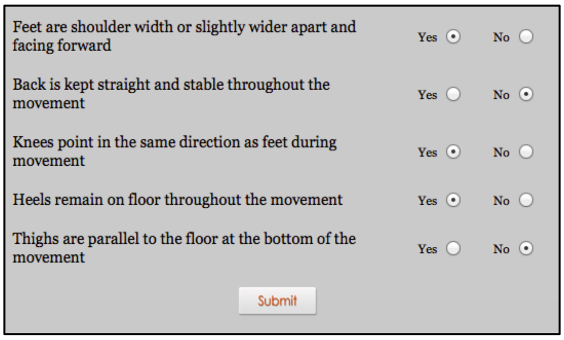


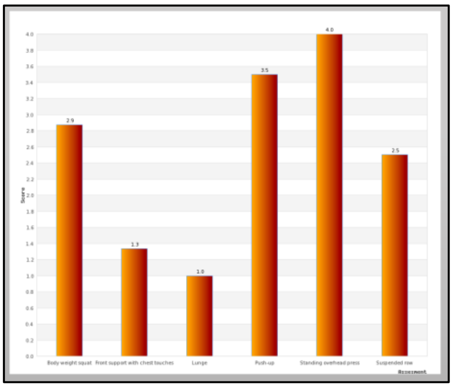
- ## My motivation

This function will be used to send tailored informational and motivational messages to students. The app will send messages based on the reasons students identify that motivate them most to increase their activity, reduce their screen-time and limit their consumption of sugary drinks.

- ## My technique

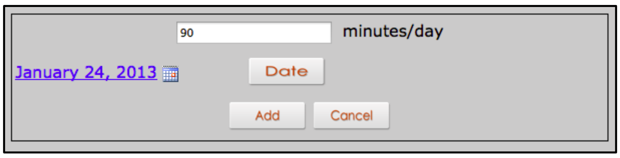
This function will be used by students to assess their resistance training skills. The research team has identified 6 resistance training skills (push-up, lunge, squat, overhead press, suspended row, front support with chest touches) that form the foundation for more advanced resistance training movements. Students can assess each other's level of skill competency by viewing a performance and selecting the technique points that they do and don't demonstrate. Their scores are recorded and stored. Student progress can be reviewed using the graph view.





- ## My goals

This function allows students to set and monitor goals related to physical activity (steps & training sessions) and screen-time. As was mentioned earlier, a requirement for ATLAS accreditation is for students to set and achieve 3 goals during the course of the study period. Using this app, students can easily show you the goals they have set and achieved.

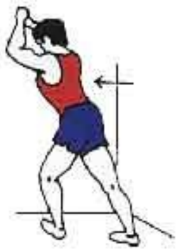


Date	Goal	Status
2013-03-06	1234 steps/day	Completed
2013-01-22	13000 steps/day	Completed
2013-01-23	10 sessions/week	Completed
2013-01-24	3 sessions/week	☐

Warm-ups and cool-downs

- Instruct students to complete 3-5 minutes of cardio-respiratory activity and dynamic stretching to warm-up before starting their Gymstick sessions. You may also want to use some minor partnered games (i.e., arm pull or shoulder slaps).
- **Following each session** students should complete the following stretches- 2 repetitions on each stretch- hold for 10-20 seconds.

Hamstring
(back of thigh)



Calf

Tricep

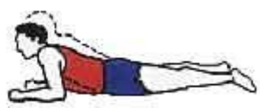
Hip flexors
(groin)

Chest

Abductor
(outer thigh)

Shoulder

Lower back



Abdom

Quadricep
(front of thigh)

Aductors
(inner thigh)

Resistance training for youth

What is resistance training?

- Resistance training (RT) is exercise designed to increase muscular strength and endurance through increased load on muscles
- RT may include the use of free weights, machine weights, elastic tubing/stretch bands, hydraulic machines or body weight (e.g. push-ups, chin-ups)

What are the resistance training recommendations for youth?

- RT is safe if correct technique is used and supervision provided.
- Avoid competitive weight lifting, power lifting, body building, and maximum lifts
- Combine resistance training with aerobic physical activity
- Include warm-ups and cool downs
- Exercises should be learnt first, before load is added
- Successful completion of 8-15 reps before increasing resistance
- Resistance training should address all muscle groups and exercise through full range of movement

Source: Sports Medicine Australia (2008)

Additional information

Drinks and their energy content

Drink	Energy (KJ)	Time taken to burn off
Coca Cola (375mL)	675	25 mins (jogging)
Coke Zero (375mL)	4	Less than 1 min (walking)
Orange juice (250mL)	570	19 mins (cycling)
Red bull (250mL)	480	42 mins (weight training)
Mother energy drink (500mL)	975	1hr 15mins (weight training)
Flat white with full cream milk (300mL)	705	56 mins (walking)
Flat white with low-fat milk (300mL)	390	31 mins (walking)
Powerade (600mL)	798	21 mins (swimming – mod/vig)
Oak chocolate milk (600mL)	2256	1 hr 14 mins (jogging)

Source: http://www.calorieking.com.au
http://www.fitwatch.com/qkcalc/burncalc.html

NB: Calculations for energy expenditure are based on a body weight of 54kg. This is the mean body weight of the boys in the ATLAS study. These values are approximations and will vary depending on the individual.

Estimated energy requirements for boys (kJ)

Age	Low active	Moderately active	Highly active
11	8,800	9,900	11,000
12	9,300	10,500	11,600
13	10,000	11,200	12,400
14	10,600	11,900	13,200
15	11,200	12,600	14,000

Source: Department of health www.betterhealth.vic.gov.au

Hydration guidelines

When	Guideline
Before exercise	Ensure adequate hydration 4 hours prior to exercise. Drink approximately 470 – 590mL of water 10-15 minutes before exercise
During exercise	Drink approximately 85 – 235mL every 15-20 mins during exercise. If exercise duration is less than 60 mins there is no need to consume a sports beverage to replace lost electrolytes
After exercise	After exercise consume enough water to return body weight to pre-exercise level. This should be achieved within 2 hours post training. A body weight difference of -1% to + 1% from pre-training weight is considered well hydrated

Source: American College of Sports Medicine

Program registration & session planning

Term 1

Week 1

Warm-up:	RT skill development: (tick one)	Fitness challenge:
Rats and rabbits Monkeys and baboons Dynamic stretches	• Workout ☐ • Circuit ☑	Assassins creed **OR** Student choice ☐
	Games: (at least one involving contact)	
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**
Triangle tag Dragon's tail	Shoulder taps Arm pull Stand challenge	10 passes - with fitness infusion

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☑

Equipment required:
30 x braids (2 x colours)
2 x balls

Comments:

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Week 2

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	________________________ **OR** Student choice ☐
	Games: (at least one involving contact)	
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

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Week 3

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 4

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 5

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ OR Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 6

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ OR Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 7

Warm-up:	RT skill development: (tick one) • Workout ☐ • Circuit ☐	Fitness challenge: ____________________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 8

Warm-up:	RT skill development: (tick one) • Workout ☐ • Circuit ☐	Fitness challenge: ____________________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)
- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 9

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	________________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching)	Comments:
Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	
Equipment required:	

Week 10

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	________________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching)	Comments:
Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	
Equipment required:	

Term 2

Week 1		
Warm-up:	**RT skill development:** (tick one) • Workout ☐ • Circuit ☐	**Fitness challenge:** __________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching) Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	**Comments:**
Equipment required:	

Week 2		
Warm-up:	**RT skill development:** (tick one) • Workout ☐ • Circuit ☐	**Fitness challenge:** __________ **OR** Student choice ☐
Games: (at least one involving contact)		
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching) Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	**Comments:**
Equipment required:	

