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Improving Health-Related Fitness in Adolescents: The CrossFit Teens™ Randomized Controlled Trial

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Abstract

Objective: The aim of this study was to evaluate the preliminary efficacy and feasibility of the CrossFit Teens™ resistance training program for improving health-related fitness and resistance training skill competency in adolescents.

Methods: This assessor-blinded RCT was conducted in one secondary school in the Hunter Region, Australia from July-September, 2013. Ninety-six (96) students (age =15.4 (.5) years, 51.5% female) were randomized into intervention (n=51) or control (n= 45) conditions for 8-weeks. Waist circumference (primary outcome), body composition (BMI, BMI-Z score), cardiorespiratory fitness (shuttle run test), muscular fitness (standing jump, push-up, handgrip, curl-up test), flexibility (sit and reach) and resistance training skill competency, were measured at baseline and immediate post-intervention. Feasibility measures of recruitment, retention, adherence and satisfaction were assessed.

Results: Significant group-by-time intervention effects were found for waist circumference [-3.12cm, p<0.001], BMI [-1.28 kg/m^2, p<0.001], BMI-Z [-0.46 z-scores, p<0.001], sit and reach [+3.02cm, p<0.001], standing jump [+0.13m, p=0.021] and shuttle run [+10.34 laps, p=0.019]. The recruitment rate was 100%, and retention rate was 82.3%. All program sessions were delivered and participant satisfaction scores ranged from 4.2- 4.6 / 5.

Conclusions: CrossFit Teens™ is a feasible and efficacious resistance training program for improving body composition and health-related fitness in adolescents.

Key words:
physical activity, physical education, sport, body composition, resistance training

Trial Registration No: ACTRN12613001310752

Introduction

High levels of physical fitness in youth are associated with improved physical and mental health - both in the short and long term (Ortega et al. 2013, Smith et al. 2014). The fitness components that have been shown to directly relate to improvements in health are: body composition, cardiorespiratory fitness, muscular fitness (strength, power and endurance) and flexibility - commonly referred to as the health-related fitness (HRF) components (Cooper Institute for Aerobics Research 2013). However, there is a large proportion of youth who do not participate in physical activities of sufficient quantity or intensity to accrue the associated health benefits, and a decline in fitness levels in youth has been reported worldwide (Armstrong 2012). Variability in fitness testing batteries makes comparison of fitness levels across countries problematic, however, studies have shown that in many countries more than 30% of adolescents are not meeting cardiorespiratory fitness recommendations (Hardy et al. 2010) and up to 80% are not meeting physical activity guidelines (Hallal et al. 2012). Furthermore, physical activity declines sharply during adolescence and individuals in this age group have reported difficulty starting, and adhering to, regular exercise (Dumith et al. 2011, Armstrong 2012), and often exhibit associated high levels of overweight and obesity (Ogden et al. 2010). Consequently, the promotion of physical activity and fitness among youth to emerge as a global health priority (World Health Organisation 2014).

Physical activity guidelines recommend the promotion of physical fitness in adolescence (World Health Organisation 2014). Recent recommendations encourage young people to increase the intensity of their physical activity (i.e., vigorous physical activity three times per week) and incorporate specific fitness exercise to enhance muscle and bone strength three times per week (World Health Organisation 2014). Despite these recommendations, current trends in declining fitness levels highlight the need for researchers to find engaging ways of helping adolescents participate in activity of vigorous intensity, to improve their fitness levels and to foster positive attitudes towards lifelong physical activity (Dobbins et al. 2013). It has been suggested that youth who are not exposed to regular physical activity opportunities that enhance muscular strength and motor skill proficiency early in life may not develop the prerequisite skills, confidence or abilities for future and long-term physical activity participation (Lubans et al. 2010, Faigenbaum et al. 2013). It has also been proposed that the promotion of physical activity for adolescents should shift towards lifelong activities (e.g. fitness, leisure and recreation activities (such as resistance training, swimming, bike riding, tennis, golf) that can be easily carried into adulthood (Faigenbaum et al. 2013). Moreover, novel programs are needed that meet the needs and motivations of young people (Stratton et al. 2004). Resistance training is a lifelong physical activity that has proven to be safe, effective and worthwhile for increasing muscular fitness and health in adolescents (when implemented with qualified instruction and appropriate supervision (Lloyd et al. 2013) (Faigenbaum et al. 2013).

Given that schools hold a unique position for providing physical activity opportunities for adolescents, it is appropriate that they explore novel fitness-based physical activity programs that engage young people and equip them with the necessary skills to be physically active within and beyond the school setting (Lubans et al. 2011, Lubans et al. 2012). It has also been suggested that fitness improvements in adolescents need to be targeted by combining low-tech resistance training exercises (requiring minimal equipment, organisation or space) with other HRF activities, and integrated back into school physical education (PE) and sport programs (Stratton et al. 2004, Lloyd et al. 2013). Recent school-based resistance training programs for adolescents have shown varying impact on improving health-related fitness levels, using combinations of free weights, elastic tubing, body weight exercises (e.g. push-ups, chin-ups), machine weights, plyometrics, medicine ball activities and circuit training (Faigenbaum and Mediate 2006, Faigenbaum et al. 2007, Faigenbaum et al. 2007, Lubans et al. 2010, Meinhardt et al. 2013). Generally, these studies have involved small samples, often targeted specific population sub-groups (e.g., males, overweight or obese adolescents, athletes, disadvantaged schools), had low instructor to student ratios and have focused specifically on muscular fitness improvements (rather than overall fitness).

CrossFit™ is a form of training that targets multiple components of fitness and has recently emerged as a popular lifetime physical activity choice for adults in over 115 countries worldwide (Glassman 2003). Various modified programs have also been developed under the CrossFit™ training system, that cater for the age, maturity and skill level of younger participants (e.g., CrossFit Teens™ , CrossFit Kids™) (Glassman 2003). The CrossFit Teens™ program was designed specifically for improving the fitness levels of adolescents (ages12-18 years) and incorporates combinations of nine core strength exercises in a group training setting (Glassman 2010). This novel program also requires minimal equipment and has the potential to align with physical education and sport objectives in secondary schools. Despite the growing popularity of CrossFit-style training programs, to the authors' knowledge, there are no published studies supporting the physical and psychological benefits of participating in CrossFit™ in adolescent or adult populations. Furthermore, it is not known if such programs can be delivered feasibly in the school setting. Therefore, the aim of this study is to evaluate the preliminary efficacy and feasibility and of the CrossFit Teens™ resistance training program for improving body composition, health-related fitness and resistance training skill competency in the school setting in a sample of adolescents.

