Improving health-related fitness in adolescents: the CrossFit Teens™ randomized controlled trial.

Abstract

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. This assessor-blinded randomized controlled trial 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 (60 min. twice per week). Waist circumference, BMI, BMI-Z score (primary outcomes), 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. Significant group-by-time intervention effects were found for waist circumference [-3.1cm, p<0.001], BMI [-1.38 kg/m^2, p<0.001], BMI-Z [-0.5 z-scores, p<0.001], sit and reach [+3.0cm, p<0.001], standing jump [+0.1m, p=0.021] and shuttle run [+10.3 laps, p=0.019]. Retention rate was 82.3%. All program sessions were delivered and participants' mean satisfaction scores ranged from 4.2 to 4.6 out of 5. The findings demonstrate that CrossFit Teens™ is a feasible and efficacious program for improving health-related fitness in adolescents.

Key words: *Physical fitness, physical education, body composition, resistance training, adolescents*

Trial Registration No: ACTRN12613001310752

Introduction

High levels of health-related physical fitness (especially body composition, cardiorespiratory fitness and muscular fitness) are associated with improvements in a range of physical, cognitive and psychological health outcomes (Ortega, Ruiz, & Castillo, 2013; J. J. Smith et al., 2014). However, physical activity levels decline dramatically during adolescence and global estimates suggest that 80% are not meeting physical activity guidelines (Hallal et al., 2012). It is of additional concern that weight gain occurs rapidly during adolescence, almost 25% of adolescent girls and boys are overweight or obese (Ng et al., 2014), and that the majority of overweight youth remain overweight in adulthood (Herman, Craig, Gauvin, & Katzmarzyk, 2009; Water et al., 2011). There is clearly a need for researchers to find engaging and novel ways of helping adolescents participate in health-enhancing physical activity (e.g., high intensity activity, and muscle and bone strengthening exercise) (Dobbins, Husson, DeCorby, & LaRocca, 2013; Faigenbaum, Lloyd, & Myer, 2013; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Stratton et al., 2004), especially given that both adolescent boys and girls report difficulty starting and adhering to regular exercise (Dumith, Gigante, Domingues, & Kohl, 2011; Huotari, Nupponen, Mikkelsson, Laakso, & Kujala, 2011).

It has been proposed that the promotion of physical activity for adolescents should focus on enjoyable lifelong activities that can be easily carried into adulthood, such as exercise programs that meet needs and motivations of both girls and boys (Biddle, Atkin, Cavill, & Foster, 2011) (Dobbins et al., 2013; Faigenbaum et al., 2013; Lubans, Morgan, et al., 2010; Stratton et al., 2004). 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, Morgan, Aguiar, & Callister, 2011). However, consideration of maturational status and the variance between

boys and girls physical activity behaviours, fitness levels and attitudes towards fitness should be considered in program design, as these variations are often reflective of associated physiological, sociological and demographic issues experienced during this time (Cumming, Standage, Gillison, & Malina, 2008).

Resistance training is a recommended lifelong physical activity that has proven to be safe and effective for increasing fitness and health in adolescent boys and girls when implemented with qualified instruction and appropriate supervision. Resistance training can also be easily integrated with other health-related fitness activities in physical education and sport programs using combinations of low-tech exercises (i.e., requiring minimal equipment, organisation or space) (Faigenbaum et al., 2013; Lloyd et al., 2013; Stratton et al., 2004). 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), medicine ball activities and circuit training (Faigenbaum, McFarland, & Keiper, 2007; Faigenbaum, McFarland, Johnson, et al., 2007; Faigenbaum & Mediate, 2006; Lubans, Sheaman, & Callister, 2010; Meinhardt, Witassek, Petrò, Fritz, & Eiholzer, 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 health-related fitness).

CrossFit™ is a form of training that targets multiple components of fitness and has emerged as a popular and effective lifetime physical activity choice for adults worldwide (Heinrich, Patel, O'Neal, & Heinrich, 2014; M. M. Smith, Sommer, Starkoff, & Devor, 2013). The CrossFit Teens™ program was designed specifically for improving fitness and resistance training skill competency in adolescents (ages 12-18 years) and incorporates combinations of nine core strength exercises in a group training setting (Glassman, 2010). The short

duration, high intensity focus and station-based organisation also draws from existing training methods such as circuit training and high intensity interval training (HIIT). This novel program requires minimal equipment and has the potential to align with physical education and sport objectives in secondary schools. Concerns have been raised regarding the potential injury risks associated with the intense and repetitive nature of CrossFit ™ training and the technique requirements needed to perform some core exercises safely. Based on a small number of participants, CrossFit ™ has resulted in cases of musculo-skeletal injury and exertional rhabdomyolysis in adult populations (Hak, Hodzovic, & Hickey, 2014). However, injury rates in adults are similar to those reported for sports such as weight-lifting and gymnastics and lower than competitive contact sports such as rugby union and rugby league (Faigenbaum et al., 2013; Hak et al., 2014). Despite these concerns and the growing popularity of CrossFit™ training programs, to the authors' knowledge, there are no published studies supporting the physical and psychological benefits of participating in CrossFit™ in adolescent populations. One article by Sibley (2012) explained how CrossFit content can be used within a Sport Education model for secondary school students, but there is no empirical evidence demonstrating that such programs can be delivered feasibly and safely in the school setting (Sibley, 2012). Therefore, 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. It was hypothesised that health-related fitness and resistance training skill competency would improve as a result of participants completing the CrossFit Teens™ resistance training program, and that possible sex differences would exist in study outcomes.