Week 3

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)	Comments:
Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	
Equipment required:	

Week 4

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)	Comments:
Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	
Equipment required:	

Week 5

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 6

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 7

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 8

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________ **OR** Student choice ☐

Games: (at least one involving contact)

Aerobic challenge:	Strength challenge:	Modified ball game:

Cool down: (Static stretching)
Reinforce ATLAS behavioural message (tick one)

- Walk whenever you can ☐
- Get some vigorous physical activity on most days ☐
- Reduce your recreational screen- time ☐
- Drink more water and less sugary drinks ☐

Equipment required:

Comments:

Week 9

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐
	Games: (at least one involving contact)	
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching) Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	**Comments:**
Equipment required:	

Week 10

Warm-up:	RT skill development: (tick one)	Fitness challenge:
	• Workout ☐ • Circuit ☐	____________________ **OR** Student choice ☐
	Games: (at least one involving contact)	
Aerobic challenge:	**Strength challenge:**	**Modified ball game:**

Cool down: (Static stretching) Reinforce ATLAS behavioural message (tick one) • Walk whenever you can ☐ • Get some vigorous physical activity on most days ☐ • Reduce your recreational screen- time ☐ • Drink more water and less sugary drinks ☐	**Comments:**
Equipment required:	

Challenge workout recording sheet

Term 1

	Term 1 - Weeks									
Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Joe Bloggs	AC 5.13	SM 2.55								

Challenge workout key

Assassins creed	AC
Usain Bolt	UB
Black ops	BO
Hit man	HM
Bear Grylls	BG
Spiderman	SM
Scorpion	S
Mohammed Ali	MA
Doom	D
Max Payne	MP

Term 2

	Term 2 - Weeks									
Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Joe Bloggs	AC 5.13	SM 2.55								

Challenge workout key

Assassins creed	AC
Usain Bolt	UB
Black ops	BO
Hit man	HM
Bear Grylls	BG
Spiderman	SM
Scorpion	S
Mohammed Ali	MA
Doom	D
Max Payne	MP

Notes

Sample workouts

Sample workout 1:

Perform 2 sets of each exercise

Exercise	Body part	Repetitions Term 1	Repetitions Term 2
Military press	Upper	8-10	10-12
GS back squat	Lower	8-10	10-12
Crunch	Core	8-10	10-12
Push up	Upper	8-10	10-12
BW lunge	Lower	8-10 (4-5 each leg)	10-12 (5-6 each leg)
Bicycles	Core	8-10 (4-5 each leg)	10-12 (5-6 each leg)
Triceps press	Upper	8-10	10-12
Mountain climbers	Core	8-10 (4-5 each leg)	10-12 (5-6 each leg)
BW squat	Lower	8-10	10-12
Jumping jacks	Whole	12	15
Biceps curl	Upper	8-10	10-12
Squat thrusts	Core	8-10	10-12

NB: GS= Gymstick, BW= body weight

Sample workout 2:

Perform 2 sets of each exercise

Exercise	Body part	Repetitions Term 1	Repetitions Term 2
Straight leg deadlift	Lower	8-10	10-12
Sit up with biceps curl	Core	8-10	10-12
Military press	Upper	8-10	10-12
Running on the spot	Whole	20 seconds	30 seconds
BW lunge	Lower	8-10 (4-5 each leg)	10-12 (5-6 each leg)
Crunch	Core	8-10	10-12
Push up	Upper	8-10	10-12
Boxing (uppercuts)	Whole	2 x 20 seconds	2 x 30 seconds
Prisoner squat	Lower	6-8	8-10
Side bridge	Core	2 x 20 seconds	2 x 30 seconds
Upright row	Upper	8-10	10-12
Boxing (jabs)	Whole	2 x 20 seconds	2 x 30 seconds

Sample workout 3:

Perform 2 sets of each exercise

Exercise	Body part	Repetitions	
		Term 1	**Term 2**
BW rear lunge	Lower	8-10 (4-5 each leg)	10-12 (5-6 each leg)
Reverse crunch	Core	8-10	10-12
Kneeling press	Upper	8-10	10-12
Burpees	Whole	8-10	10-12
Jump squat	Lower	6-8	8-10
Standing body rotation	Core	8-10	10-12
Bar row	Upper	8-10	10-12
Squat thrusts	Whole	10	15
GS back squat	Lower	8-10	10-12
Side bridge	Core	2 x 20 seconds	2 x 30 seconds
Biceps curl	Upper	8-10	10-12
Jumping jacks	Whole	20	30

Adverse event report

In the event of an accident or injury sustained during participation in the ATLAS program please:

- Fill out the necessary fields
- Retain with your records.

Date:_____/_____/ 2013 Time:________am / pm School: ____________________________

Student's name:______________________________

Teacher's name:______________________________

Location of incident:___________________________

Details of incident:____

Action taken:____

Follow-up required:____

Adverse event report

In the event of an accident or injury sustained during participation in the ATLAS program please:

- Fill out the necessary fields
- Retain with your records.

Date:_____/______/ 2013 Time:________am / pm School: ____________________________

Student's name:______________________________

Teacher's name:______________________________

Location of incident:___________________________

Details of incident:____

Action taken:____

Follow-up required:____

Adverse event report

In the event of an accident or injury sustained during participation in the ATLAS program please:

- Fill out the necessary fields
- Retain with your records.

Date:____/____/ 2013 Time:_______am / pm School: ________________________

Student's name:___________________________

Teacher's name:___________________________

Location of incident:________________________

Details of incident:____
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Action taken:____
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Follow-up required:____
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Adverse event report

In the event of an accident or injury sustained during participation in the ATLAS program please:

- Fill out the necessary fields
- Retain with your records.

Date:_____/_____/ 2013 Time:________am / pm School: ____________________________

Student's name:______________________________

Teacher's name:______________________________

Location of incident:___________________________

Details of incident:____

Action taken:____

Follow-up required:____

SAAFE lesson observation checklist

School:			Teacher:	Weather conditions:	
Term:	Date:	Time:	Participating students:	Non-participating students:	

Was the teacher using the ATLAS teaching resources (e.g. activity cards)?	YES	NO

Adherence to session structure *(circle responses and provide comments)*			
WARM-UP	i) Warm-up involves movement-based games	YES	NO
	ii) Warm-up includes dynamic stretching	YES	NO
	Comments:		
RT SKILL DEVELOPMENT	i) Sessions provides opportunity for students to develop RT skills	YES	NO
	Comments:		
FITNESS CHALLENGE	i) Session involves CrossFit style challenge	YES	NO
	Comments:		
GAMES	i) Session involves strength games	YES	NO
	ii) Session involves challenge games	YES	NO
	iii) Session involves modified ball games	YES	NO
	Comments:		
COOL DOWN	i) Session includes static stretching	YES	NO
	ii) Teacher discusses ATLAS behavioural messages	YES	NO
	iii) Teacher reinforces key skill components or concepts	YES	NO
General comments:			