Materials and methods

Research design

The study involved a randomised controlled trial conducted in one secondary school. Ethics approval for this study was obtained from the University of Newcastle, NSW, Australia, and is registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12613001310752). To ensure study quality, the design, conduct and reporting of this study adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Moher et al. 2010). Information leaflets, parental and participant consent forms were sent home with all students in Grade 10, and those who returned signed consent forms were permitted to participate in the study. All Grade 10 students were eligible to participate unless they had a medical condition preventing assessment or participation in the program. A member of the research team explained the program to the students prior to recruitment and the study was promoted by PE teachers at the study school. School Principals and teachers also provided written informed consent. Randomization into dose-matched treatment conditions occurred at the class level (n=4 classes) and was conducted after baseline assessments. A computer-based random number-producing algorithm was generated and completed by an independent researcher (not a member of the research team) to ensure an equal chance of allocation to each group.

Sample size calculation

Power calculations were based on the primary outcome, waist circumference (adjusted difference between groups = 2±2.2cm) using estimates from the literature reporting the effect of resistance training on waist circumference (Benson et al. 2008), resulting in a required sample size of 21 per group (treatment and control) or a total of 42. To account for potential attrition, a sample of 60 was targeted for recruitment.

Intervention:

The CrossFit Teens™ fitness program used in this study was designed specifically for secondary school-aged children by the two experienced CrossFit™ instructors who delivered the program from CrossFit Horizons, Newcastle, Australia. It incorporated combinations of core strength exercises (including squat jumps, lunges, medicine ball toss, push-ups, deadlifts and shoulder press), utilised the outdoor facilities and basic equipment available at the participating school (e.g., school bags, medicine balls, PVC pipe, broom sticks, brick wall, basketball court, dumbbells and barbells), and targeted improvement in various fitness components (incl., cardiorespiratory fitness, muscular fitness and flexibility). A detailed outline of the program is displayed in Table 1. The training methods used in the program were based on individual performance within a "group training" atmosphere and a game setting, to engage adolescent participants (Glassman 2010). The program was dosed-matched to the control conditions and was delivered twice a week for 8-weeks during normal PE (60min) and sport lessons (60min). Participants' age, maturity, fitness levels and experience with resistance training was taken into consideration when designing the program sessions, where the instructors focused specifically on teaching and improving resistance training technique and using gradual and progressive increases in exercise loading. A typical session included: a dynamic warm-up (10min), a technique-based skill session (10min), a Workout of the Day (WOD =10-20min) and a stretching session (5min).

Control (wait- list control group): The control group participated in a 60min/week sport lesson (student choice, e.g., ice skating, team sport, tennis for the 8 weeks) and their usual 60min / week HPE lesson (eight fitness lessons focusing on a variety of fitness activities) delivered by their PE teacher over the 8-week intervention period. The control group was offered the CrossFit Teens™ program after the final assessments.

Measures

Assessments were conducted in July (baseline) and September (immediate post-intervention), 2013, and completed by trained research assistants who were blinded to treatment conditions at baseline and follow-up assessments. Measurements were completed at the study school using the same instruments at each time point (i.e., morning, midday or afternoon) and conducted under similar conditions (i.e., location, weather and equipment).

Due to the sensitive nature of some body composition assessments, steps were followed to ensure that female researchers assessed female students and similarly, a male researcher conducted assessments on male students.

Primary outcome

Body composition:

1) Waist circumference: was defined as the narrowest point from the anterior aspect or the mid-point of the lowest lateral rib and iliocristale landmark, measured to the nearest millimetre with a tolerance of 1% (Gore 2000).

2) Body mass index (BMI) and BMI z-score: Weight was measured on a calibrated scale and height was measured using the stretch stature method and PE87 portable stadiometer, using standardised procedures (Cooper Institute for Aerobics Research 2013). BMI calculated using the standard equation (weight[kg]/height[m]2) (Cooper Institute for Aerobics Research 2013) and body mass index z-scores (BMIz) were also used to determine relative weight status (Must and Andersen 2006).

Secondary outcomes

Muscular fitness (MF) was measured using:

1. The 90-degree push-up test was used as a measure of upper body muscular endurance. Standard testing procedures from the FITNESSGRAM® testing manual were adhered to (Cooper Institute for Aerobics Research 2013).
2. The standing long jump test was use to assess muscular power (Castro-Pinero et al. 2010). 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 best score was used in the analysis.
3. Abdominal muscular endurance was assessed using the curl-up test. Standard testing procedures from the FITNESSGRAM® testing manual were adhered to (Cooper Institute for Aerobics Research 2013).
4. Grip strength was assessed using a grip dynamometer (Smedley's TTM Tokyo)(Roberts et al. 2011). The grip-span was adjusted to suit the hand size of the participant. 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 twice on the dominant hand and the highest score in kilograms was recorded.

Cardiorespiratory fitness (CRF) was measured using the 20m shuttle run test (PACER) using standardized testing protocols from the FITNESSGRAM® testing manual (Cooper Institute for Aerobics Research 2013). The level and number of shuttles within the level completed was recorded.

Flexibility: was measured using the sit and reach test using standardized protocols and equipment (Cooper Institute for Aerobics Research 2013).

Resistance training skill competence: Resistance training skill competency was measured using the Resistance Training Skills Battery (RTSB)(Lubans et al. 2014) and standardized protocols and equipment were used. Participants observed demonstrations and then completed two trials of four repetitions for six skills, including: (i) body weight squat (ii) push-up (iii) lunge (iv) suspended row (v) standing overhead press and (vi) front support with chest touches.

