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Title: Improvements in fundamental movement skill competency mediate the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children

Running title: Mediators of the SCORES cluster RCT

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Abstract

Background: Studies have identified a positive association between fundamental movement skill competency and physical activity in children, however the causal pathways have not been established.

Objective: To determine if changes in fundamental movement skill competency mediated the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children.

Methods: Eight primary schools (25 classes) and 460 children (aged 8.5 ± 0.6 , 54% girls) were randomized to the SCORES intervention or control group for the 12-month study. Outcomes were accelerometer-determined moderate-to-vigorous-physical-activity (MVPA) and cardiorespiratory fitness. Hypothesized mediators were actual fundamental movement skill competency and perceived sport competence. Mediation analyses were conducted using multi-level linear analysis in MPlus.

Results: From the original sample, 138 (30.0%) and 370 (80.4%) children provided useable physical activity and cardiorespiratory fitness data at post-test assessments. There were significant treatment effects for locomotor skills and overall fundamental movement skills. Changes in MVPA were associated with changes in object-control skills, overall fundamental movement skills and perceived competence. Overall fundamental movement skills had a significant mediating effect on MVPA ($AB=2.09$, $CI=0.01-4.55$). Overall fundamental movement skills ($AB=1.19$, $CI=0.002-2.79$) and locomotor skills ($AB=0.74$, $CI=0.01-1.69$) had a significant mediating effect on cardiorespiratory fitness.

Conclusion: Actual but not perceived movement skill competency mediated the effect of the SCORES intervention on physical activity and cardiorespiratory fitness.

Introduction

The physical, social, cognitive and psychological benefits of regular participation in physical activity for children are well established (Janssen & LeBlanc, 2010).

Moreover, high cardiorespiratory fitness in children is associated with a reduction in the prevalence of cardiovascular risk factors (Andersen et al., 2006; Weiss et al., 2004). However, many children do not participate in physical activity of adequate volume and intensity to acquire the associated physical and psychological health benefits (Hallal et al., 2012). These physical activity and cardiorespiratory fitness trends in childhood often track into adolescence and adulthood (Cleland, Dwyer, & Venn, 2012; Ortega, Ruiz, Castillo, & Sjöström, 2008; President's Council on Physical Fitness and Sports, 2001), emphasizing the need to find effective strategies for increasing physical activity and cardiorespiratory fitness in young people.

The school setting is an ideal environment for the promotion of physical activity and cardiorespiratory fitness (Centers for Disease Control & Prevention, 2011; Dobbins, De Corby, Robeson, Husson, & Tirilis, 2009), and numerous school-based physical activity and cardiorespiratory fitness interventions have been evaluated (Kriemler et al., 2011). Although school-based interventions have achieved some level of success (Kriemler, et al., 2011), there is limited understanding on the causal mechanisms of behavior change. Mediation analyses may assist in explaining intervention effects by identifying the mechanisms of behavior change. In physical activity interventions, mediators are the intervening causal variables necessary to complete the pathway from the intervention to the outcome of interest (Bauman, Sallis, Dzewaltowski, & Owen, 2002). Despite its importance, limited studies have assessed mediators of physical activity and cardiorespiratory fitness in interventions among children, and there is large variability in the design and quality of these studies (Lubans, Foster, & Biddle, 2008;

van Stralen et al., 2011). In a recent review, on the basis of limited studies, self-efficacy and intention were found to be the most relevant mediators for physical activity interventions (van Stralen, et al., 2011). Indications for a mediated effect of self-regulation, intrinsic motivation, enjoyment, perceived benefits, proxy efficacy and autonomy support on physical activity interventions were also found. However, the majority of studies were conducted in secondary schools. In addition, many studies (Lubans, et al., 2008; van Stralen, et al., 2011) have used self-report measures of physical activity, which are limited by children's ability to accurately recall their behaviors and generally have low levels of validity and reliability in youth populations (Chinapaw, Mokkink, van Poppel, van Mechelen, & Terwee, 2010). The review identified that more high-quality research into relevant mediators in children is needed (van Stralen, et al., 2011).