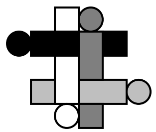
Adherence to SAAFE teaching principles *(circle and provide comments)*		*(1 = Not at all true to 5 = Very true)*				
SUPPORTIVE	i) Teacher provides individual skill specific feedback	1	2	3	4	5
	ii) Teacher provides feedback on student effort and involvement	1	2	3	4	5
	iii) Teacher promotes positive interactions between students	1	2	3	4	5
	Comments:					
ACTIVE	i) Activities involve small-sided games and circuits	1	2	3	4	5
	ii) Teacher monitors students' activity levels (visually or using pedometers)	1	2	3	4	5
	iii) Equipment is plentiful	1	2	3	4	5
	iv) Efficient transitions between activities	1	2	3	4	5
	Comments:					
AUTONOMOUS	i) Teacher reinforces the relevance of the activities	1	2	3	4	5
	ii) Students are given choices about the tasks and activities	1	2	3	4	5
	iii) Students are involved in the set-up and running of activities	1	2	3	4	5
	Comments:					
FAIR	i) Teacher ensures that students are evenly matched in activities	1	2	3	4	5
	ii) Teacher acknowledges and rewards good sportsmanship	1	2	3	4	5
	iii) If necessary, teacher modifies activities to maximise opportunities for success	1	2	3	4	5
	Comments:					
ENJOYABLE	i) Session starts with an enjoyable activity	1	2	3	4	5
	ii) Session finishes with an enjoyable activity	1	2	3	4	5
	iii) Students appear to be enjoying themselves in the session	1	2	3	4	5
	Comments:					
General comments:						

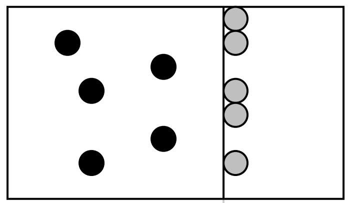
Activity list

NB: P= Partnered, I= Individual, T= Team, (C) = Contact

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Knee taps (C)	P	None	Aerobic	Players standing up facing each other with hands down ready to slap knees.	To slap your opponent on the knee (lightly) and avoid being slapped.
Arm pull (C)	P	None	Strength	Standing on right leg holding opponent's right arm using a monkey grip (holding onto each others' forearms).	To pull your opponent off balance by pulling them forward, sideways or backwards. If your opponent touches the ground with their left leg you score 1 point. Swap arms after 3 trials.
Tootsies (C)	P	None	Aerobic	Players standing up facing each other with hands on each other's shoulders.	To step on your opponent's toes (lightly) and avoid being stepped on.
Push-up arm pull (C)	P	None	Strength	Players face each other in the push up position with heads nearly touching.	To pull your opponents arm from underneath them causing them to fall down while avoiding having your own arm pulled.
Horse and jockey	P	Coloured braids	Aerobic / strength	Set up a playing area of appropriate size. Players partner up with someone of similar stature. One player (horse) piggybacks the other player (jockey). Jockeys have a braid tucked into the collar of their shirt, hanging down their back.	To steal braids from other players and avoid having your own stolen. Once a braid is stolen it is tucked into the jockey's collar with the others. Play for a predetermined time (e.g. 1 min) then have partners swap positions.
Sock wrestle (C)	P	Soft mats	Strength	Players sitting on soft mats with a sock on 1 foot only.	To wrestle the sock off your opponent without losing your own sock.

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Shoulder slaps (C)	P	None	Strength	Players standing up facing each other. Players start by holding each other's right wrist with their left hand. Both players should have their right hand free.	To slap your opponent on the shoulder (lightly) without being slapped yourself. Swap arms after 3 trials.
Hoop push (C)	P	Hoops	Strength	Players standing facing each other in their own hoop.	Players are required to use their strength and balance to push the other out of their hoop while remaining in their own.
Chinese wrestle (C)	P	Soft mats	Strength	Sitting on the ground (on soft mats) with backs together and arms linked.	To wrestle your right shoulder (partner's left shoulder) to the ground. At the same time your opponent will be attempting to wrestle their right shoulder to the ground. Players must stay seated and not get to their feet.
Stand challenge (C)	P	None	Strength	Opponents facing each other, standing on right leg, holding left leg with left arm.	To push your opponent off balance. Players score 1 point when their opponent loses balance and touches the ground with their left foot. Swap legs after 3 trials.
Balloon keep-ups	P / I	Balloons	Aerobic	Played either as individuals or as partners. Players find some space holding their balloons.	To keep all of your balloons in the air without any falling to the ground within a set time period. Start with two balloons and introduce more to increase difficulty. For a progression individuals can form pairs and work together.
Ball catch challenge	I	Tennis balls	Strength	Players find their own space with one tennis ball	To throw your ball into the air, stand up and catch it again from different positions. Kneeling on one knee (level 1), kneeling on both knees (level 2), sitting (level 3), lying on back (level 4), lying on front (level 5).

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Wrestling challenge 1 (C)	P	Soft mats	Strength	Partner up with someone of similar stature. One player kneeling up on mat, other player kneeling on all fours next to partner.	Objective of player one is to flip partner onto his back. Objective of player two is to resist being flipped onto back from all fours.
Wrestling challenge 2 (C)	P	Soft mats	Strength	Partner up with someone of similar stature. One player lying on back, other player lying on top of them.	Objective of player one is to try to get from their back to their front. Objective of player two is to try and stop partner from getting off their back.
Human conveyor belt	T	Soft mats	Strength	Separate class into two teams. Players (except for the box) lie closely next to each other on their backs with arms to their sides (conveyor belt). The 'box' lies on his back across the midsection of the first player of the conveyor belt.	To get the box from one end of the conveyor belt to the other before the other team does without using arms. The team that gets their box off the end first wins.
Missing chair game	T	4 chairs / team	Strength	Separate class into teams of four players. Set up four chairs so that each of the players can sit down, with feet on the floor, and lie back onto the lap of the player next to them creating an interlocking structure. See below: 	Take the chairs away one by one from each team at the same team. The team that can maintain their position the longest wins.

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Line defence	T	Coloured braids	Aerobic	Set up playing area on a half court or grass equivalent. Separate class into two or four teams. Team 1 are defenders, team 2 are attackers 	Attacking team's objective is to get a player across the defending team's line (baseline of court). The defending team must prevent attacking players from getting across their line by tagging them. Tagged players are eliminated and can perform exercises while waiting for the next game. Attacking players can only be tagged once they leave their safe zone (centre line of court). Swap team roles after each point. For a progression have both teams attacking and defending at the same time.
Army roll classic catch	I	Soft mats, tennis balls	Aerobic	One player stands to the side of the mat. Their partner stands to the front facing their partner.	To perform an army roll and catch a tennis ball with increasing levels of difficulty. Perform a roll without catching (level 1); Perform a roll and pick up a ball that is placed on the mat (level 2); Catch a ball thrown by partner while performing a roll (level 3); Pick up ball that is rolled onto mat by partner while performing a roll (level 4).
Chinese stand up	P / T	None	Strength	Can be done either as partners or teams. Players sit down with their back to each other and arms linked.	Players must get to their feet from the floor without falling. To increase difficulty perform without arms linked.
Skipping challenge	I	Skipping ropes	Aerobic	Pair up students. Select a skipping skill (e.g. single unders, double unders, crossovers).	To perform as many of the set skill in a row as possible within the time limit (e.g. 1 min). Partner counts and keeps score, then pairs switch roles.

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Opposites	I	2 pairs of coloured cones	Aerobic	Use a centre line on a court or mark one out with cones. Mark out two ends with different coloured cones. Line up class on centre line	Call out a colour, direction (L/R), or number (1/2 or odds/evens). Players have to sprint to the end that is the opposite of the one called out. The last person to cross the line is eliminated. Eliminated players can perform some exercises while waiting for the next game. Try to trick the players by pointing to the wrong end.
Circle tug of war	T	None	Strength	Separate class into two or four teams. Players hold arms in monkey grip to create a circle around a mark on the floor.	Each team attempts to pull the other over the mark on the floor. Once completed reset and start again. Play First to 5 points and change players or teams over if one team is dominating the other.
Pairs or 3's med ball forcy backs	T	Medicine balls	Strength	Set up an appropriately sized playing area. Separate class into teams of pairs or 3's.	Players must throw the medicine ball over the oppositions line. The ball cannot be interfered with after a throw until it has touched the ground (no catching!).
Ab blast circle race	T	Balls	Strength	Separate the class into teams of about 5-6. Teams are seated with legs extended to form a circle with feet in the middle.	Players must get the ball around the circle by carrying the ball with their feet and passing it to the player's feet next to them. Make it a race between teams and increase the number of laps around the circle to increase difficulty.