Process evaluation

The feasibility of the program was examined using a number of measures. Measures of *recruitment* (evaluation of the recruitment process, dissemination of information and obtaining informed consent), *retention* (measure of how many participants completed the program and participated in all assessments pre and post-intervention), *adherence* (evaluation of the degree to which participants followed the CrossFit™ program), and *satisfaction* (level of satisfaction and engagement in program by participants) were used. A questionnaire was administered at the completion of the program to determine participants' perceptions of the various program components and attendance, and to gather information relating to potential injuries that may have occurred as part of the program. Questions utilized a 5-point Likert scale format to assess satisfaction (14 items), with responses ranging from "Strongly Disagree" = 1 through to "Strongly Agree" = 5. Example item: *I think all schools should have the opportunity to try CrossFit*). Four items of similar structure where used to assess future behaviour plans (e.g., *In the future I plan to participate in muscle strengthening physical activities*), and participants were also asked to indicate the specific activities they enjoyed participating in during the program by ticking the appropriate boxes (e.g., individual strength activities, circuits, ball games, stretching, partner strength activities). Participants were then asked to comment on aspects of the program they did not enjoy and to provide further comments about the program using two open ended questions.

Statistical methods

All analyses were conducted using the statistical software package IBM SPSS 21 (SPSS Inc. Chicago, IL) and alpha levels were set at $p < 0.05$. Independent samples t-tests were performed on continuous variables (e.g. age) and chi-square tests were performed on dichotomous variables (e.g. sex) for identifying differences between groups at baseline in key demographic and outcome variables. A descriptive analysis (percentage and frequency counts) was conducted to assess retention, recruitment, adherence and satisfaction among participants. Linear mixed models were fitted with an unstructured covariance structure to compare intervention and control groups for continuous variables. Mixed models were used to assess primary and secondary outcomes for the impact of group (intervention or control), time (treated as categorical with levels baseline, 3-months and 6-months) and the group-by-time interaction. Linear mixed models are consistent with the intention-to-treat principle and analyses included all participants with baseline data, regardless of whether or not they completed follow-up assessments (Mallinckrodt et al. 2004).

Results

Overview

The flow of participants through the study process is displayed in Figure 1. In summary, CrossFit Teens™ involved 96 Stage 5 (Grade 10) students from one secondary school (mean age 15.43 ± .49 years; 51.5% female) located in the Hunter Region, NSW, Australia. Of the 96 participants, 91.8% were born in Australia and 92.8% spoke English at home (Table 2), 13.5% were classified as overweight and 3.1% were classified as obese. At baseline, there were no significant differences between intervention and control groups for any of the demographic variables (i.e., sex, age, country of birth, primary language, or parents' level of education) or weight status. In comparison to the control group, participants in the intervention group achieved significantly more push-ups (mean difference 4.9 repetitions p=0.02) and more shuttles on the shuttle run test (mean difference 13.0shuttles p=0.01) at baseline. There were no significant differences at baseline in any fitness measure between those who completed the study and those who dropped out ($p>0.05$).

Changes in primary outcome

There was a significant group-by-time interaction effect for waist circumference [adjusted mean difference = -3.12cm (95% Confidence Interval (CI)-5.00 to -1.25), $p<0.001$] (Table 3).

Changes in secondary outcomes

Significant group-by-time interaction effects were found for BMI [adjusted mean difference = -1.28 kg/m^2 (95% CI, -1.86 to -0.70), $p<0.001$], BMI-z [adjusted mean difference = -0.46 z-scores (95% CI, -0.68 to -0.23), $p<0.001$], sit and reach test [adjusted mean difference = 3.02cm (95% CI, 0.78 to 5.26), $p<0.001$], standing jump [adjusted mean difference = 0.13m (95% CI, 0.02 to 0.24), $p=0.021$] and the shuttle run test [adjusted mean difference = 10.3 laps (95% CI, 1.8 to 18.9), $p=0.019$]. No significant group-by-time interaction effects were found for the other muscular fitness assessments including the push-up, curl up and grip strength tests ($p>0.05$) (Table3).

An investigation of primary and secondary fitness outcomes according to sex revealed that females made greater improvements than males in waist circumference [Females: adjusted mean difference = -3.47cm (95% CI-6.55 to -1.61), $p=0.002$, Males: adjusted mean difference = -1.61cm (95% CI,-13.75 to 1.59), $p=0.17$], BMI [Females: adjusted mean difference = -5.16 kg/m^2 (95% CI, -2.89 to -1.27), $p<0.001$, Males: adjusted mean difference = -1.85kg/m^2 (95% CI, -1.50 to 0.07), $p=0.07$], BMI-z [Females: adjusted mean difference = -4.45 z-scores (95% CI, -1.07 to -0.4), $p<0.001$, Males: adjusted mean difference = -1.6z-scores (95% CI, -0.53 to 0.06), $p=0.12$], and the shuttle run test [Females: adjusted mean difference = 3.05 laps (95% CI, 4.44 to 26.43), $p=0.006$, Males: adjusted mean difference = 1.45 laps (95% CI, -4.71 to 26.43), $p=0.16$]. Males showed greater gains than the female in the standing jump [Females: adjusted mean difference = 0.15m (95% CI, -.06 to .38), $p=0.15$, Males: adjusted mean difference = 0.25m (95% CI, -.06 to .38), $p=0.015$].

No significant group-by-time interaction effects were found for resistance training skill competency. Given the small sample for this assessment, within-group changes were also examined (Table 4). In the intervention group, significant within-group improvements were evident for all six individual skills and for total resistance training skill competency ($p<0.01$). In comparison, the control group exhibited significant improvements in competency in the body weight squat ($p=0.015$), the push-up ($p=0.033$), and total resistance training skill competency ($p=0.011$).

Process evaluation

Recruitment: One school principal, one sport coordinator and three PDHPE teachers were invited to participate in the study and all agreed to participate. All of the 96 Grade 10 students who were given information booklets 100% consented to participate and all students participated in baseline assessments (some students did not participate in selected activities due to existing injuries-see Figure 1 for participant flow through the study). No injuries or adverse effects were reported during the assessment sessions and only four minor injuries (e.g., grazed knee from tripping, pain from being hit by a ball) were reported during the program. The injuries did not require medical attention and occurred during participation in the games session (during a tag game and a ball game) and not during resistance training activities.

Retention: Of the 96 eligible participants, 96.9% completed baseline assessments and 82.3% completed 8-week follow-up measures (see Figure 1). There was no significant difference between study groups with regard to retention ($p > 0.05$).

Adherence: A member of the research team observed all 16 sessions (100%) delivered at the treatment school with an attendance rate of 94% for 15 sessions. One session was disrupted due to an existing excursion and only the girls participated in this session. All students participated in all activities during the sessions and were encouraged to perform to their capacity (modified activities were provided for any students attending with pre-existing injuries or illness).