Materials and methods

Research design

The study involved a randomized 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). 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 (ages 15-16 years), and those with 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 school Principal and teachers 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 to ensure an equal chance of allocation to each group.

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, Torode, & Fiatarone Singh, 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 adolescents by the two experienced CrossFit™ instructors who delivered the program, and was based on a ‘group training’ atmosphere and a game setting, to engage adolescent participants (Glassman, 2010). It incorporated combinations of core strength exercises that

adolescents could perform safely (e.g., squat jumps, push-ups, deadlifts), utilised the outdoor facilities and basic equipment available at the participating school (e.g., school bags, medicine balls, broom sticks, basketball court), and targeted improvement in health-related fitness. The instructors also observed the participants to ensure that they did not progress to a heavier load / advanced level of any exercise until they could consistently demonstrate correct technique at the existing level. Staying true to the CrossFit™ methodology, separate programs were not given to males and females, and participants were not performing set exercises repetitively or for longer than 30secs before they rested or changed activities – minimising the risk of fatigue or exhaustion. A detailed outline of the program is displayed in Table 1. The program was dosed-matched to the control conditions and was delivered twice a week for 8-weeks during normal physical education (60min) and sport lessons (60min) (cost $60 per session per group). Each session, the instructors focused on meeting student's needs by allowing them to work with peers of similar ability and to select activities based on their fitness and skill levels. By providing a range of exercises in a gradually progressing training program, and by specifically focusing on teaching and improving resistance training technique, the instructors aimed to provide an effective and safe experience for the participants. A typical session included: a dynamic warm-up (10min), a technique-based skill session (10min), a Workout of the Day (WOD =10-20min), a stretching session (5-10 min) and time allocated for organisation, transition and changing into physical education uniform (10min).

Control (wait- list control group)

The control group participated in a 60min/week sport lesson (student choice, e.g., ice skating, team sport, tennis) and their usual 60min / week physical education lesson (fitness lessons covering a variety of fitness activities) delivered by their physical education 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 conducted at the study school during one physical education and one sport lesson under similar environmental conditions and using the same instruments at each time point. Research assistants were responsible for conducting and recording the results of all assessments. All assessments used in this study are commonly used with adolescents and data pertaining to reliability and validity of each measure have been previously published (Cooper Institute for Aerobics Research, 2013; Institute of Medicine, 2012; Lubans, Smith, Harries, Barnett, & Faigenbaum, 2014).

Note: r = reliability; v = validity; ICC = test-retest reliability

Primary outcomes

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% (r=0.96, v=0.93)(Institute of Medicine, 2012).

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 (mass [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 (v=0.37-0.81) (Institute of Medicine, 2012).

Secondary outcomes

Standard testing procedures from the FITNESSGRAM® testing manual (Cooper Institute for Aerobics Research, 2013) were followed for the:

1. 90-degree push-up test (upper body MF). (r=0.96, v=0.4, ICC=0.96))

2. Curl-up test (abdominal MF) (r=0.7-0.97)

3. 20m shuttle run test (CRF) (r=0.64-0.9, v=0.72-0.87, ICC=0.78-0.93)

4. Sit and reach test (F) (r=0.93-0.99, v=0.27-0.30, ICC=0.98)

5. The standing long jump test was use to assess muscular power (Institute of Medicine, 2012). Participants 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 best score from two attempts was used in the analysis (r=0.52-0.99, v=0.70-0.91).

6. Grip-strength (MF) was assessed using a grip dynamometer (Smedley's TTM Tokyo)(Roberts et al., 2011). Participants 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 (r=0.71-0.90, v=0.52-0.84).

7. Resistance training skill competence was measured using the Resistance Training Skills Battery (RTSB)(Lubans et al., 2014). 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. The skill scores were then added to create a resistance training skill quotient (RTSQ) (v= 0.4, ICC=0.88).

Process evaluation

The feasibility of the program was examined using measures of recruitment, retention, adherence and satisfaction. An evaluation survey was also administered at the completion of the program. Items assessing satisfaction (14) (Example item: *I think <u>all</u> schools should have*

the opportunity to try CrossFit), and future behaviour plans (4) (e.g., *In the future I plan to participate in muscle strengthening physical activities*) utilized a 5-point Likert scale format (responses ranging from "Strongly Disagree" = 1 through to "Strongly Agree" = 5). Participants were also asked to indicate the specific activities they enjoyed (e.g., circuits, ball games, partner strength activities) and to comment on aspects of the program they did not enjoy (open-ended format).