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
Wheelbarrow race	P	Braids	Strength	Set up a start line and a row of braids at a distance from the line. Students in pairs.	One person is the wheelbarrow and the other is the pusher. Objective is to get to the other end, have the wheelbarrow put the braid over their head (while still in the wheelbarrow position) then make it back as quickly as possible. Swap roles when done or halfway through the race.
No-mat twister	I	None	Strength	Ensure each student has enough space	Call out specific body parts (e.g. left hand, right foot, head). Students must get themselves into a position where they can have these body parts touching the ground at the same time. Must be able to hold for 5 seconds. Start easy then make more difficult. Can be done as pairs also.
Steal the braid	P	Braids	Aerobic	Separate class into pairs. One student is the thief, the other is the protector. The protector has a braid hanging from the back of their shirt, tucked into their collar.	The thief has to try and steal the braid from the their partner. The protector has to avoid having their braid stolen. Swap roles after each point.
Dragons tail	T	None	Aerobic	Separate class into teams of 4-5. Players in each team in a single line with hands resting on each others' shoulders. One player at the front facing them 	The player at the front has to try and tag the player at the back. The other players have to move to try to prevent the front player from tagging the player at the back. Once back player is tagged or time is up each player moves up in the line. As a progression join teams together to create a longer tail.

Activity	P/I/T	Equipment	Aerobic / strength	Organisation	Objective
The monster	T	None	Strength	Set up a playing area approximately 20 m across. Separate class into teams of 4-5 players.	To get from one side to the other while only having 3 (or 4) points of contact on the ground at any one time. If teams have any more than 3 points of contact they must return to the start and try again.
Triangle tag	T	None	Aerobic	Separate class into teams of 4 players. 3 players form a triangle by holding arms. One player is the tagger.	The tagger must attempt to tag a player previously chosen. The triangle must move to protect their player from the tagger.
Indian chief	T	None	Strength	Separate class into two teams and have them stand in a circle. Select one person to stand away (the 'guesser') from the group and one person in the circle as the Indian chief.	The identity of the Indian chief is known to the circle but not to the guesser. The players in the circle must copy the movements of the Indian chief (squats, air punches etc), the guesser must guess the identity of the Indian chief. Progress to one large group to make it more difficult for the guesser.
5 star ball pass	T	Balls	Strength	Separate class into groups of 5. Players stand in a circle with 1 ball.	To bounce pass the ball to the player across from you to get the ball around the circle as many times as possible within the set time (e.g. 2 mins). After passing the ball, players must also complete a rep of an exercise (e.g. push up, squat etc).
Oz tag red rover	I	Braids or Oz tag belts	Aerobic	Set up a playing area. Select 2 players to be 'in'.	Players must make it to the other side without having their braids/belts removed. Those that do go to the middle for the next run.

Modified ball games

Game	Explanation
10 passes	Separate class into 4 teams. 2 games playing at once. The objective is for the team with the ball to get 10 consecutive passes. The team without the ball must prevent the opposition from doing so. Players cannot move once they have the ball in their hand. Once the ball is spoiled teams swap roles. Play for a set time period then swap teams. Incorporate fitness elements such as performing a specific skill (e.g. squat) on the whistle blast. The best technique gets the ball.
Offside touch	Played the same as regular touch football except that players can stand anywhere they want on the field. The ball can be passed in any direction but has to be passed backwards first after each play the play.
Forever ball	Played with a soccer ball. This game is a combination of soccer and touch football. When the ball is on the ground it is normal soccer rules. However, the ball can be caught from a kick or flicked up and caught by the player with the ball, in which case the game changes to touch football.
Hit and run paddle tennis / volleyball / badminton	Separate class into two or four teams (depending on resources). Halve each team and have the players stand to the side of their playing area next to the net. The objective is to get as many continuous hits over the net in a row as possible. Once a player hits the ball they move to the other side and line up for their next hit. The ball can only bounce once per side and has to land in the playing area. The team with the longest continuous rally in a set time wins.
Dog and bone	Separate the class into 4 teams on a basketball court. Each team is in a single line starting at centre court. The two teams on each half court are against each other. The position of the students in the line is their number. Place a basketball on a cone in the middle of the 3 point line. Call out a number. The students that have that number race to the ball and have a shot at the hoop. Once one player shoots the other player must be allowed to shoot. The winner of the point is the player that makes the shot first. After a shot is made return to the start and reset. Incorporate fitness while waiting to call a number and even include a set of cones outside the playing area as an agility course that must be finished first before going for the ball.
Continuous dodge ball	Played like regular dodge ball, players must attempt to hit opposing players with a ball to eliminate them. Players that are eliminated however can then move to the rear of the opposing team, behind the back boundary, and attempt to hit players from behind with balls that roll through.

Some other options include:

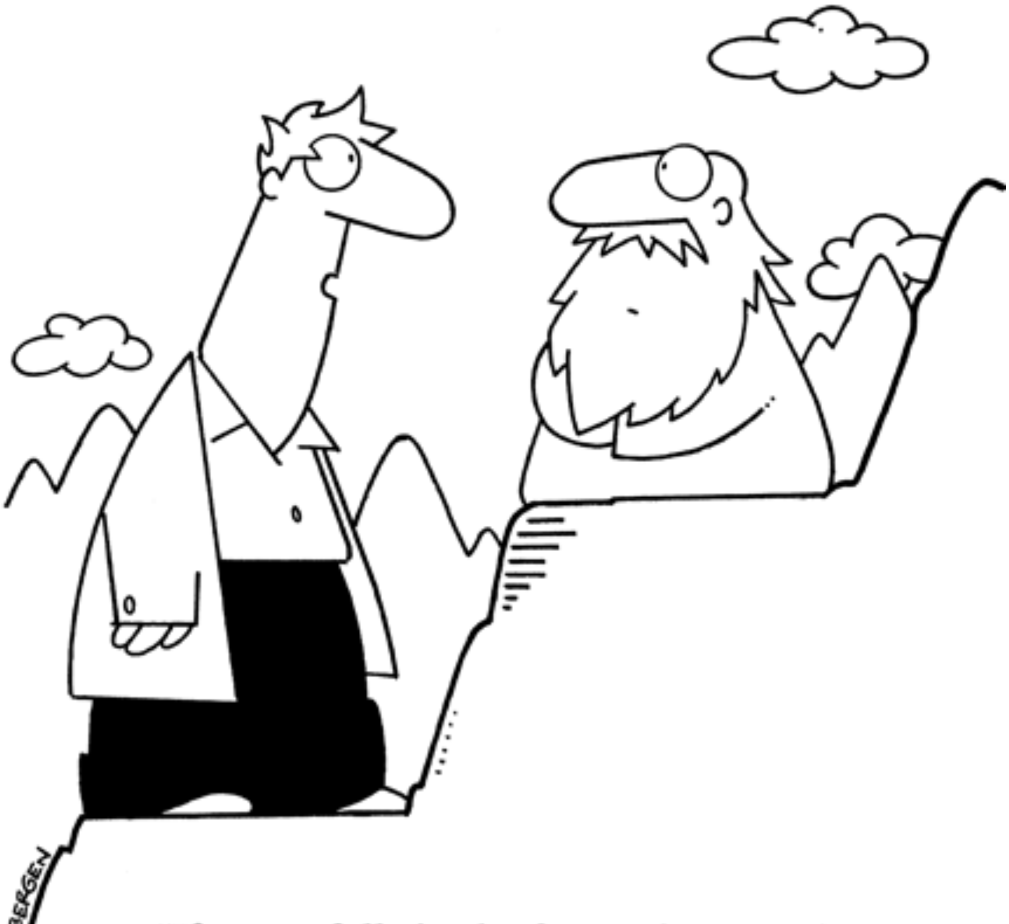
- Beach touch football
- 2-ball touch football
- Retreat touch football
- Pairs or 3's forcy backs
- Small sided ultimate Frisbee

Feel free to use others as well and look for ways to incorporate extra activity into the games – FITNESS INFUSION!