Satisfaction: Mean scores on the evaluation survey categories ranged from 4.17 to 4.56 out of 5 (1=*Strongly disagree* to 5=*Strongly agree*) (see Table 5) for the four scales on the evaluation survey, indicating high-to-very high overall satisfaction rates. Furthermore, participants indicated that they enjoyed the program components, especially the partner activities (94%), circuits (90%), and team activities (84%).

Discussion

The primary aim of this study was to evaluate the preliminary efficacy and feasibility of the CrossFit Teens™ resistance training program for adolescents. Intervention effects were found for waist circumference, body composition (BMI and BMI z-score), cardiorespiratory fitness, flexibility and muscular fitness (standing jump). Our process data also supports that students were highly satisfied with the program, recruitment and retention levels were high, and adherence to the program was excellent -suggesting that incorporating CrossFit™ training into the PE curriculum in secondary schools may be a safe, valid, and appealing approach to promote physical fitness in adolescents.

The improvements in multiple health-related fitness domains in this study are particularly encouraging – especially among female participants. The magnitude of the improvements in the primary outcome, waist circumference, and body composition measures of BMI and BMI z-score, exceed previous school-based resistance training interventions. Pollestad Kolsgaard (2011) reported that even stable / modest reductions of BMI z-scores (≥0.00- to <0.01) are associated with a reduction in several cardiovascular risk factors in obese adolescents. Although, the majority of participants in the CrossFit Teens™ study were of a healthy weight status, the large improvements in body composition observed may have clinical significance (Pollestad Kolsgaard et al. 2011). Our findings also provide preliminary evidence for the CrossFit Teens™ program as a novel strategy to prevent weight gain in adolescents. The literature has consistently reported difficulties in improving BMI in adolescents through school-based physical activity interventions, especially among non-overweight children (Dobbins et al. 2013), and resistance training interventions have demonstrated mixed results (Dorgo et al. 2009, Meinhardt et al. 2013). For example, Meinhardt and colleagues (2013) implemented a 19-week guided strength training program for 10-14year olds (n=102) and Dorgo and colleagues (2010) conducted a RCT (n=222) using manual resistance training in PE, and both found no significant effects in body composition (Dorgo et al. 2009, Meinhardt et al. 2013). These studies provided limited explanation for their findings regarding body composition, with Dorgo identifying external factors (such as nutrition and sedentary behaviour) as possible barriers. In contrast, Benson, Torode, and Fiatarone Singh (2008) found that an 8-week high-intensity progressive resistance training intervention significantly improved waist circumference and BMI scores in 10-15 year-olds (mean change: waist circumference = -2.2 cm, BMI = -0.01) (Benson et al. 2008). Similarly, Lubans, Sheaman and

Callister (2010) reported significant improvements in body composition (BMI d=0.1) but no significant changes in waist circumference in a sample of adolescents who participated in 8-weeks of resistance training (elastic tubing and free weights) (Lubans et al. 2010). The authors in both studies associated the improvements in body composition to improvements in strength. Unlike previous studies, the unique combination of various high intensity core exercises targeting multiple fitness components used in the CrossFit Teens™ program may explain the positive impact on all three measures of body composition (waist circumference, BMI and BMIz Scores). Further research into the physiological and / or psychological mechanisms directly responsible for facilitating the fitness changes in this study is warranted.

Our results also indicate that adolescents can significantly enhance cardiorespiratory performance through a school-based program. The vigorous physical activities embedded in the CrossFit Teens™ program may explain the success of the program in improving cardiorespiratory fitness. A recent Cochrane review cited only one school-based physical activity intervention for adolescent reporting significant effects on cardiorespiratory fitness (assessed females via the Queen's College Step Test) (Dobbins et al. 2013), and resistance training programs for adolescents have demonstrated varied levels of success. Benson and associates (2009) reported non-significant improvements in VO_{2max} using a progressive resistance training program (Benson et al. 2008) and Dorgo and colleagues (2010) reported significant improvements in 1-mile run performance following a manual resistance training program implemented in secondary PE (Dorgo et al. 2009). Other resistance training programs have not reported cardiorespiratory fitness outcomes (Faigenbaum and Mediate 2006, Faigenbaum et al. 2007, Lubans et al. 2010, Meinhardt et al. 2013). The significant improvement in cardiorespiratory fitness in the intervention group after only 8 weeks supports the effectiveness of the CrossFit Teens™ program for enhancing aerobic fitness and supports the benefit of using high intensity resistance training programs with adolescents. These results are also encouraging given that the control group participated in a PE and sport program of the same duration and time commitment.

The CrossFit Teens™ program specifically targeted muscular fitness and in this study significant intervention effects were found in muscular fitness, measured by the standing jump. There was a lack of significant intervention effect for upper body and core fitness. These results were perhaps due to the program structure, whereby the majority of exercises activated the movement patterns and muscle groups of the lower body (e.g., squat jumps, lunges, burpees, dead lifts). Furthermore, the majority of students were inexperienced in resistance training so many of the upper body activities (e.g., shoulder press, cleans, clean and press) were implemented with a focus on technique and were conducted using minimal, if any resistance (e.g., no weight, broom sticks, pipes). The focus on improving resistance training skill compentency, although important for injury prevention and long term exercise adoption, may have reduced upper body and core muscular fitness gains. If the program was extended and participants were given the opportunity to build the resistance / weight used in the upper body activities then improvements in these measures may be observed.

Many existing school-based physical activity and fitness interventions have been ineffective in improving muscular fitness in adolescents, while others have not reported their effects on muscular fitness (Kriemler et al. 2011). Alternatively, interventions specifically using resistance training techniques have shown high levels of success (Faigenbaum and Mediate 2006, Faigenbaum et al. 2007, Lubans et al. 2010), yet the range of assessment tools used in previous studies makes it difficult to make meaningful comparisons regarding the impact of such programs on muscular fitness. However, given the importance that muscular fitness has on health outcomes (Smith et al. 2014), any significant improvements in muscular fitness gained through participation in fitness training programs lends support to their integration in PE and sport in the school setting.