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 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 and applied to the pooled data and for boys and girls separately. Mixed models were used to assess all outcomes for the impact of group (intervention or control), time (treated as categorical with levels baseline and immediate post-intervention) and the group-by-time interaction. Linear mixed models are consistent with the intention-to-treat principle (Mallinckrodt, Watkin, Molenberghs, Carroll, & Lilly, 2004). Cohen's d effect size was calculated (d= mean difference in change scores / pooled variance) and interpreted as: .20 = small, .50 = moderate and .80 = large effect.

Results

Overview. The flow of participants through the study process is displayed in Figure 1. 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:

For girls, there was a significant group-by-time interaction for waist circumference [adjusted mean difference = -3.5cm (95%CI, -6.00 to -1.09), p<0.01, d= 0.2], BMI [-2kg/m^2 (95% CI, -2.81 to -1.27), p <0.001, d= 0.6] and BMI-z [-0.7 z-scores (95% CI, -1.05 to -0.4), p<0.001, d= 0.7]. For boys, there was a moderate effect for BMI (d=0.6, p=0.09) and a large effect for BMI-Z (d=1.5, p=0.1)(Tables III, IV).

Changes in secondary outcomes: There were significant group-by-time effects for boys' flexibility [3.4cm (95% CI, 0.21 to 6.5), p=0.04, d= 0.3] and standing jump [0.2m (95% CI, 0.02 to 0.36), p=0.03, d= 0.6], and for girls in the shuttle run test [3.3 laps (95% CI, 5.07 to 22.72), p=0.004, d= 1.5]. No significant group-by-time effects were found for either girls or boys in the push-up, curl-up and grip-strength tests (p>0.05).

No significant group-by-time effects were found for resistance training skill competency. Given that time constraints and unforeseeable conflicting school commitments impacted on the sample completing this test at both time-points, within-group changes were also examined (Table III, IV). In the intervention group (pooled data), 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*:* 100% of invited teaching staff and students agreed to participate. All students were assessed for eligibility to participate in baseline assessments

(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) were reported during the games session of the program. Retention*:* 82.3% completed 8-week follow-up measures with no significant difference found between study groups (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 by a school excursion and only the girls participated in this session. Satisfaction: Mean scores on the evaluation survey ranged from 4.2 to 4. 6 out of 5 (1= S*trongly disagree* to 5=*Strongly agree*) (see Table V) for the four scales, indicating high-to-very high overall satisfaction rates. Furthermore, participants indicated that they enjoyed the program, 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 adolescent boys and girls. Results from the pooled data indicate that the program was successful in significantly improving all three measures of body composition, flexibility, cardiorespiratory fitness and muscular fitness (measured by the standing jump), but not for resistance training skill or for three measures of muscular fitness (grip strength, curl-up, or push-up). The results for girls and boys revealed that significant intervention effects for body composition and cardiorespiratory fitness were evident in girls only, and that significant intervention effects were found in boys (and not girls) for measures of flexibility and muscular fitness (standing jump). Our process data also supports that students were highly satisfied with the program. In addition, recruitment and retention levels were high, and adherence to the program was excellent.

The CrossFit Teens™ program led to significant improvements in all three measures of body composition for the pooled data. Additionally, the significant and moderate effect on two measures of body composition in girls, and large effect on BMI-Z in boys exceed previous school-based resistance training interventions. The literature has consistently reported difficulties in preventing unhealthy weight gain among adolescents using school-based physical activity interventions (Berkey, Rockett, & Colditz, 2008)(Dobbins et al., 2013), and resistance training interventions have also demonstrated mixed results (Dorgo et al., 2009; Meinhardt et al., 2013). For example, Meinhardt and colleagues (2013) implemented a guided strength training program for 10-14year old boys, and Dorgo and colleagues (2010) used manual resistance training in physical education for boys and girls, and both found no significant changes in body composition (Dorgo et al., 2009; Meinhardt et al., 2013). In contrast, Benson, Torode, and Fiatarone Singh (2008) found that a high-intensity progressive resistance training intervention significantly improved waist circumference and BMI z-scores in 10-15 year-old boys and girls (mean change: waist circumference = -2.2 cm, BMI = -0.01) (Benson et al., 2008). Similarly, Lubans, Sheaman and Callister (2010) reported significant improvements in BMI, but no significant changes in waist circumference in adolescents using elastic tubing and free weights resistance training programs (Lubans, Sheaman, et al., 2010). The authors in both studies associated the improvements in body composition to improvements in strength. The majority of the studies cited above implemented a similar intervention dose to this study (twice a week for 8 weeks), but the unique combination of various high intensity core exercises targeting multiple fitness components used in the CrossFit Teens™ program (typically not popular among adolescent girls) (Dumith et al., 2011) may explain the significant and positive impact on body composition in girls.