Appendix 12: Parent screen-time activity book and newsletters

Priority Research Centre for Physical Activity and Nutrition

Reducing youth screen-time



"If a tree falls in the forest, but you don't hear about it on Facebook, MySpace, YouTube or Twitter, did it really happen?"

SCREEN-TIME RULES

The rules that follow refer to 'recreational' screen-time (i.e. screen-time outside of school hours for the purposes of entertainment – not homework). Any of the following can be amended to suit one or more particular screen device(s) (e.g. gaming console, laptop, i Phone, i Pad etc.)

- No more than 2 hours per day spent using screens.
- No screens between _____ and _____ (e.g. between 3pm and 6pm)
- No screens after ________ (e.g. 10pm)
- No internet without permission.
- No screens before homework is completed.
- No screens while doing homework (unless computer is required for homework).
- Only 1 hour of computer use per day.
- Only 1 hour of video gaming per day.
- No screens in bedroom.
- No screens during dinner.

This list represents a number of options, which are available to you. You are not required to use all of the above rules. You have the choice of selecting one or a number of rules that suit your particular situation and that you feel comfortable using within your home.

MY SCREEN-TIME BEHAVIOUR CONTRACT



I AGREE TO:

________ hours of screen-time / day

OR

_________ hours of video games / day

_________ hours of TV / day

_________ hours of computer time / day

The benefits of achieving my screen-time goal(s) are:

____

____

____

When I successfully complete this contract, I will be rewarded by:

____

____

If I don't make the appropriate changes, I will have this consequence:

____

____

We will review this contract on this date: _________________

Child's signature: __________________ Date: ___________

Parent's signature: _________________ Date: ___________

Instructions:

This activity can be used to monitor the family's screen-time habits. Fill this out as a family. Each family member can record their own daily screen time.

- Fill in the amount of time spent using screens each day this week **outside of school hours.**
- Screen-time includes any time using a screen device for entertainment purposes (do not include time spent on screens doing homework)
- There is enough room for up to 5 family members to take part. Simply write your name in the top row and go down the column for each day of the week.
- Make sure you add up all the hours in the week and write the total number of screen-time hours in the row at the bottom.

	Hours of screen viewing					
Name:	Example					
Mon	3.5 hrs	hrs	hrs	hrs	hrs	hrs
Tues	2 hrs	hrs	hrs	hrs	hrs	hrs
Wed	3 hrs	hrs	hrs	hrs	hrs	hrs
Thurs	2.5 hrs	hrs	hrs	hrs	hrs	hrs
Fri	4 hrs	hrs	hrs	hrs	hrs	hrs
Sat	3.5 hrs	hrs	hrs	hrs	hrs	hrs
Sun	4.5 hrs	hrs	hrs	hrs	hrs	hrs
Total	23 hrs	hrs	hrs	hrs	hrs	hrs

How did you go?

Recommended weekly screen-time = 14 hours or less. Subtract 14 from your total to see how many hours of screen-time you need to reduce per week to match national guidelines.

Example: Total screen time = 23 hrs – 14 hrs = 9 hrs

- ❖ I need to reduce my weekly screen-time by 9 hours

Total screen-time = ________ hrs - 14 hrs = ________ hrs

- ❖ I need to reduce my weekly screen-time by ________ hrs

Teens & Screens

Welcome to 'teens & screens', a newsletter series aimed at helping parents reduce screen-time in the family home. Over the coming weeks these newsletters will provide you with important information, tips and strategies related to screen-use. This newsletter will provide you with some background information about the ATLAS program and an explanation of the features you will see in the coming series of newsletters. Lets get started!

What is this program all about?

This series of newsletters has been developed to support the Active Teen Leaders Avoiding Screen-time (ATLAS) program being conducted at your son's school. One of the main goals of the program is to try and reduce the amount of time that teenage boys spend sitting in front of screens. We feel that parents are key to achieving this goal.

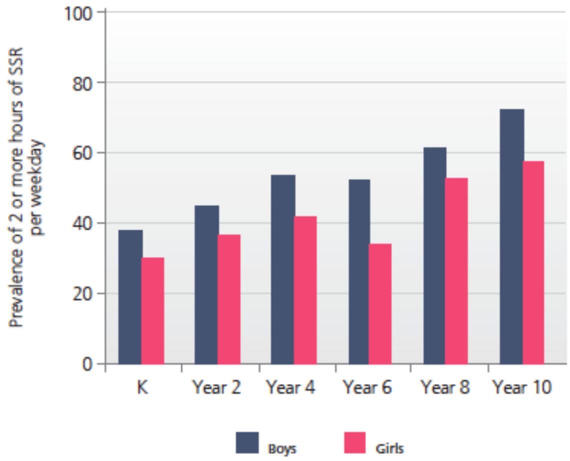
Screen-time defined

Screens are used for a wide variety of purposes including communication, entertainment and homework. When we refer to screen-time we are talking about recreational screen-use, **outside of school hours**, for the purposes of **entertainment.** *We are not trying to reduce screen-time for homework purposes (e.g. internet research for a project or typing up an assignment).*

Screen-time refers to:

- ✓ Watching TV / DVD's
- ✓ Playing video games on a console (e.g. Xbox), computer or portable device (e.g PSP).
- ✓ Using the computer for internet surfing or social media (e.g. Facebook/Twitter)
- ✓ Using a smartphone or tablet device (e.g. iPhone/ iPad).

Today's generation of young people are the first to grow up in such a screen-rich environment and rates of screen-use among youth are higher than ever before. The graph below shows the percentage of students from kindergarten to year 10 that exceed the national screen-time guidelines. You can clearly see a consistent increase in the percentage of students engaging in excessive screen-use across year groups. You can also see that across every age group boys spend more time on screens than girls!



Source: SPANS short report, 2010

Features of our newsletters

There will be a number of features, which you will notice in our newsletter series. Below is a brief description of what they mean:

Did you know?
Here you will be given up to date information from scientific studies on the consequences of excessive screen-use among youth.

Strategies to try
Here we will provide examples of strategies you can use to reduce your child's screen-time.

Avoiding conflict
This section provides tips to help avoid and manage any conflict that may arise.

Teens & Screens

Screen-time: An issue of balance

Screen-time is like junk food. A little bit isn't going to do too much harm. It's when it is done to excess that it becomes a problem. The issue with young people today (and even many adults!) is that they fail to realise when screen-use becomes excessive. When considering the screen-time of your son think about whether there is a balance between physical activity, schoolwork, socialising and screen-time.