Although flexibility research among adolescents is extremely limited and often inconclusive, being flexible may decrease the chances of sustaining muscle injury or soreness and contribute to sports performance (Herbert and Gabriel 2002). In this study, improvements in flexibility in the treatment group add to the evidence supporting the effectiveness of the core exercises used in the CrossFit Teens™ program (see Table 1), and may lead to other health and performance related benefits.

In this study, no significant intervention effects in resistance training skill competency were found and these results may be due to sample size for this assessment. However, there were within-group time effects in the intervention group for all six resistance training skills, suggesting that the program was successful in improving resistance training skill competency in the study sample. During the program, designated time was allocated for learning the correct technique and for practicing the shoulder press, push-up, lunge and squat, so our results were expected for these particular skills. Surprisingly, the control group also made small positive changes in resistance training skill competency. A possible explanation is that the PE and sport program that the control group participated in during the intervention period (which included eight fitness lessons focusing on a variety of fitness activities, and eight community-based sport sessions) included participation in similar movement patterns. Alternatively, there could have been learning effect for the RTSB once the participants had completed the test once and observed others performing the test at baseline and follow-up. However, the RTSB has good test-retest reliability which contradicts this premise (Lubans et al. 2014).

Our process evaluation results indicate that CrossFit Teens™ is a feasible program for improving health-related fitness and resistance training in Grade 10 students during PE and sport. Recruitment was successful with both students and staff eager to participate. These results are indicative of the fact that PE teachers are seeking engaging ways to improve the fitness levels of adolescents and adolescents are turning to teachers to encourage, support, and enable them to be involved in more healthful physical activity behaviours (Rink et al. 2010). Retention rates were also very high and there were no dropouts from the program. Similarly, adherence to the program was also excellent (100%), and attendance was very high (94% for 15/16 sessions). Accessing the students through mandatory timetabled PE and sports sessions impacted positively on adherence rates, but also suggests that using these opportunities within the school setting is a key to maximising the effectiveness of the program. Satisfaction scores were also very high with mean scores on the evaluation survey indicating high to very high overall satisfaction rates. The high satisfaction scores could be explained by the program focus on mastery climate which was facilitated by the instructors' focus on learning new skills, self-improvement (rather than competition), effort and participation. A positive relationship between a mastery climate and intrinsic motivation in PE has been demonstrated (Sproule et al. 2007), whereby adolescents are more likely to participate in PE for reasons related to enjoyment, fun, and a desire to learn - and as a consequence are more likely to persist with difficult (or intense) activities (Ferrer-Caja and Weiss 2000). Participant perceptions relating to program structure and the delivery of the program were also assessed via written feedback on the evaluation survey. In general, positive comments were made relating to the quality of the instructor and the benefits of the program (eg., "… *I am a stronger person especially for my size and I thank Jamie* (instructor) *for that!*" "*Jamie* (instructor) *is awesome. I would like to continue to do Crossfit*"). A small number of participants highlighted activities that they did not enjoy (e.g., "*working on my own,*" "*exercising in the heat*" "*doing sessions without partners and/or competition*"*).*

Strengths and Limitations

To the authors' knowledge, this is the first study to evaluate a CrossFit™ program designed specifically for adolescents and our findings have important implications for the development of physical fitness and resistance training skill competency in young people. Our study involved an experimental design, which adhered to the CONSORT statement. However, there are some limitations that should be noted. First, we could not randomize participants at the individual level due to timetabling constraints at the participating school. Secondly, an extensive evaluation of the control conditions was not performed, other than obtaining an outline of the PE course content and a list of student sport selections during the study period. Under these circumstances, the true impact of the CrossFit Teens™ program may not be evident as the control conditions also involved students participating in a range of physical activities. Furthermore, information regarding physical activity and sports participation outside the school setting, along with nutritional behaviors, were not collected and the impact that these factors may have impacted upon study outcomes.

Perspectives

Improving physical fitness levels in adolescents is a major health priority and developing and testing feasible and efficacious programs that are engaging, enjoyable and evidence-based for adolescents is clearly warranted. CrossFit™ training programs (such as CrossFit Teens™) have been running as community-based programs for several years and are providing an after-school physical activity opportunity for young people. However, these programs are not always accessible to young people because of the cost of participating, they are not always tested prior to implementation and the link between school physical activity promotion and community programs is often missing. By providing adolescents with opportunities to participate in well designed and evidence-based high intensity fitness programs (Buchan et al. 2011) that are also available in the community, and to build their skill competencies and confidences for participating in such programs within the school setting (Huotari and Kujala 2013), the link between community and school health promotion may strengthen. It may also lead to increase long term participation and program sustainability. While future research investigating the potential long-term benefits of youth fitness training is needed, this study has shown that the CrossFit Teens™ fitness program has the potential to improve health outcomes in adolescents.

Conclusion

The CrossFit Teens™ program has demonstrated significant success in improving multiple components of health-related fitness in adolescents. Our findings provide evidence of the efficacy and feasibility of the CrossFit Teens™ program for use in the school setting. Future research is needed to establish long term health gains, sustainability in the school setting and impact on out-of –school physical activity participation.

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Table 1: CrossFit Program Components (Australia, 2013)