Our results also indicate that adolescent girls can significantly improve their cardiorespiratory fitness through a school-based program. A recent Cochrane review cited only one school-based physical activity intervention for adolescent reporting significant

effects on cardiorespiratory fitness in girls (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 physical education (Dorgo et al., 2009). Other resistance training programs have not reported cardiorespiratory fitness outcomes (Faigenbaum, McFarland, & Keiper, 2007; Faigenbaum & Mediate, 2006; Lubans, Sheaman, et al., 2010; Meinhardt et al., 2013). The vigorous physical activities embedded in the CrossFit Teens™ program may also explain the success of the program in improving cardiorespiratory fitness in girls, who are less likely to engage in these types of exercise behaviours when compared with males of a similar age (Dumith et al., 2011). The significant and large effect on cardiorespiratory fitness in girls after only 8 weeks supports the potential effectiveness of the CrossFit Teens™ program for enhancing health outcomes in adolescent girls and for curbing the fitness decline often typical of girls in this age group. These results are also encouraging given that the control group participated in a physical education and sport program of the same duration and time commitment, but the lack of improvement in boys warrants further consideration.

The CrossFit Teens™ program specifically targeted muscular fitness and although there was significant improvement for the standing jump and a large positive effect on push-up performance for the pooled data, no significant differences between groups for any measure of muscular fitness for girls or boys (separately) were observed. Evidence is building to support the success of resistance training programs for improving muscular fitness in adolescents (Faigenbaum, McFarland, & Keiper, 2007; Faigenbaum & Mediate, 2006; Lubans, Sheaman, et al., 2010), but our results align with the largely ineffective findings of previous school-based physical activity and fitness interventions (Kriemler et al., 2011). Given the importance that muscular fitness has on health outcomes (J. J. Smith et al.,

2014), any improvements in muscular fitness gained through participation in fitness training programs lends support to their integration in physical education and sport in the school setting – thus the small positive effect demonstrated in several measures add support for the program. These unexpected results were perhaps due to the program length and structure. The majority of students were inexperienced in resistance training so many of the program sessions focused on technique and were conducted using minimal, if any resistance (e.g., broom sticks, pipes, body weight only). The focus on improving resistance training skill competency, although important for injury prevention and long term exercise adoption, may have reduced muscular fitness gains. If the program was extended and participants were given the opportunity to progressively increase the training load, improvements in these measures may be observed.

In this study, no significant intervention effects in resistance training skill competency were found for the pooled sample. Given the small sample size, and the lack of power to detect significant change in this measure, an investigation of within-group changes and Cohen's d effect size in resistance training skill competency in the intervention group was conducted. The findings demonstrate improvement in the intervention group for all six resistance training skills –suggesting that improvement in resistance training skill is possible using a 2-day per week CrossFit Teens™ program. However, either a longer or more frequent program may be needed for facilitating the acquisition of resistance training skill. Additionally, physical capacity may hinder the rapid development of these skills (e.g., push-up), suggesting that a longer term program may result in the development of muscular fitness and a corresponding improvement in skill. Surprisingly, the control group also made small positive changes in resistance training skill competency. A possible explanation is that the physical education and sport program that the control group participated in during the study period (which included eight fitness lessons focusing on a variety of fitness activities, and eight community-based sport sessions) involved similar movement patterns.

Our process evaluation results indicate that CrossFit Teens™ is a feasible program for use with Grade 10 students. Recruitment was successful with both students and staff willing to participate, retention rates were very high (there were no dropouts from the program), and there were no major injuries reported as a result of participating. Similarly, adherence to the program was excellent (100%), and attendance was very high (94% for 15/16 sessions). Accessing the students through mandatory timetabled physical education and sports sessions impacted positively on adherence rates, but also suggests that using these opportunities within the school setting is important. 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, and may have led to greater motivation (Ferrer-Caja & Weiss, 2000).

Strengths and limitations: To the authors' knowledge, this is the first study to evaluate a CrossFit™ program designed specifically for adolescents. The strengths of our study include the assessor blinded RCT study design and the use of valid and reliable measures of fitness and skill competency. 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 physical education 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 maturational status, physical activity and sports participation outside the school setting, or nutritional behaviours and exercise intensity during the CrossFit sessions, were not collected.

Implications: CrossFit™ training programs 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, 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 engaging, well- designed and evidence-based high intensity fitness programs (Buchan et al., 2011; Moore, Beets, Barr-Anderson, & Evenson, 2013) that are available in the community, and to build their skill competence to participate in such programs within the school setting (Huotari & Kujala, 2013), the link between community and school health promotion may strengthen. It may also lead to improved fitness and health, increase long term participation and program sustainability (Moore et al., 2013).

Conclusion

The CrossFit Teens™ program has demonstrated success in improving HEALTH-RELATED FITNESS outcomes in adolescent girls and boys - suggesting that incorporating CrossFit™ training into the physical education curriculum in secondary schools may be a safe, effective, and appealing approach to promote physical fitness in adolescents. However, the varied adaptations stimulated in boys and girls participating in the program, imply that different approaches may be needed for boys and girls if targeting identical outcomes in the future. Further research is also needed to establish long term health gains, sustainability in the school setting and impact on physical activity beyond the school setting.