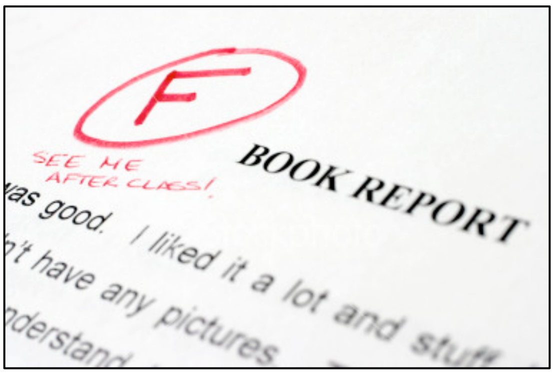
National guidelines recommend that adolescents spend no more than <u>2hrs per day</u> engaged in screen-based entertainment.

Did you know?

- Research has linked high screen use during adolescence to poor academic performance.
- According to one scientific study high screen-users during childhood and adolescence (i.e. >3hrs/day) were significantly less likely to get a post-school qualification, such as a university degree, by age 26 than low screen-users.

Strategies to try

Reducing screen-time starts with YOU. *Role modelling* responsible screen behaviour will ensure that you're not asking your son to do anything that you aren't willing to do yourself. So if you spend a bit too much time (>2hrs) in front of the TV or computer outside of work, be prepared to reduce your own screen-time too.



Screen-time rules

Rules and boundaries form a framework for appropriate behaviour. If you want to reduce your son's screen time you need to set and enforce screen-time rules. A list of examples can be found in the activity booklet provided with this newsletter. When setting a rule ensure that you:

- Explain the rule so that there are no misunderstandings. Ask your son to repeat back what is expected of him.
- Clearly outline the consequences if he does not follow the rule.
- Most importantly, make sure you follow through with the consequences you have mentioned if the rule is not adhered to.

Behaviour contract

A behaviour contract can be used to hold your son accountable for his screen-use. Have a discussion with your son about the restrictions you want to place and ask him to sign the contract to indicate that he agrees to the terms. A behaviour contract has been provided.

Avoiding conflict

Adolescence is a time when your son is becoming more independent. Conflict can arise in situations where teenagers feel they are being controlled. Your son will probably not welcome the idea of reducing his screen-time and this could easily become a cause for conflict. Always remember you are doing this to help him, not to punish or control him. Make sure that as the adult you speak calmly and always remain mature (even if your son loses his cool).

Teens & Screens

Sitting – the silent killer

Many people think that the inappropriate content on television programs, in video games, and on the Internet is the biggest concern regarding screen-time. Media content does have a part to play but there is a silent and unnoticed problem associated with screen use - *prolonged sitting*. Screen-time generally involves long periods of sitting still which requires almost no energy at all to do. This can have some pretty serious implications for physical health.

Did you know?

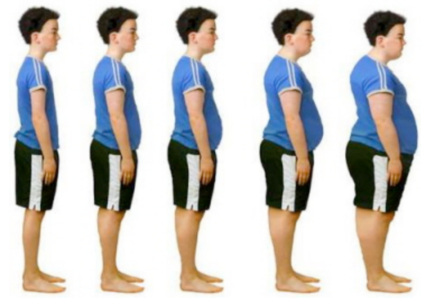
- Sitting makes you fat – Among people watching 3 hours of television per day rates of obesity are the same regardless of how much exercise they do.
- High screen-use during adolescence is linked to high cholesterol, a risk factor for heart disease.
- Boys spending 2 or more hours per day on screens have double the risk of abnormal insulin levels (a risk factor for type II diabetes) compared with those spending less than 2 hours.

Strategies to try

Screen-time not only makes you sit more it also takes up time that could otherwise be used for physical activity. Physical activity is very important for the healthy development of young people.

The afternoon period between the end of school and dinnertime is an ideal time to be outside of the house being active.

Create a screen-free time period during this time. Make it a family rule and be sure to enforce it. If it doesn't become a habit it will never take off.



Encourage your son to adopt active alternatives such as:

- ✓ Kicking a ball in the backyard
- ✓ Playing outside with the family pet
- ✓ Going for a walk
- ✓ Playing outside with siblings or friends
- ✓ Riding a bike
- ✓ Learning a new sport or fitness activity

Avoiding conflict

- Make sure you give reasons for your decisions to set and enforce screen-time rules.
- Try appealing to things he may find important.

For example: *physical activity helps build muscle and makes you look and feel good*.

Looking muscular and fit is an important concept for young males. Having something more valuable to do than screen-use might be more likely to persuade him to change.

Teens & Screens

Screen-time and sleep-time

Adequate sleep is important for all of us but it is of particular importance to teenagers. The growth and development associated with puberty occurs mostly during sleep and adolescents should be getting about 9-10 hours each night. Adequate sleep also ensures that teens are well rested for school the following day. Lack of sufficient sleep can cause irritability and can affect concentration and alertness in class. High screen-use has been shown to negatively impact both the amount and quality of sleep among young people.

Did you know?

- High screen-use is linked to poor sleep.
- Young people with a television in their bedroom spend about 1.5 hours a day longer using screens than those without.
- Teenagers with a TV, gaming console or computer in their bedroom are less likely to get sufficient sleep than those without.

Strategies to try

You can choose one or more of the following strategies depending on your situation and what you think will work best.

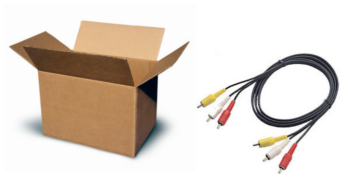
1) Create screen-free bedrooms.

Your son has no real need for a television or computer in the bedroom and removing it will encourage him to spend more time with the family.

2) Use a 'screen-box'

Find a medium sized box and collect all your son's screen devices (including mobile phone) from his bedroom before bedtime and store them in your own bedroom.

If removing the television, Xbox or PC is too difficult you can put the AV cables or power cords in the screen box. This will ensure that he is not watching or gaming while he should be asleep.



3) Set a curfew on evening screen-time

The stimulating images and even the *light* of a TV or computer screen can disrupt the body's natural 'winding down' process in the evening. This can make falling asleep more difficult. Create a curfew – a time when all screens are switched off for the night. Teenagers should be in bed by 10pm on weekdays in order to get the rest they require.

Avoiding conflict

Compare the following 2 statements:

1) "You spend too much time playing video games, go outside and do something active"

2) " I would like you spend less time playing video games. Why not go outside and do something active?"

The main point of each statement is the same but the second one seems a lot less confrontational. 'You-statements' will often cause people to become defensive. Try to use 'I-statements' instead. They are less likely to be met with a defensive attitude and will allow you to explain to your son why you want him to reduce his screen-time.

Teens & Screens

Screen-use and mental health

About 14% of Australian youth currently experience mental health problems of some kind. These problems include depressive feelings, anxiety and low self-esteem. Due to the nature of mental health problems many sufferers go unnoticed and even parents can be unaware that their children are experiencing mental health difficulties! Reducing screen-time and increasing physical activity are important goals for maintaining positive psychological health among adolescents.

Did you know?

- High screen-use is associated with anxiety and depression.
- Video gaming may be the most harmful screen-activity for adolescent mental health. One scientific study found that high levels of video gaming (rather than TV viewing) were significantly associated with feelings of psychological distress.
- Video gaming is also associated with problem behaviours such as aggression, delinquency and social withdrawal.

Strategies to try

Physical activity provides a lot of health-related benefits. It has also been shown to be one of the best treatments for mental health problems and is a great way for everyone to maintain positive psychological health.

- Set a daily time limit on video gaming (e.g. no more than 1 hour per day).
- Encourage physical activity as an alternative to screen-time. Health guidelines recommend young people engage in **at least 1 hour** of activity every day.
- Make screen-time = active time. Instead of remaining sitting during TV advertising breaks, get everyone to stand up. You can even add in some star jumps, push-ups, squats or lunges!