wk	Day	Program Components	Specific Exercises	Sets / time
1	1	Warm up	Mountain climb, star Jumps, walking Lunges	3 x 30secs
		Skills / technique	Squats, deadlifts, burpees	20min
		WOD / AMRAP	10x squats / 10 x Deadlifts (school bag) / 10x burpees	10min
		Cool Down	Third world sit	5 min
	2	Warm up	3 x inchworm, 10 x bear walk, 6 x squat	3 sets
		Skills / technique	Refresh squat, push-up, box jump	10min
		Pair WOD / AMRAP	10 x box jumps / 10 x squats (BW) / 5 x push-up	10min
		Cool Down	Hip and gluteal stretches (static)	5 min
2	1	Warm up	3 x squats, 3 x burpees, 1 x shuttle runs	3 sets
		Skills / technique	Goblet squat, skipping, deadlift	
		WOD	1min x goblet squat (medicine ball), deadlift (school bag), push-ups, shuttle run	3 rounds
		Cool Down	Hip and gluteal stretches (static)	5 min
	2	Warm up	15secs x burpees, 15sec x star jumps, 15secs x squat	3 sets
		Skills / technique	Wall ball, box jump, overhead squat	10min
		WOD / AMRAP	Station 1.Wall ball Station 2. 10 x Box jump, 15 x push-ups, 50m hill run Station 3.Overhead squat	8min per station
		Cool Down	Hip and gluteal stretches (static)	5min
3	1	Warm up	Hip stretch x 2 (3min each), walking lunges x 30m, run 30min	3 sets
		Skills / technique	Deadlift (barbell), clean (pvc pipe), kettle bell swing	
		Pair WOD / AMRAP	10 x deadlift / 5 x burpees / 10 x kettle bell swings	12min
		Cool Down	Hip and gluteal stretches (static)	5 min
	2	Warm up	Farmers and foxes (agility game) Hip and gluteal stretches (static)	10min
		Skills / technique	Clean and Jerk (pvc pipe), push Press	10min
		WOD / AMRAP	Station 1: clean and jerk x 10, Push Press Station 2: 8 x hands overhead walking lunges, 10x squats, 15 x situps Station 3: 8 x Medicine ball cleans, 8 x push-ups	10min per station
		Cool Down	Hip and gluteal stretches (static)	5min
4	1	Warm up	30sec bear walk, 30sec crab walk, 30sec walking lunge	3 sets
		Skills / technique	Thruster	5 min
		WOD	10 x thrusters / Run 50m / 10 x box jumps / Run 100m	20min
		Cool Down	Hip and gluteal stretches (static)	5min
	2	Warm up	30sec squats, 30sec star jumps, 30sec lunges	3 sets
		Skills / technique	Sit ups, push-ups, handstands	15 min
		WOD *Game Day*	Station 1: Baseball (5 push-ups, 5 burpees, 5 squats, 5 sit ups in diamond shape) Station 2: Ball Tag / Monster Ball Station 3: Handstand	15min per station
		Cool Down	Hip and gluteal stretches (static)	5 min
5	1	Warm up	Hip and gluteal stretches (static)	5 min
		Skills / technique	Thumb thrusters, thumb front squats, thumb Push press (all BW)	15 min
		Group (4) WOD / AMRAP	100 x burpees, push press (dumbells), thrusters (dumbells), situps	20min
		Cool Down	Hip and gluteal stretches (static)	5min
	2	Warm up	30sec duck walk, 30sec inch worm, 30sec shuttle run	3 sets
		Skills / technique	Medicine ball cleans	
		WOD / AMRAP	Station 1: 10 x box jump, 8 x push-up, 6 x medicine ball cleans Station 2: Bear walk 30m, broad jump x 1 burpees x 3 30m)	8 min per station

			Station 3: Build to 3RM dumbbell press	
		Cool Down	Hip and gluteal stretches (static) Hovers x 2 (maximum time)	5min
6	1	Warm up	10 x squat (5 sec count), 30sec duck walk, good mornings 30sec	3 sets
		Skills / technique	Wall ball toss, overhead lunge walks	5 min
		Partner WOD / AMRAP	0 wall ball toss to partner (medicine ball) 20m overhead medicine ball lunge walks	15min
		Cool Down	Hip and gluteal stretches (static)	5min
	2	Warm up	10 x leg swings 10 x squats (5 sec count) Hip and gluteal stretches (static)	10 min
		Skills / technique	Squats (school bag)	5min
		WOD *Game Day*	Station 1: Dodge ball with Crossfit penalties (e.g. burpees, push-ups) Station 2: Chasing games (e.g. octopus, red rover, build up tag) Station3: AMRAP 50m hill sprint with school bag, 10 bag squats	10min per station
		Cool Down	Hip and gluteal stretches (static)	5min
7	1	Warm up	30sec duck walk, 30sec bear crawl, 30sec crab walk	3 sets
		Skills / technique	Dumbell snatch, burpee, broad jump	10min
		Partner WOD	AMRAD Dumbell snatch (alternate arms) / burpee broad jump 20m	15min
		Cool Down	Hovers (maximum) 1min hovers plus 20 burpees 1-2min plus 15 burpees 2-3min plus 10 burpees 3 plus minutes no burpees Hip and gluteal stretches (static)	10min
	2	Warm up	30 sec squats, 30 sec star jumps, 30 sec burpees	3 sets
		Skills / technique	Box jumps	5min
		WOD	Station 1: 5 x box jump per minute – add 5 more each minute Station 2: Head stands Station 3: 1min sprint trial x 4	10 min per station
		Cool Down	Hip and gluteal stretches (static)	5min
8	1	Warm up	30 sec squats, 30 sec star jumps, 30 sec burpees	3 sets
		Skills / technique	Forward roll, dead lifts	5 min
		Partner WOD / AMRAP	Station 1: Forward roll, standing jump x 5 burpees x 5 Station 2: Wall ball x 10, sit ups x 10, push-up x 10, box jump x 10 Station 3: Dead Lifts (bar plus weights) x 10, 10 x jumps, 5 x burpees	10min per station
		Cool Down Hovers (maximum)	1min hovers plus 20 burpees 1-2min plus 15 burpees 2-3min plus 10 burpees 3 plus minutes no burpees Hip and gluteal stretches (static)	
	2	Warm up	30 sec squats, 30 sec start jumps, 30 sec burpees	3 sets
		Skills / technique	Revise all core movements	
		WOD	Crossfit Games multi station	30min
		Cool Down	Hip and gluteal stretches (static)	5min

WOD = Workout of the Day AMRAP = As Many Reps / Rounds as Possible BW=Body weight
RM = repetition maximum

Table 2: Baseline demographic data and health-related scores (Australia, April 2013)

Demographic Characteristics		**Control** (*n* =41)		**CrossFit** (*n* =55)		**Total** (*N* = 96)	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)		15.34	.480	15.49	.505	15.43	.497
		No.	**%**	**No.**	**%**	**No.**	**%**
Participants born in Australia, n (%)		38	92.7%	51	92.7%	89	91.8%
English language spoken at home, n (%)		39	95.1%	51	92.7%	90	92.8%
Sex (male)		50	46.3%	58	49.2%	47	48.5%
Mother's level of education	School Certificate	1	2.4	2	4.9	6	6.2
	HSC	2	4.9	2	4.9	15	15.5
	University	28	68.3	24	58.5	58	59.8
	TAFE	6	14.6	5	12.2	7	7.2
Father's level of education	School Certificate	5	9.1	4	7.3	6	6.2
	HSC	13	23.6	7	12.7	9	9.3
	University	30	54.5	33	60	57	58.8
	TAFE	1	1.8	6	10.9	7	7.2