Fundamental movement skills are considered the 'building blocks' for movement in a range of sports and physical activities. Fundamental movement skills include locomotor (e.g., running and jumping), object-control (e.g., throwing and kicking) and stability (e.g., balancing and twisting) skills (Gallahue & Ozmun, 2006). In a recent review, fundamental movement skill competency was found to be significantly associated with physical activity and cardiorespiratory fitness in youth (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). In addition, lack of perceived competence in the physical domain is associated with lower levels of physical activity in children and adolescents (Babic et al., 2014; Raudsepp, Liblik, & Hannus, 2002; Stodden et al., 2008). Indeed, Stodden et al. (2008) have proposed a model suggesting that the development of actual fundamental movement skill competency is a primary underlying mechanism that determines physical activity engagement. While they acknowledge that actual fundamental movement skill competency interacts with other factors such as perceived competence and health-related fitness,

they contend that actual competence is largely responsible for participation and persistence in physical activity among young people (Stodden, et al., 2008).

Although numerous cross-sectional and longitudinal studies have identified a positive association between fundamental movement skill competency and physical activity and cardiorespiratory fitness in young people (Lubans, et al., 2010), the causal pathways of influence have not been established in experimental studies.

Therefore, the primary aim of the current study was to determine if changes in fundamental movement skill competency mediated the effect of the Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) intervention on physical activity and cardiorespiratory fitness in children attending primary schools in low-income communities. The secondary aim of the study was to determine if changes in perceived competence mediated the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children attending primary schools in low-income communities. In a cluster randomized controlled trial (RCT), the SCORES intervention resulted in significant group-by-time effects for moderate-to-vigorous physical activity (MVPA), cardiorespiratory fitness and overall fundamental movement skill competency, which have been described in detail elsewhere (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014).

Methods

Study design

The design and methods of the SCORES cluster randomized controlled trial (RCT) have been reported in detail elsewhere (Lubans et al., 2012). The design, conduct, and reporting of this cluster RCT adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for group trials (Campbell, Elbourne, & Altman, 2004) and was registered with the Australia and New Zealand Clinical Trials registry (ACTRN12611001080910). Ethics approval for this study was

obtained from the Human Research Ethics Committees of the University of Newcastle, Australia and the New South Wales (NSW) Department of Education and Communities. School principals, teachers, parents and study participants provided written informed consent. Data for this study were used from the baseline (conducted February through March 2012) and post-test (12-months post baseline; conducted February through March 2013) assessments.

Setting and participants

Eight low socio-economic status (SES) government primary schools (25 classes) from the Newcastle area, NSW, Australia identified using the Socio-Economic Indexes for Areas (SEIFA) index of relative socioeconomic disadvantage (Australian Bureau of Statistics, 2011) with a SEIFA index of ≤ 5 (lowest 50%) consented to participate (50% consent rate). A total of 460 students (Grades 3 and 4; aged 7 to 10 years) at the study schools consented to participate (78% consent rate). Following baseline assessments, the eight schools were match-paired (i.e. 4 pairs of schools) based on their size and SES (based on post-code of school). Pairs of schools were then randomized to control or intervention conditions by an independent researcher using a computer-based random number producing algorithm. Assessors were blind to treatment allocation at baseline but not at follow-up assessments.

Study arms

SCORES was a 12-month multi-component physical activity and fundamental movement skill intervention for primary schools in low-income communities. A detailed description of the SCORES intervention has been reported previously (Lubans, et al., 2012). Briefly, the socio-ecological model (McLeroy, Bibeau, Steckler, & Glanz, 1988) provided a framework for the intervention and the intervention components included teacher professional learning, student leadership, school committee and physical activity policies, provision of physical activity

equipment, parental engagement (newsletters, parent evening, and fundamental movement skill homework) and school-community sport and physical activity links. The control schools were requested to follow their usual physical education and school sport program.

Outcomes

Data collection was conducted at the study schools by trained research assistants. For consistency and accuracy, a protocol manual, which included specific instructions for conducting all assessments, was developed to standardize procedures and for quality assurance. The same research assistants were used across all time-points.