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Table 1: CrossFit Program Components (Australia, 2013)

Wk	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	10 squats / 10 deadlifts (school bag) / 10 burpees	10min
	Cool Down	third world sit	5 min
1.2	Warm up	3 inchworms, 10 bear walks, 6 squats	3 sets
	Skills / technique	refresh squat, push-up, box jump	10min
	Pair WOD / AMRAP	10 box jumps / 10 squats (BW) / 5 push-ups	10min
	Cool Down	hip and gluteal stretches (static)	5 min
2.1	Warm up	3 squats, 3 burpees, 1 shuttle runs	3 sets
	Skills / technique	goblet squat, skipping, deadlift	
	WOD	1min goblet squat (medicine ball), deadlift (bag), push-ups, shuttle run	3 rounds
	Cool Down	hip and gluteal stretches (static)	5 min
2.2	Warm up	15secs burpees, 15sec star jumps, 15secs squat	3 sets
	Skills / technique	wall ball, box jump, overhead squat	10min
	WOD / AMRAP	Station 1: wall ball Station 2: 10 box jumps, 15 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 30m, run 30m	3 sets
	Skills / technique	deadlift (barbell), clean (pvc pipe), kettle bell swing	
	Pair WOD / AMRAP	10 deadlifts / 5 burpees / 10 kettle bell swings	12min
	Cool Down	hip and gluteal stretches (static)	5 min
3.2	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 hands overhead walking lunges, 10 squats, 15 situps Station 3: 8 medicine ball cleans, 8 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	thrusters	5 min
	WOD	10 thrusters / run 50m / 10 box jumps / run 100m	20min
	Cool Down	hip and gluteal stretches (static)	5min
4.2	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 (BW)	15 min
	Group (4) AMRAP	100 burpees, push press (dumbells), thrusters (dumbells), situps	20min
	Cool Down	hip and gluteal stretches (static)	5min

5.2	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	8 min per
		Station 2: bear walk 30m, broad jump x 1 burpees x 3 30m)	station
		Station 3: build to 5RM dumbbell press	
	Cool Down	hip and gluteal stretches (static)	5min
		hovers x 2 (maximum time)	
6.1	Warm up	10 squats (5 sec count), 30sec duck walk &, good mornings	3 sets
	Skills / technique	wall ball toss, overhead lunge walks	5 min
	Partner WOD /	10 wall ball toss to partner (medicine ball)	15min
	AMRAP	20m overhead medicine ball lunge walks	
	Cool Down	hip and gluteal stretches (static)	5min
6.2	Warm up	10 leg swings	10 min
		10 squats (5 sec count)	
		hip and gluteal stretches (static)	
	Skills / technique	squats (school bag)	5min
	WOD *Game Day*	Station 1: dodge ball with Crossfit exercise penalties	10min per
		Station 2: Chasing games (e.g. octopus, Red Rover)	station
		Station3: AMRAP 50m hill sprint (school bag), 10 bag squats	
	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 alternating dumbell snatch / burpee broad jump 20m	15min
	Cool Down	hovers (maximum time)	10min
		1min hovers plus 20 burpees	
		1-2min plus 15 burpees	
		2-3min plus 10 burpees	
		3 plus mins no burpees	
		hip and gluteal stretches (static)	
7.2	Warm up	30sec squats, 30sec star jumps, 30sec burpees	3 sets
	Skills / technique	box jumps	5min
	WOD	Station 1: 5 x box jump per minute – add 5 more each minute	10 min per
		Station 2: head stands	station
		Station 3: 1min sprint trial x 4	
	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 /	Station 1: Forward roll, standing jump x 5 burpees x 5	10min per
	AMRAP	Station 2: 10 wall balls, 10 sit ups, 10 push-up, 10 box jumps	station
		Station 3: 10 dead lifts (bar plus weights), 10 jumps, 5burpees	
	Cool Down	hover challenge (maximum time)	
	Hovers (maximum)	hip and gluteal stretches (static)	
8.2	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 II: Baseline data (Australia, April 2013)

Demographic Characteristics	Boys		Girls		Total	
	Total (n=46)		Total (n=50)		Total (n=96)	
	mean	sd	mean	sd	mean	sd
Age (years)	15.3	0.47	15.5	0.5	15.4	0.5
Physiological Characteristics	**Total (n=46)**		**Total (n=50)**		**Total (n=96)**	
	mean	sd	mean	sd	mean	sd
Height (m)	1.77	0.72	1.65	0.59	1.70	0.89
Mass (kg)	65.1	12.3	58.5	9.4	61.7	11.3
Waist circumference (cm)	72.3	13.8	72.5	18.3	72.2	16.7
BMI (mass / height2)	21.3	3.4	21.3	3.3	21.2	3.2
BMI Z-score	-0.00	1.13	0.08	1.08	0.04	1.10
Sit and reach (cm)	1.8	9.3	11	7	6.1	8.2
Push-up test (reps)	16.7	10.3	6.8	7.4	10.4	9.9
Curl-up test (reps)	41.8	23.3	32.7	13.5	35.2	18.4
Standing jump (m)	2.01	0.23	1.40	2.82	1.70	0.40
Grip-strength (kg)	41.4	6.9	27.1	6.8	34.2	1.3
Shuttle run test (laps)	44.3	17.1	16.7	10.3	48.6	20.2
Resistance Training Skill	**Total (n=24)**		**Total (n=32)**		**Total (n=58)**	
	mean	sd	mean	sd	mean	sd
Squat [c]	7.3	2	7.2	1.8	7.0	2.2
Lunge [c]	8.3	2.1	8.1	2.0	6.9	2.0
Push-up [d]	7.1	1.5	5.5	2.0	3.8	1.9
Suspended row [d]	6.6	1.1	7	1.2	3.7	1.2
Front support [c]	6.0	1.7	5.8	2.0	4.5	1.2
Shoulder press [c]	9.2	1.0	8.3	1.1	7.7	1.5
RTSQ (total)	44.8	5.5	42.2	6.5	42.2	5.9