A final note

This will be the last newsletter in our series 'teens & screens'. We hope that the information and strategies provided have been informative and helpful. Managing youth screen-use is a difficult but necessary challenge and we congratulate you for taking these positive steps forward. Good luck in the future!

Appendix 13: Expert feedback and suggested amendments to the Resistance Training Skills Battery for adolescents

Resistance Training Skills Battery: Suggested amendments

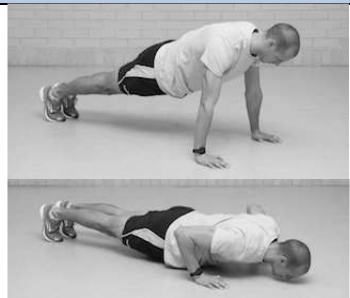
RT expert(s)	Exercise	Feedback	Suggested action
#1, #2	Squat	Use back squat rather than front squat.	Use body weight squat with arms extended forward at shoulder height. The exercise will no longer require a bar or PVC pipe.
#3	Squat	Additional criteria for squat (additional text in bold): 1. Feet are shoulder width or slight wider apart facing forward or slightly splayed. 2. Heels remain on floor throughout the movement 3. Back is kept straight and stable throughout the movement 4. Knees point in the same direction as feet during movement. 5. Lower hips until thighs are parallel to the floor at the bottom of the movement.	My comments to these: 1. Feet might be angled slightly outwards. It is more important that knees point in same direction as feet during movement. 2. Not necessary. 3. Not necessary. 4. Not necessary. We are using criteria to assess skill competency rather than guide their execution.
#4	Squat	Include criterion that knees don't go over toes	The following performance criterion has been added: "Heels remain on floor throughout the movement"
#1	Lunge	Use front on video analysis to assess lateral displacement in the lunge.	All skills will be analyzed using front and side-on video cameras.
#3	Lunge	1. What happens to arms? 2. "Knee bends in a straight line with front foot"- criteria is unclear	1. Lunge will be demonstrated with hands on hips. This would be included in the picture but not in the performance criteria, as lunges can be done holding dumbbells or with a barbell on shoulders. 2. Change to "There is alignment between hip, knee and foot of each leg'.
#2	Lunge	The following suggestions included: 1. Step forward with first leg landing with your heel then forefoot, ensure you have stepped far enough that you have approximately 90 degrees of knee bend upon your lunge. 2. Finish by driving off the heel and returning to an upright position (or if you're doing a walking lunge) bring back leg forward 3. Assuming you were going for a traditional lunge but some description of how to finish should be put such as above step 5	1. Changed to "Takes an exaggerated step forward and lands heel first". 2/3. Changed to "Returns to starting position in one movement". Additional point added: "There is alignment between hip, knee and foot of each leg". *Note.* We need to include a comment in the methods section explaining that the performance criteria were devised to assess competency, not to be used as instructions for completing the exercise. Therefore, all of the criteria were required to be "observable".
#5	Push-up	I think that we should give participants the option to complete their push-ups on their toes or their knees.	Suggested wording: "Provide demonstrations of modified (on knees) and full (on toes) push-ups. Instruct the participant to perform 4 modified or full push-ups".
#6	Push-up	Place hands directly under the shoulders to allow for comparison with the Canadian Society for Exercise Physiology fitness and health tests.	Change to "Hands are shoulder width or slightly wider apart".
#3	Push-up	"Shoulders are held down and away from ears"- not sure about this	This criterion is needed to assess scapular control, a key indicator of successful performance of a push up.

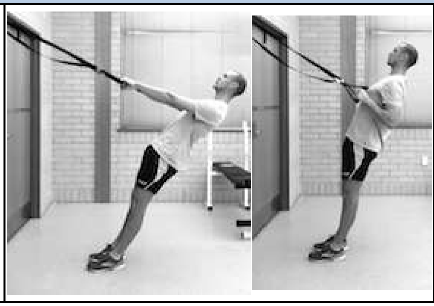
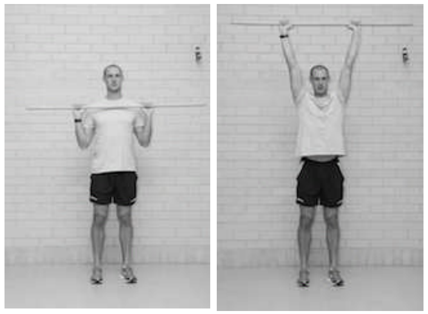
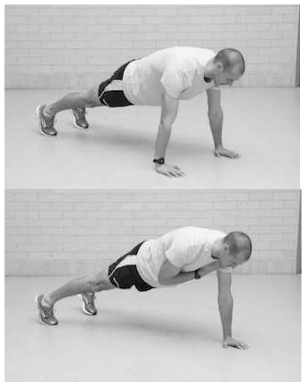
		criteria	Change to the following: "Shoulders are held down and away from ears (shoulders are not shrugged)"
#7	Push-up	Existing criterion- "Body is lowered in a controlled manner until elbows are at a 90 degree angle to the ground"- Is this about the elbows or the controlled manner?	Remove the "controlled manner" part because we will assess participants on their position at the bottom of the push-up. It is important to remember that this is a skill check list not an instruction guide for skills.
#2	Push-up	"To make this chest strength instead of just triceps strength, I would specify the elbow position during lowering as well, e.g. Hands are slightly wider than shoulder width apart. Elbows are out."	I don't think that we need to specify the elbow position. We are assessing upper body pushing movement, which can involve the following muscles: chest, triceps and anterior deltoids. Therefore, elbow position may vary.
#1, #7	Suspended row	Increase the angle from 45 to 60 for the suspended row for students who cannot complete task.	Description is changed to the following: "Instruct the participant to perform 4 repetitions starting from a 45-60 degree body angle with knees bent".
#3	Suspended row	Additional criteria for row (additional text in bold): "Chest is pulled upwards to touch handles or bar **(elbows-description of chicken wing)"**	We are assessing an upper body pulling movement. Elbow position will determine which muscle groups are isolated. Therefore, elbow position may vary.
#1	Suspended row	Include a vertical pulling test	The suspended row is a more appropriate "pulling exercise". Many children will not be able to complete a chin-up.
#1	Shoulder press	Confusion on exercise	Change name to "Standing overhead press" and include picture.
#3	Shoulder press	Standing or seated shoulder press?	As above.
#2	Shoulder press	"Bar starts at chest height and is pressed upward, keeping the chin tucked, until arms are fully extended. The bar should be overhead at the top of the lift".	"Keeping the chin tucked" is a teaching cue. We have added the following criterion: "Bar is overhead at the top of the lift".
#6	Push-up hold and chest touches	Confusion on exercise	Change name to "front support with chest touches" and include pictures.
#6	General comment	Include an exercise directly targeting the trunk/core	I would argue that the front support with chest touches addresses this concern. However, we need to make it explicit in the rationale and description of the battery that we have included exercises that address the major body movements and body parts.
#2, #4, #7, #8	General comment	Consistency on repetitions	All exercises will involve 4 repetitions (bi-lateral exercises, e.g. lunge will involve 2 repetitions for each limb). This will provide participants with sufficient opportunity to demonstrate their "best technique", without introducing a substantial fitness requirement.
#8	General comment	Scoring protocol	The following has been added to the scoring sheet: All skills will be video analysed and scoring will be based on their "best repetition technique". Participants will be awarded a 1 for each performance criteria that is correctly demonstrated. If the participant does not perform the component correctly, they will be assigned a score of 0. Scores of 0.5 will not be awarded.
#8	General	Utility of measure- who is it for?	The following will be added to manuscript describing the

	comment		rationale for the skill battery: The battery has been designed for the general population, but should be appropriate for some clinical groups (e.g. overweight/obese adolescents). Therefore, the exercises need to be "entry level". I think that the most important use of the battery will be to evaluate school- and community-based resistance training programs by teachers/practitioners and researchers. For researchers, it is important to include baseline and post-test assessments, but teachers might use it at the end of PE unit of work (on resistance training) to evaluate students' skill levels.
#2, #3, #6	General comments	Inclusion of pictures to illustrate technique	Although the study participants will not see the pictures, I suggest that we include pictures to assist those assessing the skills.
#3	General comment	Breathing hasn't been mentioned in the instructions.	Breathing could be considered part of correct technique, in which case we will not we should not be instructing the participants. We could instruct participants to breath out during the concentric phase (the difficult part) and in on the eccentric phase. Thoughts?