Physical activity

Physical activity was assessed using triaxial ActiGraph GT3X+ accelerometers (ActiGraph, LLC, Fort Walton Beach, FL). Trained research assistants, adhering to standardized accelerometer protocols (Trost, McIver, & Pate, 2005), fitted the accelerometers and explained the monitoring procedures to participants. Participants wore accelerometers during waking hours for seven consecutive days, except while bathing and swimming. MeterPlus version 4.3 software (Santech Inc., San Diego, US) was used to analyze accelerometer data. Data were collected and stored in 10-second epochs with a frequency of 30 Hz. Valid wear time for total physical activity was defined as a minimum of three weekdays and a weekend day with at least eight hours (480 minutes/day) of total wear time recorded (Cain, Sallis, Conway, Van Dyck, & Calhoun, 2013). Non-wear time was defined as strings of consecutive zeroes equating to 20 minutes (Cain, et al., 2013). The mean activity counts per minute (CPM) were calculated; activity thresholds were used to calculate time spent in sedentary (≤ 25 counts), light (26-573 counts), moderate (574–1002 counts) and vigorous (≥ 1003 counts) activity (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008).

Cardiorespiratory Fitness

Cardiorespiratory fitness was assessed using the 20 meter Multistage Fitness Test (Leger & Lambert, 1982). The 20 meter Multistage Fitness Test is a valid and reliable test to assess cardiorespiratory fitness in children (Ruiz et al., 2011).

Participants were required to run back and forth between two lines over a 20 meter distance within a set time limit. Running speed started at 8.5 km/hour and increased by 0.5 km/hr each minute using the multistage test cadence CD. Participants were required to run in a straight line and to place one foot over the 20 meter line before the next beep. The test was completed when a participant failed to reach the line for two consecutive shuttles. Scores were recorded as the level and shuttle reached, which was converted to the number of 20 meter laps completed to provide a continuous variable for analysis.

Hypothesized mediators

Fundamental movement skill competency

Fundamental movement skill competency was assessed using the Test of Gross Motor Development 2 (TGMD-2) (Ulrich, 2000). This test has been established as a valid and reliable assessment of fundamental movement skill competency (Ulrich, 2000). The TGMD-2 includes six locomotor (i.e., run, gallop, hop, leap, horizontal jump, slide) and six object control (i.e., striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll) skills. Participants performed each skill twice and skills were video-taped for assessment. Each skill includes several behavioral components. If the participant performed a behavioral component correctly they received a score of 1; if they performed it incorrectly they received a 0. This procedure was completed for each of the two trials, and scores were summed to obtain a total raw skill score. The raw skill scores were added to obtain a raw locomotor subtest score and a raw object-control subtest score, which were then

added to obtain a raw overall fundamental movement skill score (Ulrich, 2000). Inter-rater reliability (98% agreement rate) and intra-rater reliability (97% to 99% agreement rate) were established for fundamental movement skill scores using pre-coded video tapes before movement skills were assessed by three assessors. Kappa values were also calculated to take into account agreement beyond chance. These were 0.97 (95% CI, 0.96 to 0.98) for inter-rater reliability and ranged from 0.94 (95% CI, 0.91 to 0.97) to 0.98 (95% CI, 0.97 to 0.99) for intra-rater reliability.

Perceived sport competence

Perceived sport competence was assessed using the perceived competence sub-scale from Harter's Self-Perception Profile (SPP) (Harter, 1985b). The SPP uses a four-choice structured alternative format to reduce socially desirable responses.

Participants first decide which of the two statements best describes them and then choose whether the statement is '*sort of true*' or '*really true*' for them. Each item was scored from 1 (*low perceived sport competence*) to 4 (*high perceived sport competence*). Scores were summed to obtain a total score for perceived sport competence.

Demographics and weight status

Participants completed a questionnaire to obtain demographic information including sex, age, and suburb. The suburb of the child's residence was used to determine their socio-economic status (SES) using the SEIFA index of relative socioeconomic disadvantage (Australian Bureau of Statistics, 2011). Height was recorded to the nearest 0.1 cm using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia). Weight was measured in light clothing without shoes using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo Japan) to the nearest 0.1 kg. Body mass index (BMI) was calculated using the standard

equation ($\text{weight}[\text{kg}]/\text{height}[\text{m}]^2$) and BMI-z scores were calculated using the 'LMS' method (Cole, 2000).