SD = standard deviation; %=percentage; No.= number HSC= Higher School Certificate; *Sig. difference between groups P<0.05; SC = School Certificate; HSC= Higher School Certificate; [c] = maximum score =10; [d]= maximum score = 8; reps = repetitions; RTSQ: Resistance training skills quotient- total score for the 6 skills

Table III: CrossFit Study intervention effects (by treatment group) – Fitness (Australia, 2013)

All Participants							
Measure	**Baseline, Mean (SD)**		**8 week, Mean (SD)**				
	Control Group (n = 41)	**CrossFit Teens (n =55)**	**Control Group (n =34)**	**CrossFit Teens (n =49)**	**Adjusted Difference in Change (95% CI)[a]**	**Group*Time *P* value**	**Cohen's *d***
Waist circumference (cm)	74.1 (11.6)	75.2 (7.7)	74.5 (14.1)	73.5 (7.4)	-3.1 (-5.00 to -1.25)	<0.001	0.2
BMI (mass / height2)	20.6 (3.7)	21.6 (3.0)	21.7 (1.3)	21.5 (3.0)	-1.3 (-1.86 to -0.70)	<0.001	0.4
BMI Z-score	-0.22 (1.26)	0.24 (1.32)	0.07 (1.32)	0.16 (0.88)	-0.46 (-0.68 to -0.23)	<0.001	0.5
Sit and reach (cm)	4.9 (11.4)	7.7 (7.4)	1.5 (13.0)	7.9 (7.3)	3.0 (0.78 to 5.26)	0.01	0.4
Curl-up test (reps)	34.3 (17.6)	39.6 (19.2)	50.3 (22.6)	60.3 (18.0)	5.5 (-3.53 to 14.61)	0.23	0.3
Push-up test (reps)	8.7 (9.3)	13.6 (10.4)	11.6 (8.5)	17.1 (10.2)	-8.0 (-2.91 to 4.48)	0.68	0.8
Standing jump (m)	1.72 (0.37)	1.71 (0.43)	1.68 (0.33)	1.80 (0.38)	0.08 (0.02 to 0.24)	0.02	0.1
Grip-strength (kg)	33.7 (11.1)	34.4 (8.1)	34.9 (11.3)	35.7 (8.9)	0.5 (-1.78 to 2.73)	0.69	0.4
Shuttle run test (laps)	41.9 (16.7)	54.9 (21.2)	46.3 (19.3)	71.0 (23.9)	10.3 (1.76 to 18.92)	0.02	0.5
	Control Group (n = 22)	**CrossFit Teens (n =34)**	**Control Group (n =22)**	**CrossFit Teens (n =34)**	**Adjusted Difference in Change (95% CI)[a]**	**Group*Time *P* value**	**Cohen's *d***
Squat [c]	6.3 (2.2)	7.8 (1.7)	6.4 (2.3)	8.4 (2.0) [b]	0.5 (-0.85 to 1.88)	0.45	0.4
Lunge [c]	7.9 (1.9)	8.3 (1.7)	8.1 (1.7)	8.7 (1.6) [b]	0.3 (-0.91 to 1.43)	0.66	0.2
Push-up [d]	6.0 (2.1)	6.2 (1.8)	5.8 (2.1)	7.3 (1.3) [b]	0.8 (-0.09 to 1.71)	0.08	0.9
Suspended row [d]	6.9 (1.1)	6.8 (1.8)	6.9 (1.1)	7.3 (1.0) [b]	0.5 (-0.22 to 1.19)	0.17	1.2
Front support [c]	6.2 (1.1)	6.2 (1.9)	6.3 (2.0)	6.5 (1.4) [b]	-0.8 (-1.85 to 0.28)	0.15	-1.2
Shoulder press [c]	8.5 (1.2)	8.8 (1.2)	8.3 (1.3)	8.9 (1.4) [b]	0.3 (-0.47 to 1.05)	0.45	0.5
RTSQ (Total)	39.7 (5.5)	44.7 (6.2)	41.8 (7.0) [b]	46.6 (4.3) [b]	0.1 (-3.14 to 2.88)	0.17	0.2

Abbreviations: BMI, body mass index; CI, confidence interval; MVPA, moderate-to-vigorous physical activity; SD, standard deviation; RTSQ: Resistance training skills quotient- total score for the 6 skills; [c] = maximum score =10; [d] = maximum score = 8; reps = repetitions; [a]Adjusted mean difference and 95% CI between CrossFit Teens™ and control groups after 8-weeks (Intervention minus control) –adjusted for baseline scores; [b] Within group change over time; Cohen's d calculated as d= mean difference in change scores / pooled variance