Physiological Characteristics	**Control** (*n* =41)		**CrossFit** (*n* =55)		**Total** (*N* = 96)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Waist Circumference (centimetres)	72.13	18.53	72.17	15.07	72.15	16.69
BMI (weight / height2)	20.41	3.62	21.88	2.65	21.17	3.21
BMI Z-score	-0.24	1.21	0.36	0.80	0.07	1.06
Sit & Reach (metres)	4.69	9.36	7.39	6.74	6.08	8.16
Curl Up Test (number)	33.69	17.61	36.55	19.20	35.17	18.35
Push-Up Test (number)	8.10	9.28	12.58*	10.04	10.42	9.86
Standing Jump (meters)	1.75	0.36	1.67	0.40	1.71	0.38
Grip Strength (kilograms)	34.76	11.06	33.58	9.03	34.15	1.30
Shuttle runTest (level)	41.62	16.67	55.03*	21.22	48.55	20.16

Resistance Training Skills Battery	**Control** (*n* =17)		**CrossFit** (*n* =36)		**Total** (n=53)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Squat	5.88	2.18	7.50	2.01	6.98	2.18
Lunge	6.71	1.86	6.97	2.135	6.88	2.04
Push-up	3.53	2.10	3.86	1.83	3.75	1.91
Suspended row	3.59	1.06	3.69	1.21	3.65	1.15
Front support	4.47	1.13	4.46	1.30	4.46	1.23
Shoulder press	7.18	1.19	7.94	1.56	7.69	1.48
Total resistance training skill competency	31.35	5.49	34.50	5.88	33.45	5.90

SD = standard deviation; %=percentage; No.=number HSC= Higher School Certificate; *Sig. difference between groups $p<0.05$

Table 3: CrossFit Study intervention effects – Fitness (Australia, 2013)

Measure	Baseline, Mean (SD)		8 week, Mean (SD)		Adjusted Difference in Change (95% CI)[a]	Group* Time P value
	Control Group (n = 41)	Intervention Group (n =55)	Control Group (n =34)	Intervention Group (n =49)		
Waist Circumference (cm)	74.05 (18.53)	75.16 (15.07)	75.17 (14.08)	73.16 (7.45)	-3.12 (-5.00 to -1.25)	<0.001
BMI (weight / height2)	20.56 (3.62)	21.64 (2.65)	21.69 (4.32)	21.49 (2.97)	-1.28 (-1.86 to -0.70)	<0.001
BMI Z-score	-0.22 (1.21)	0.24 (0.80)	0.16 (1.35)	0.16 (0.89)	-0.46 (-0.68 to -0.23)	<0.001
Sit & Reach (metres)	4.88 (9.36)	7.65 (6.74)	1.99 (13.03)	7.79 (7.31)	3.02 (0.78 to 5.26)	0.009
Curl Up Test (repetitions	34.27 (17.61)	40.09 (19.20)	49.38 (22.59)	60.77 (18.01)	5.53 (-3.53 to 14.61)	0.228
Push-Up Test repetitions	8.73 (9.28)	13.61 (10.04)	11.36 (8.55)	17.03 (10.51)	-7.9 (-2.91 to 4.48)	0.676
Standing Jump (meters)	1.71 (0.36)	1.72 (0.40)	1.68 (0.32)	1.80 (0.38)	0.13 (0.02 to 0.24)	0.021
Grip Strength (kilograms)	33.70 (11.06)	34.40 (9.03)	35.02 (11.30)	36.19 (8.87)	0.47 (-1.78 to 2.73)	0.675
Shuttle runTest (level)	41.90 (16.67)	54.92 (21.22)	46.21 (19.28)	69.57 (23.94)	10.34 (1.76 to 18.92)	0.019

Abbreviations: BMI, body mass index; CI, confidence interval; MVPA, moderate-to-vigorous physical activity, SD, standard deviation
[a]Adjusted mean difference and 95% CI between CrossFit Teens™ and control groups after 8-weeks (Intervention minus control).

Table 4: CrossFit Study intervention effects- Resistance Training Skills (Australia, 2013)

Measure	Control Group, Mean (SD)			Intervention Group, Mean (SD)			Adjusted Difference in Change (95% CI)[a]	Group* Time P value
	Baseline (n=17)	8 week (n=16)	P value[b]	Baseline (n=36)	8 week (n=35)	P value[b]		
Squat	5.88 (2.18)	7.21 (1.85)	P=0.015	7.50 (2.01)	8.76 (1.26)	P=0.001	-0.14 (-1.39, 1.21)	.892
Push-up	6.71 (1.86)	8.07 (1.53)	P=0.033	6.97 (2.14)	8.54 (1.63)	P<0.001	0.29 (-1.28, 1.71)	.773
Lunge	3.53 (2.10)	3.86 (2.32)	P=0.561	3.86 (1.83)	5.11 (2.36)	P=0.002	1.29 (-0.50, 2.29)	.204
Suspended row	3.59 (1.06)	4.36 (1.78)	P=0.083	3.69 (1.21)	4.74 (1.40)	P=0.001	1.53 (-0.75, 1.3)	.595
Shoulder Press	4.47 (1.13)	5.00 (1.18)	P=0.203	4.46 (1.3)	5.56 (1.54)	P<0.001	1.03 (-0.51, 1.57)	.309
Front support	7.18 (1.19)	7.25 (1.00)	P=0.814	7.94 (1.56)	9.06 (1.19)	P<0.001	2.26 (0.11, 1.96)	.029
Total RTS	31.35 (5.49)	35.86 (6.19)	P=0.011	34.50 (5.88)	41.94 (5.86)	P<0.001	1.40 (-1.25, 6.90)	.169

Abbreviations: CI, confidence interval; SD, standard deviation
[a]Adjusted mean difference and 95% CI between CrossFit Teens™ and control groups after 8-weeks (Intervention minus control).
[b] Within group change over time
RTS: Resistance Training Skill