Statistical analyses

IBM SPSS Statistics for Windows (Version 20, SPSS Inc., IBM Corp., Armonk, NY) was used to analyze the difference between groups at baseline, and differences between those who completed the study and those who did not. Intervention effects and single mediation analyses were conducted using multi-level linear analysis in MPlus (Version 7.2, Muthen and Muthen). Two levels were defined in the multi-level analyses: 1) student and 2) class. All analyses were adjusted for participants' sex, age, BMI-z score, SES and baseline values, which were included as covariates. Analyses were conducted for participants who provided useable data at baseline and post-test.

The product-of-coefficient mediation analysis was conducted and consisted of three stages: Stage 1, the action theory test, was calculated by regressing the hypothesized mediators onto treatment condition (A coefficient). Stage 2, the conceptual theory test, involved regressing physical activity and cardiorespiratory fitness onto treatment condition and the hypothesized mediators (B coefficient). This model also generates the direct effect of the intervention on physical activity and cardiorespiratory fitness after controlling for the mediators (C' coefficient). In stage 3, the R mediation package developed by Tofighi and MacKinnon (Tofighi & MacKinnon, 2011) was used to test the significance of the product-of-coefficients (AB) by computing the confidence intervals for the mediated effect on the basis of the distribution-of-product method. This approach is recommended for small samples and has more power than traditional mediation tests, such as the Baron and Kenny test, which requires a much larger sample size (Fritz & MacKinnon, 2007). For a variable to satisfy the criteria for mediation, the 95% confidence intervals for

the product-of-coefficients (AB) must not include zero. The proportion of the total effect that was mediated was also calculated $[AB/(C' + AB)]$.

Results

Overview

Eight schools (25 classes) including 460 children (199 children in intervention group and 261 in control group) participated in the SCORES study. The mean (SD) age of participants was 8.5 (SD = 0.6) years, 54.1% of the sample were girls and 97.6% spoke English at home. Retention rate at post-test for physical activity was 30.0% (265 did not provide valid data, 42 participants left the schools, 12 participants absent and 3 participants withdrew from the study), cardiorespiratory fitness was 80.4% (42 participants left the schools, 33 arrived late or left school early on day of assessment, 12 participants absent and 3 participants withdrew from the study), locomotor skills was 83.0% (42 participants left the schools, 21 arrived late or left school early on day of assessment, 12 participants absent and 3 participants withdrew from the study), and object-control skills were 75.0% (58 arrived late or left school early on day of assessment, 42 participants left the schools, 12 participants absent and 3 participants withdrew from the study). Participants with a baseline assessment but no post-test assessment did not differ from the remaining participants in terms of sex, age, physical activity, object-control skills or cardiorespiratory fitness (all $p > 0.05$). Participants who did not complete post-test assessment had lower locomotor skill competency at baseline ($p = 0.002$) compared to those who completed post-test assessments.

Intervention effects for physical activity, cardiorespiratory fitness and fundamental movement skill competency have been reported previously (Cohen, et al., 2014). In summary, using linear mixed models, at post-test (12-months post baseline), significant group-by-time interaction effects were found for daily

moderate-to-vigorous physical activity (MVPA) (adjusted mean difference, 12.7 MVPA mins/day; SE, 3.8; $p=0.008$), cardiorespiratory fitness (5.4 laps; SE, 1.6; $p=0.003$), and overall fundamental movement skill competency (4.9 units; SE, 2.4; $p=0.045$). No significant group-by-time effects were found for locomotor skills, object-control skills or perceived sport competence.

Mediation effects for physical activity as the outcome

Action theory test

Mediation results for physical activity (MVPA minutes) as the outcome are presented in Table 1. The action theory test revealed a significant beneficial intervention effect for locomotor skills ($A=1.76$, $SE=0.88$, $p=0.044$) and overall fundamental movement skills ($A=4.09$, $SE=2.08$, $p=0.049$). There were no significant effects for object-control skills or perceived competence ($p>0.05$).

Conceptual theory test

The results from the conceptual theory test showed a significant relationship between post-test object-control skills ($B=0.86$, $SE=0.15$, $p=0.000$), overall fundamental movement skills ($B=0.51$, $SE=0.10$, $p=0.000$), perceived sport competence ($B=0.48$, $SE=0.36$, $p=0.027$) and MVPA levels, adjusting for baseline. The relationship between locomotor skills and MVPA levels approached significance ($B=0.49$, $SE=0.26$, $p=0.056$).