Table IV: CrossFit Study intervention effects (by sex) – Fitness (Australia, 2013)

Boys							
Measure	**Baseline, Mean (SD)**		**8 week, Mean (SD)**				
	Control Group (n=22)	**CrossFit Teens (n=24)**	**Control Group (n=22)**	**CrossFit Teens (n=24)**	**Adjusted Difference in Change (95% CI)a**	**Group*Time P value**	**Cohen's d**
Waist circumference (cm)	76.0 (13.9)	75.5 (5.5)	75.2 (14.1)	74.8 (14.1)	-2.2 (-5.12 to 0.69)	0.13	0.1
BMI (mass / height^2)	20.8 (4.0)	21.2 (2.7)	21.3 (4.3)	21.1 (4.3)	-0.7 (-1.52 to 0.11)	0.09	0.6
BMI Z-score	-0.15 (1.27)	0.13 (0.99)	0.02 (1.36)	0.04 (0.83)	-0.25 (-0.56 to 0.05)	0.10	1.5
Sit and reach (cm)	-0.8 (10.2)	3.3 (7.4)	-4.0 (13.0)	3.5 (13.0)	3.4 (0.21 to 6.5)	0.04	0.3
Curl-up test (reps)	13.3 (10.1)	20.3 (9.0)	16.1 (22.6)	23.4 (21.3)	2.3 (-10.86 to 15.46)	0.91	0
Push-up test (reps)	35.8 (21.3)	46.9 (24.6)	51.8 (8.6)	65.3 (8.6)	0.3 (-10.86 to 15.46)	0.73	0.1
Standing jump (m)	1.99 (0.23)	2.03 (0.24)	1.86 (0.27)	2.10 (0.35)	0.19 (0.02 to 0.36)	0.03	0.6
Grip-strength (kg)	42.2 (7.5)	40.9 (6.5)	42.0 (11.3)	43.6 (11.3)	2.9 (-0.52 to 5.56)	0.10	0.3
Shuttle run test (laps)	46.1 (18.4)	67.8 (21.9)	53.9 (19.3)	86.1 (19.3)	10.3 (-5.90 to 26.60)	0.20	0.1
	Control Group (n= 8)	**CrossFit Teens (n=16)**	**Control Group (n=8)**	**CrossFit Teens (n=16)**	**Adjusted Difference in Change (95% CI)[a]**	**Group*Time *P* value**	**Cohen's *d***
Squat [c]	7.1 (2.2)	7.2 (2.0)	5.9 (1.9)	8.5 (1.9)	2.0 (-0.53 to 4.54)	0.12	1.0
Lunge [c]	7.7 (1.5)	8.5 (2.3)	7.5 (1.5)	8.3 (1.5)	0.0 (-1.91 to 1.93)	0.99	0
Push-up [d]	6.7 (2.1)	7.1 (1.2)	6.3 (2.3)	7.1 (2.3)	0.2 (-0.89 to 1.38)	0.67	0.1
Suspended row [d]	7.0 (1.2)	6.4 (1.1)	6.9 (1.8)	7.4 (1.8)	1.2 (0.15 to 2.22)	0.26	1.1
Front support [c]	6.1 (2.1)	6.3 (1.4)	6.2 (1.2)	6.7 (1.2)	0.7 (-0.99 to 0.62)	0.29	0.4
Shoulder press [c]	9.0 (1.1)	9.3 (0.9)	8.0 (1.0)	8.9 (1.0)	0.7 (-0.39 to 1.76)	0.20	0.7
RTSQ (Total)	41.3 (7.0)	46.0 (4.2)	40.7 (6.2)	46.8 (6.2)	1.4 (-3.56 to 6.28)	0.58	0.3
Girls							
Measure	**Baseline, Mean (SD)**		**8 week, Mean (SD)**				
	Control Group (n=19)	**CrossFit Teens (n=31)**	**Control Group (n=19)**	**CrossFit Teens (n=31)**	**Adjusted Difference in Change (95% CI)a**	**Group*Time P value**	**Cohen's d**
Waist circumference (cm)	72.2 (8.5)	75.0 (9.1)	72.7 (7.5)	71.9 (7.5)	-3.5 (-6.00 to -1.09)	0.01	0.2
BMI (mass / height^2)	20.3 (3.4)	22.0 (3.2)	22.2 (3.0)	21.8 (3.0)	-2.0 (-2.81 to -1.23)	<0.001	0.6
BMI Z-score	-0.31 (1.27)	0.32 (0.88)	0.33 (1.32)	0.24 (0.93)	-0.72 (-1.05 to -0.40)	<0.001	0.7
Sit and reach (cm)	11.4 (9.1)	11.0 (5.6)	9.2 (7.3)	11.1 (7.3)	2.3 (-1.1 to 5.72)	0.18	0.2