Figure 1: Flow of Participants through the Study

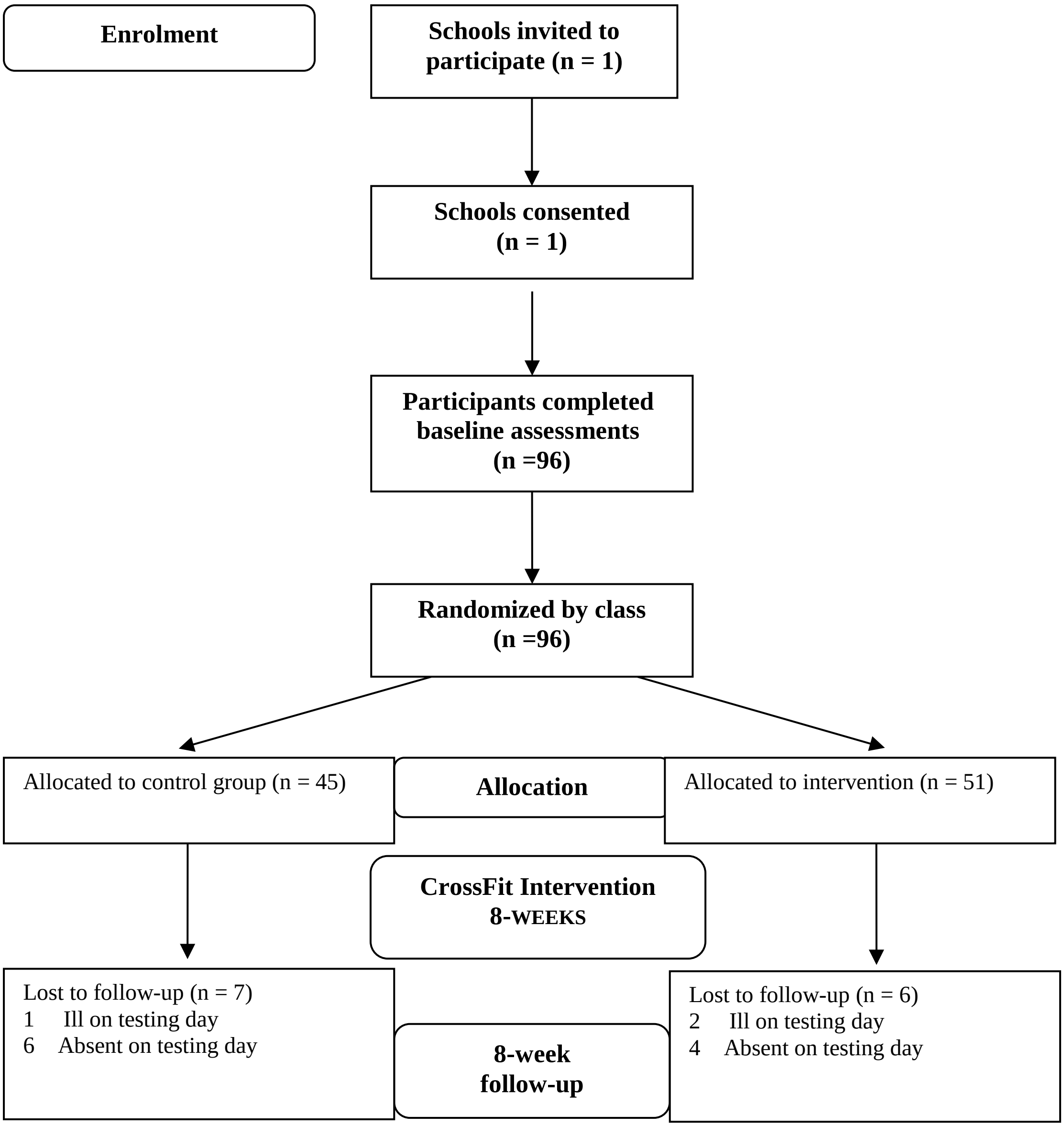

Table 5: Overall participant satisfaction for the CrossFit Teens™ program (Australia, 2013)

Questions evaluating the Fit-4-Fun Program (n=45)	**Mean**	**SD**
***Perceived benefits of the program**	**4.22**	
CrossFit Teens™ helped to improve my health	4.20	.625
CrossFit Teens™ helped to improve my overall fitness	4.27	.654
CrossFit Teens™ helped to improve my muscular fitness	4.16	.737
CrossFit Teens™ helped to improve my aerobic fitness	4.02	.621
CrossFit Teens™ helped to improve my resistance training technique	4.49	.549
CrossFit Teens™ may help improve my performance in other sports and activities	4.20	.661
***Enjoyment of the program**	**4.56**	
I enjoyed doing the program with my friends / peers	4.67	.522
I enjoyed participating in the CrossFit sessions	4.31	.596
I think all schools should have the opportunity to try CrossFit	4.71	.458
*** Rating of self with regards to participation in the CrossFit program**	**4.32**	
I feel better about myself having participated in CrossFit	4.02	.753
I put in a lot of effort during the CrossFit sessions	4.29	.589
I would like to know if my fitness levels have changed after participating in the CrossFit program	4.58	.583
Overall I am satisfied with my involvement in the CrossFit program	4.38	.490
***Future plans**	**4.17**	
In the future I plan to participate in muscle strengthening physical activities (e.g. resistance training, CrossFit)	4.00	.798
In the future I plan to participate in running / walking / cycling and other aerobic activities	4.51	.626
In the future I plan to join a gym, fitness centre or health club	4.24	.857
In the future I plan to participate in CrossFit	3.91	.763
#Enjoyment of specific program components	**1.24**	
I enjoyed participating in individual strength activities (on your own)	1.4	.495
I enjoyed participating in partner strength activities (2 people)	1.07	.038
I enjoyed participating in team strength challenges (more than 2 people)	1.18	.387
I enjoyed participating in stretching	1.33	.477
I enjoyed participating in strength activities using equipment (e.g. medicine balls, bars, dumbells, skipping ropes)	1.24	.435
I enjoyed participating in strength activities without equipment	1.27	.477
I enjoyed participating in ball games / challenges (e.g. ball tag)	1.22	.420
I enjoyed participating in chasing games without equipment (e.g. red rover)	1.33	.477
I enjoyed participating in circuits (e.g. involving a range of activities in one session)	1.09	.043

*Likert Ratings:1=strongly disagree; 2=disagree; 3= neutral; 4= agree; 5= strongly agree.

#Likert Rating: 1= yes 2= no