Significance test of mediated effect

Overall fundamental movement skill competency mediated the effect of the intervention on MVPA ($AB=2.09$, 95% $CI=0.01$ to 4.55 , proportion=23%).

Locomotor skills, object-control skills and perceived sport competence did not satisfy the criteria for mediation.

Mediation effects for cardiorespiratory fitness as the outcome

Action theory test

Mediation results for cardiorespiratory fitness as the outcome are presented in Table 2. The action theory test revealed a significant beneficial intervention effect for locomotor skills ($A=1.76$, $SE=0.88$, $p=0.044$) and overall fundamental movement skills ($A=4.09$, $SE=2.08$, $p=0.049$). There were no significant effects for object-control skills or perceived competence ($p>0.05$).

Conceptual theory test

The results from the conceptual theory test showed a significant relationship between post-test locomotor skills ($B=0.42$, $SE=0.11$, $p=0.000$), overall fundamental movement skills ($B=0.29$, $SE=0.08$, $p=0.000$), perceived sport competence ($B=0.55$, $SE=0.15$, $p=0.000$) and cardiorespiratory fitness, adjusting for baseline. The relationship between object-control skills and cardiorespiratory fitness approached significance ($B=0.24$, $SE=0.12$, $p=0.050$).

Significance test of mediated effect

Overall fundamental movement skill competency ($AB=1.19$, 95% CI=0.002 to 2.76, proportion=22%) and locomotor skills ($AB=0.74$, 95% CI=0.01 to 1.69, proportion=15%) mediated the effect of the intervention on cardiorespiratory fitness. Object-control skills and perceived sport competence did not satisfy the criteria for mediation.

Discussion

The primary aim of this study was to determine if changes in fundamental movement skill competency mediated the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children attending primary schools in low-income communities. This study demonstrated that overall fundamental movement skill competency mediated the effect of the SCORES intervention on physical activity and cardiorespiratory fitness. To the authors' knowledge, this is the first

study to explore the mediating effects of fundamental movement skill competency within the context of a successful physical activity intervention.

SCORES was a school-based multi-component intervention that resulted in a significant intervention effect for children's MVPA, cardiorespiratory fitness and fundamental movement skill competency (Cohen, et al., 2014). These results provide further evidence for the effectiveness of school-based multi-component intervention strategies that combine educational, curricular and environmental elements in the promotion of physical activity and cardiorespiratory fitness in children. Such interventions are built on the assumption that changes at the individual, social or environmental levels will result in behaviour change. However, few studies conduct mediation analyses to identify the causal mechanisms (Kriemler, et al., 2011; Lubans, et al., 2008). Understanding the mechanisms through which interventions achieve success is of utmost importance. Particularly, as multi-component interventions can be very intensive, it is important to identify which components were effective in achieving the outcome. This will assist in informing researchers on which intervention components to focus on in order to design effective and efficient interventions.

Fundamental movement skills have long been considered the foundation of an active lifestyle (Gallahue & Ozmun, 2006). However, often these claims are based on cross-sectional studies and a limited number of longitudinal studies showing the significant positive association between fundamental movement skill competency and physical activity, and fundamental movement skill competency and cardiorespiratory fitness in youth (Lubans, et al., 2010). While strong evidence does exist for this relationship as synthesised in a recent systematic review (Lubans, et al., 2010), the limitation of cross-sectional studies is that the direction of the relationship cannot be inferred (i.e., whether higher fundamental movement skill competency

increases a child's physical activity or whether greater participation in physical activity improves fundamental movement skill competency). Moreover, the lack of quality longitudinal and experimental studies provides a further limitation (Morgan et al., 2013). For example, one intervention study found children in the fundamental movement skill intervention group at post-test had higher levels and greater enjoyment of physical activity, however the analysis did not test whether changes in physical activity were a result of increased fundamental movement skill competency (Salmon, Ball, Hume, Booth, & Crawford, 2008). Another intervention that resulted in post-test fundamental movement skill improvement (Zask, Adams, Brooks, & Hughes, 2012), had sustained skill effects three years later (Zask et al., 2012), but no physical activity differences between control and intervention children. This could be because physical activity was only assessed at the three year follow-up, which meant baseline and post-test values could not be adjusted for in the analysis.