Curl-up test (reps)	3.6 (4.4)	8.5 (8.3)	6.3 (18.0)	12.0 (11.3)	8.9 (-4.01 to 5.81)	0.72	0.4
Push-up test (reps)	32.7 (11.3)	34.0 (15.3)	46.6 (10.5)	56.8 (10.5)	0.9 (-4.15 to 5.8)	0.18	0.1
Standing jump (m)	1.41 (0.18)	1.45 (0.33)	1.48 (0.27)	1.56 (0.19)	0.04 (-0.09 to 0.17)	0.55	0.0
Grip-strength (kg)	23.9 (7.9)	29.4 (5.2)	26.8 (8.9)	30.5 (8.9)	-1.8 (-4.66 to 1.07)	0.21	-0.2
Shuttle run test (laps)	36.7 (16.8)	45.6 (18.4)	37.0 (24.0)	59.7 (24.0)	13.9 (5.07 to 22.72)	0.00	1.5
	Control Group (n=14)	**CrossFit Teens (n=18)**	**Control Group (n=14)**	**CrossFit Teens (n=18)**	**Adjusted Difference in Change (95% CI)[a]**	**Group*Time *P* value**	**Cohen's *d***
Squat [c]	5.9 (1.6)	7.8 (1.5)	8.8 (1.3)	8.4 (1.3)	-0.7 (-2.23 to 0.88)	0.39	-0.5
Lunge [c]	8.1 (1.5)	8.1 (2.3)	8.5 (1.6)	8.5 (1.6)	0.1 (-1.42 to 1.53)	0.94	0.1
Push-up [d]	5.3 (2.3)	5.4 (1.9)	4.9 (2.4)	6.4 (2.4)	1.4 (0.10 to 2.74)	0.36	1.1
Suspended row [d]	6.9 (1.2)	7.1 (1.2)	4.7 (1.4)	4.7 (1.4)	-0.1 (-1.04 to 0.93)	0.91	0.1
Front support [c]	6.2 (1.6)	6.1 (2.2)	6.3 (1.5)	6.4 (1.5)	-0.9 (-2.63 to 0.78)	0.28	-0.6
Shoulder press [c]	8.3 (1.1)	8.3 (1.2)	8.8 (1.2)	8.8 (1.2)	-0.1 (-1.09 to 0.87)	0.82	-0.2
RTSQ (Total)	31.4 (5.5)	35.9 (6.2)	41.8 (7.0) [b]	46.6 (4.3) [b]	-1.4 (-1.25 to 6.90)	0.17	0.2

Abbreviations: BMI, body mass index; CI, confidence interval; MVPA, moderate-to-vigorous physical activity; SD, standard deviation; RTSQ: Resistance training skills quotient- total score for the 6 skills;
[c] = maximum score =10; [d] = maximum score = 8; reps = repetitions; [a]Adjusted mean difference and 95% CI between CrossFit Teens™ and control groups after 8-weeks (Intervention minus control) –adjusted for baseline scores; [b] Within group change over time; Cohen's d calculated as d= mean difference in change scores / pooled variance

Table V: 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**	**4.2**	
CrossFit Teens™ helped to improve my health	4.2	.6
CrossFit Teens™ helped to improve my overall fitness	4.3	.7
CrossFit Teens™ helped to improve my muscular fitness	4.2	.7
CrossFit Teens™ helped to improve my aerobic fitness	4.0	.6
CrossFit Teens™ helped to improve my resistance training technique	4.5	.5
CrossFit Teens™ may help improve my performance in other sports and activities	4.2	.7
***Enjoyment of the program**	**4.6**	
I enjoyed doing the program with my friends / peers	4.7	.5
I enjoyed participating in the CrossFit sessions	4.3	.6
I think all schools should have the opportunity to try CrossFit	4.7	.5
***Rating of self with regards to participation in the CrossFit program**	**4.3**	
I feel better about myself having participated in CrossFit	4.0	.8
I put in a lot of effort during the CrossFit sessions	4.3	.6
I would like to know if my fitness levels have changed after participating in the CrossFit program	4.6	.6
Overall I am satisfied with my involvement in the CrossFit program	4.4	.5
***Future plans**	**4.2**	
In the future I plan to participate in muscle strengthening physical activities (e.g. resistance training, CrossFit)	4.0	.8
In the future I plan to participate in running / walking / cycling and other aerobic activities	4.5	.6
In the future I plan to join a gym, fitness centre or health club	4.2	.9
In the future I plan to participate in CrossFit	3.9	.8
#Enjoyment of specific program components		**Yes (%)**
I enjoyed participating in individual strength activities (on your own)		59.2
I enjoyed participating in partner strength activities (2 people)		93.9
I enjoyed participating in team strength challenges (more than 2 people)		83.7
I enjoyed participating in stretching		67.3
I enjoyed participating in strength activities using equipment (e.g. medicine balls, bars, dumbells, skipping ropes)		75.5
I enjoyed participating in strength activities without equipment		69.4
I enjoyed participating in ball games / challenges (e.g. ball tag)		77.6
I enjoyed participating in chasing games without equipment (e.g. red rover)		69.4
I enjoyed participating in circuits (e.g. involving a range of activities in one session)		89.8

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

#Likert Rating: 1= yes 2= no