Appendix 14: The Resistance Training Skills Battery for adolescents

Resistance Training Skills Battery (RTSB)

Skill	Materials	Directions	Skill Depiction	Performance Criteria	Set 1	Set 2	Score
1. Body weight squat	Flat surface	Provide a demonstration of the movement. Instruct the participant to perform 4 repetitions of the exercise with the arms extended forward at shoulder height. Repeat a second trial.	 	1. Feet are shoulder width or slightly wider apart and facing forward			
				2. Back is kept straight and stable throughout the movement			
				3. Knees point in the same direction as feet during movement			
				4. Heels remain on floor throughout the movement			
				5. Thighs are parallel to the floor at the bottom of the movement			
						Skill Score	
2. Push-up	Flat surface	Provide demonstrations of modified (on knees) and full (on toes) push-ups. Instruct the participant to perform 4 modified or full push-ups. Repeat a second trial.		1. Hands are shoulder width or slightly wider apart			
				2. Head, back and hips are held in a straight line throughout the movement			
				3. Body is lowered until elbows are at a 90 degree angle			
				4. Shoulders are held down and away from ears (shoulders are not shrugged)			
						Skill Score	
3. Lunge	Flat surface	Provide a demonstration of the movement with hands on hips. Instruct the participant to perform 4 repetitions on the same leg. Second trial is completed with the other leg.	 	1. Takes an exaggerated step forward and lands heel first			
				2. Torso is kept upright and stable at all times (no twisting)			
				3. Knee of rear leg is almost touching the floor (approx. 10cm)			
				4. There is alignment between hip, knee and foot of each leg			
				5. Returns to starting position in one movement			
						Skill Score	

4. Suspended row	Flat surface and bar suspended at hip height or suspension straps with an anchor point	Provide a demonstration of the movement. Instruct the participant to perform 4 repetitions starting with their upper body at a 45-60 degree angle. Repeat a second trial.		1. Straight line through head and back			
				2. Body is pulled upwards to touch handles or bar at chest height			
				3. Arms are fully extended in the bottom position			
				4. No bending at the hips			
						Skill Score	
5. Standing overhead press	Flat surface and barbell	Provide a demonstration of the movement. Instruct the participant to perform 4 repetitions. Repeat a second trial.		1. Bar is gripped slightly wider than shoulders			
				2. Back is kept straight and stable throughout movement			
				3. Bar starts at chest height and is pressed upward until arms are fully extended			
				4. Bar remains parallel to the ground throughout the movement			
				5. Bar is overhead at the top of the lift			
						Skill Score	
6. Front support with chest touches	Flat surface	Provide a demonstration of the movement. Instruct the participant to perform 2 repetitions per side alternating sides each repetition. Repeat a second trial.		1. Straight line through legs, hips, shoulders and head			
				2. Feet are approximately shoulder width apart			
				3. Minimal rotation of body while changing hand placement (approx. 10cm is acceptable)			
				4. Both feet remain on the ground throughout the entire trial			
				5. Chest touches are performed in a controlled manner			
						Skill Score	
						Resistance Training Skill Quotient	

Appendix 15: Contribution statements for included chapters

Statement of contribution (Chapter 3)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sports Medicine*. 2014; 44(9), 1209-1223.

Dr. Narelle Eather Date: 22/01/15

Prof. Philip J. Morgan Date: 22/01/15

Prof. Ronald C. Plotnikoff Date: 22/01/15

Prof. Avery D. Faigenbaum Date: 23/01/15

Prof. David R. Lubans Date: 22/01/15

Associate Prof. Rosalind Smith Date: 02/02/15
Assistant Dean (Research Training)

Statement of contribution (Chapter 4)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Lubans DR, **Smith JJ**, Harries SK, Barnett L, Faigenbaum AD. Development, test-retest reliability and construct validity of the Resistance Training Skills Battery. *Journal of Strength and Conditioning Research*. 2014; 28(5): 1373-1380.

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Prof. David R. Lubans Date: 22/01/15

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Mr. Simon Harries Date: 22/01/15

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Dr. Lisa Barnett Date: 23/01/15

____

Prof. Avery D. Faigenbaum Date: 23/01/15

____

Associate Prof. Rosalind Smith Date: 02/02/15
Assistant Dean (Research Training)

Statement of contribution (Chapter 5)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: An obesity prevention intervention for adolescent boys from schools in low-income communities. *Contemporary Clinical Trials*. 2014; 37(1): 106-119.

Prof. Philip J. Morgan Date: 22/01/15

Prof. Ronald C. Plotnikoff Date: 22/01/15

Dr. Kerry A. Dally Date: 29/01/15

Prof. Jo Salmon Date: 23/01/15

Prof. Anthony D. Okely Date: 23/01/15

Ms. Tara L. Finn Date: 28/01/15

Mr. Mark J. Babic　　Date: 22/01/15

Dr. Geoffrey Skinner　　Date: 22/01/15

Prof. David R. Lubans　　Date: 22/01/15

Associate Prof. Rosalind Smith　　Date: 02/02/15
Assistant Dean (Research Training)

Statement of contribution (Chapter 6)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescent boys in low-income communities. *Pediatrics*. 2014; 134(3): e723-e731.

Prof. Philip J. Morgan Date: 22/01/15

Prof. Ronald C. Plotnikoff Date: 22/01/15

Dr. Kerry A. Dally Date: 29/01/15

Prof. Jo Salmon Date: 22/01/15

Prof. Anthony D. Okely Date: 23/01/15

Ms. Tara L. Finn Date: 28/01/15

Prof. David R. Lubans Date: 22/01/15

Associate Prof. Rosalind Smith Date: 02/02/15

Assistant Dean (Research Training)

Statement of contribution (Chapter 7)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Lubans DR, **Smith JJ**, Skinner G, Morgan PJ. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Frontiers in Public Health*. 2014;2:1-11.

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Prof. David R. Lubans Date: 22/01/15

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Dr. Geoffrey Skinner Date: 22/01/15

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Prof. Philip J. Morgan Date: 22/01/15

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Associate Prof. Rosalind Smith Date: 02/02/15

Assistant Dean (Research Training)

Statement of contribution (Chapter 8)

I attest that Research Higher Degree candidate Jordan James Paul Smith contributed substantially in terms of study concept and design, data collection and analysis, and preparation of the following manuscript:

Smith JJ, Morgan PJ, Plotnikoff RC, Stodden D, Lubans DR. Mediating effects of resistance training skill competency on health-related fitness and physical activity: The ATLAS cluster randomised controlled trial. *Journal of Sports Sciences*. 2015; (In press).

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Prof. Philip J. Morgan Date: 22/01/15

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Prof. Ronald C. Plotnikoff Date: 22/01/15

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Associate Prof. David Stodden Date: 22/01/15

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Prof. David R. Lubans Date: 22/01/15

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Associate Prof. Rosalind Smith Date: 02/02/15
Assistant Dean (Research Training)