Findings from the current study suggest that improvements in overall fundamental movement skill competency may act as a causal mechanism for physical activity behaviour change and subsequent improvements in cardiorespiratory fitness among children. It is plausible to suggest that developing fundamental movement skills is a very important component of physical activity engagement. That is, through learning to move, children are able to more successfully participate in a variety of physical activities and in turn improve their cardiorespiratory fitness. This finding supports Stodden and colleague's conceptual model that contends that the development of actual fundamental movement skill competency is a primary underlying mechanism that determines physical activity engagement (Stodden, et al., 2008). While Stodden et al. (2008) support the role of psychological factors such as perceived competence that are included in many theoretical models (Eccles & Harold, 1991; Harter, 1978), they suggest that the most

important determinant of behaviour change is actual fundamental movement skill competency. While they acknowledge that actual fundamental movement skill competency interacts with other factors such as perceived competence and health-related fitness, they argue that actual competence is important in its own right and is largely responsible for engagement and persistence in physical activity among young people. They propose that across developmental time, if a child does not have actual fundamental movement skill competency, perceptions of competence will decrease when that child is more accurately able to evaluate their competency level, which will in turn influence their decision to participate in physical activity (Stodden, et al., 2008).

The findings in the current study confirm our hypothesis that improving children's fundamental movement skills will increase their participation in physical activity and increase their cardiorespiratory fitness. The capacity to participate in physical activity of moderate-to-vigorous intensity on a regular basis is crucial to changing children's cardiorespiratory fitness levels (Resaland, Anderssen, Holme, Mamen, & Andersen, 2011). Children with improved fundamental movement skill competency may increase their time in MVPA and persevere with activities that require high levels of cardiorespiratory fitness resulting in cardiorespiratory fitness adaptations (Stodden, Langendorfer, & Robertson, 2009). Interestingly, locomotor skills mediated the effect of the intervention on cardiorespiratory fitness but not physical activity. This finding is in contrast to a previous longitudinal study which found object-control competency predicted cardiorespiratory fitness, but locomotor competency did not (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008). It would seem that many cardiorespiratory fitness promoting activities (e.g., ball sports) are dependent on a certain level of object-control skill competency, rather than locomotor skill competency for participation. However, locomotor skill

competency has been recognized as an important determinant of cardiorespiratory fitness. One study found that all six fundamental movement skills (sprint run, vertical jump, overarm throw, catch, forehand strike and kick) were significantly associated with cardiorespiratory fitness; however the locomotor skill of sprint run had the highest correlation of any skill (Okely, Booth, & Patterson, 2001). Similarly, the sprint run as well as the vertical jump were also related to cardiorespiratory fitness in children (Mahon, Del Corral, Howe, Duncan, & Ray, 1996).

It is imperative that causal mechanisms are understood in childhood to assist in preventing the decline in physical activity and cardiorespiratory fitness typically observed during adolescence (Dumith, Gigante, Domingues, & Kohl, 2011; Tomkinson & Olds, 2007). The mediation findings from this study provide a rationale for the inclusion of strategies to develop fundamental movement skill competency in interventions and educational contexts in order to promote physical activity and cardiorespiratory fitness in children. A major focus of the SCORES intervention was developing children's fundamental movement skills. A number of intervention strategies were employed including teacher professional learning and lesson observations to improve the quality of physical education, implementation of school physical activity policies, weekly fundamental movement skill homework and student leadership tasks to promote fundamental movement skills in the school (Lubans, et al., 2012). Process evaluation data reported previously, indicated an improvement in the quality of the intervention schools physical education, and good adherence to the fundamental movement skill homework, student leadership tasks and some physical activity policies (Cohen, et al., 2014). This comprehensive approach to improve school-based physical education and physical activity is important, given the widely published deficiencies identified in the quality of primary school physical education programs (Morgan & Hansen, 2008).

Perceived sport competence did not mediate physical activity or cardiorespiratory fitness in this study. This is a surprising finding considering the strong support for perceived competence as an important correlate of physical activity and cardiorespiratory fitness in youth (Crocker, Eklund, & Kowalski, 2000; Raudsepp, et al., 2002) and its inclusion in a number of behavior change theories (Harter, 1985a; Weiss, 2000). Perceived competence is generally referred to as confidence to perform sport, outdoor games and physical activities (Harter, 1982). It is proposed that perceived competence is central to a child's motivation which in turn influences whether a child will maintain engagement and affects physical activity participation choices (Harter, 1978). A recent systematic review found perceived competence had the strongest association with physical activity behavior out of all the self-concept domains examined (Babic, et al., 2014). There is limited investigation of the mediating effects of perceived competence in school-based physical activity interventions for children. Similar to the results found in this study, van Stralen et al. (2012) found that perceived competence did not meet the criteria for mediation in their physical activity intervention among primary school-aged children. Interestingly, in contrast to these results, perceived competence has been shown to be an important casual mechanism in physical activity interventions in adolescents (Barnett, Morgan, van Beurden, & Beard, 2008; Neumark-Sztainer, Story, Hannan, Tharp, & Rex, 2003). The strength of the relationship between perceived competence and physical activity increases as children move into adolescence (Babic, et al., 2014) and their cognitive abilities improve and they become more aware and concerned about their physical abilities (Stodden, et al., 2008).

Although perceived competence did not meet the criteria for mediation, changes in perceived competence were significantly associated with changes in

physical activity and cardiorespiratory fitness. This indicates that perceived competence holds potential to be included in future physical activity and cardiorespiratory fitness interventions in children. The lack of mediation findings for perceived competence could be explained by a number of reasons. Firstly, the SCORES intervention was successful in improving children's actual, but not their perceived competence. Improving the quality of physical education lessons was the main strategy used to improve children's perceived sport competence. Teachers were encouraged to teach fundamental movement skills using the 'SAAFE' teaching principles (Lubans, et al., 2012). These principles utilized a mastery learning climate focusing on opportunities for the children to succeed and be encouraged to individually improve, which aimed to increase levels of perceived competence. However, the strategies to increase perceived competence in the SCORES intervention were not well developed and additional strategies may be needed to improve children's perceptions of their movement skill competence. In addition, the challenges of measuring perceived competence in children may have restricted our ability to detect changes in this construct. Children may not possess the cognitive skills to accurately assess their physical abilities. Consequently, children often report exaggerated levels of perceived competence (Harter, 1999; Harter & Pike, 1984), which may also explain the limited mediation findings in this study.

Findings in this study add to the limited but growing body of evidence examining the mediators of successful school-based physical activity interventions in children. Previous mediation studies have primarily focused on the investigation of psychological and social mediators, with strong evidence for self-efficacy as a mediator of school-based physical activity interventions (van Stralen, et al., 2011). Combined, these findings will assist in understanding the underlying mechanisms of behavior change in order to strengthen effective intervention components and

eliminate or adapt ineffective components. However, as this study is the first mediation analyses of fundamental movement skills in a physical activity intervention, further research is needed to replicate the importance of fundamental movement skills as a mediator and how this will be moderated by age and population group. Moreover, further research is needed to examine the mediating effects of perceived competence and how this may be moderated by age, in order to accurately understand its role in physical activity and cardiorespiratory fitness promotion.

Study strengths and limitations

The strengths of this study include being the first study to explore the mediating effects of fundamental movement skill competency in a physical activity intervention in children, the cluster randomized controlled trial design, the objective measures of physical activity (accelerometers) and cardiorespiratory fitness, a comprehensive battery of movement skills (both locomotor and object control skills), adjustment of all analyses for confounders, and a high level of participant retention for cardiorespiratory fitness and fundamental movement skills. However, a limitation that should be noted is that despite employing a variety of strategies (e.g., text messages and prizes) to increase accelerometer monitoring compliance, only a small number of participants provided useable accelerometer data at baseline (54.3%) and post-test (30.0%). Accelerometers are deemed to be the best practice for assessing change in physical activity, however, wear compliance appears to be a consistent challenge for physical activity researchers. Adherence to monitoring protocols is frequently poor, particularly among children of low SES, with children significantly less likely to provide reliable accelerometer data if they are socially disadvantaged or reside in disadvantaged locations (Rich et al., 2013). Compliance levels in this study appear to be comparable with other studies investigating population groups from low-income communities (Rich, et al., 2013). Furthermore, the variation in wear

time criteria can also affect compliance rates. Studies that have a reduced inclusion criteria (i.e., any three days), or measure only weekday or school time (Monday to Friday 9:00am-3:00pm) physical activity tend to attain higher rates of compliance. Studies with reduced inclusion criteria tend to have higher compliance than reported in this study, however may not provide a comprehensive representation of the participants' 'usual' weekly physical activity as the three weekdays and one weekend criteria that was used in this study (Cain, et al., 2013). Often, higher weekday or school time compliance is due to teachers being responsible for administering the accelerometers during the school day, consequently decreasing the challenges of poor compliance outside the school environment. Alternatively, the use of wrist-worn accelerometers may lead to increased rates of compliance as they may be more acceptable for children, and issuing timely reminders throughout the research period, in particular among low SES populations may be crucial to increase compliance.

Conclusions

This study has demonstrated that the SCORES school-based physical activity intervention for children which resulted in significant group-by-time interaction effects for physical activity and cardiorespiratory fitness, were mediated by actual, but not perceived movement skill competency. This provides evidence for the inclusion of fundamental movement skill development as a mechanism of behaviour change, and thus, a strategy that should be included in interventions aimed at increasing children physical activity and cardiorespiratory fitness.

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Table 1 Action theory test, conceptual theory test and significance of the mediated effect on physical activity (MVPA minutes) at post-test (12-months)

Hypothesized mediators	Direct effect		Action theory test			Conceptual theory test			Significance of mediated effect		Proportion (%)
	n	C' (SE)	n	A (SE)	p value	n	B (SE)	p value	AB	95% CI	AB/(C' + AB)
Locomotor skills	97	8.88 (2.49)	352	1.76 (0.88)	0.044	97	0.49 (0.26)	0.056	0.86	-0.12 to 2.44	9%
Object control skills	90	7.71 (2.02)	341	1.86 (1.57)	0.238	90	0.86 (0.15)	0.000	1.60	-1.04 to 4.50	17%
Overall FMS	86	7.01 (1.95)	314	4.09 (2.08)	0.049	86	0.51 (0.10)	0.000	2.09	0.01 to 4.55	23%
Perceived competence	101	9.29 (2.23)	375	0.06 (0.69)	0.934	101	0.48 (0.36)	0.027	0.03	-0.84 to 0.95	<1%

Note. C', unstandardized regression coefficient of the intervention predicting physical activity behavior accounting for effect of the mediator; A, unstandardized regression coefficient of treatment condition predicting change in hypothesized mediators; B, unstandardized regression coefficient of change in hypothesized mediators predicting change in physical activity behavior; AB, product-of-coefficients estimate; SE, standard error; 95% CI, 95% confidence interval; FMS, fundamental movement skills.

Table 2 Action theory test, conceptual theory test and significance of the mediated effect on cardiorespiratory fitness at post-test (12-months)

Hypothesized mediators	Direct effect		Action theory test			Conceptual theory test			Significance of mediated effect		Proportion (%)
	n	C' (SE)	n	A (SE)	p value	n	B (SE)	p value	AB	95% CI	
Locomotor skills	327	4.27 (1.55)	352	1.76 (0.88)	0.044	327	0.42 (0.11)	0.000	0.74	0.01 to 1.69	15%
Object control skills	313	4.72 (1.63)	341	1.86 (1.57)	0.238	313	0.24 (0.12)	0.050	0.45	-0.30 to 1.58	9%
Overall FMS	296	4.14 (1.61)	314	4.09 (2.08)	0.049	296	0.29 (0.08)	0.000	1.19	0.002 to 2.76	22%
Perceived competence	339	4.49 (1.48)	339	0.08 (0.49)	0.864	339	0.55 (0.15)	0.000	0.05	-0.51 to 0.62	1%

Note. C', unstandardized regression coefficient of the intervention predicting cardiorespiratory fitness accounting for effect of the mediator; A, unstandardized regression coefficient of treatment condition predicting change in hypothesized mediators; B, unstandardized regression coefficient of change in hypothesized mediators predicting change in cardiorespiratory fitness; AB, product-of-coefficients estimate; SE, standard error; 95% CI, 95% confidence interval; FMS, fundamental movement skills.