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Original Article

Effects of CrossFit intervention on students' physical fitness in physical education: a systematic review and meta-analysis

YANKUN HAN[1], SYED KAMARUZAMAN BIN SYED ALI[2], LIFU JI[3]
[1,2] Faculty of Education, University of Malaya, Kuala Lumpur, MALAYSIA.
[3,] Faculty of Sport and Science, Hoseo University, Asan, SOUTH KOREA.

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Abstract
Problem statement: There are inconsistent views on the effects of CrossFit on students' physical fitness in physical education. ***Purpose:*** This study aimed to systematically review the existing literature concerning effects of CrossFit intervention on students in physical education through meta-analysis. ***Material:*** A total of 60 studies were identified and screened from 4 electronic databases (SCOPUS n = 22, Web of Science n = 9, PubMed n = 28, ScienceDirect n = 1). ***Methods:*** The systematic review followed PRISMA guidelines. The process of systematic review and meta-analysis was conducted based on the Cochrane Handbook and Review Manager Software (RevMan-5.4.1). The effect sizes with 95% confidence intervals were calculated using inverse variance and random effects analysis models. The heterogeneity was evaluated using the forest plot. ***Results:*** A total of 6 articles were included in the systematic review and meta-analysis. A total of 6 articles had a high level of evidence at low risk of bias in attrition and reporting. Previous studies on the effects of CrossFit on students' physical fitness in physical education reported on upper-body strength, lower-body power, core strength, change in BMI, cardiopulmonary function, and aerobic capacity. In the meta-analysis, the outcomes suggested that CrossFit significantly increased the performance of push-ups and handgrip. Positive effects on performance in pull-ups, squats, VO_2max and shuttle runs were observed. There was a null effect in physical fitness test in core strength, standing long jump and BMI. ***Conclusion:*** This systematic review and meta-analysis show that CrossFit as a high-intensity functional and interval training program is a positive strategy for developing students' physical quality and fitness in schools' physical education courses, especially for developing upper-body strength.
Key words: High-intensity functional training, High-intensity interval training, School, Physical quality

Introduction

School has been considered as the most appropriate circumstance (Simonton et al., 2019) for teaching physical education to promote students' skills, knowledge toward living healthy lifestyle (Huang et al., 2019). Physical education serves as a component of the schools' curricular system and plays a critical role in teaching students about physical fitness (Huang et al., 2019; Lubis, 2019). However, there has been a declining trend of physical fitness in younger generations globally (Dong et al., 2019). Worldwide, an estimation that around 80.3% of youth fail to meet the suggested levels of daily physical activity, in other words, they are engaging in the suggested moderate to vigorous intense physical activity less than 1 hour each day (Hallal et al., 2012). Living a lifestyle of physical inactivity is unhealthy to well-being (Wang, 2019), and can lead to the increasing prevalence of overweight and obesity (Wanner et al., 2017). In turn, the high level of frequency of physical inactivity aggravates deterioration of physical fitness (Chen et al., 2020).

Since its inception in 2000, CrossFit (CF) has been a signboard of fitness classes (Bailey et al., 2017). According to Glassman (2004), who is the founder of CF, "CrossFit is a strength and conditioning system built on constantly varied, if not randomized, functional movements executed at high intensity." As a functional training system, CF aims to facilitate physical fitness through development and optimization of physical quality in ten aspects: cardiovascular/respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance, and accuracy (Glassman, 2002). The fitness that CF promotes and advocates is extensive, universal, and inclusive on purpose (Glassman, 2002). "Fitness is increased work capacity across broad time, modal, and age domains" (Widman, 2009). Literally, the movements that CF develops are the movements of normal life which prepare people for the basic needs of life (Widman, 2009). Studies have indicated that CF benefits professional athletes (Smith et al., 2013; Martínez et al., 2019; Mangine et al., 2020), patients (Cruz-Díaz et al., 2020) and recreational participants (Mangine et al., 2020). Recently, CF is also gradually welcomed by most students due to its functionality, variability and scalability, in which each single functional movement, including load and intensity can be regulated to meet students' ability, ensuring their ability can be maximumly unleashed during workouts (Bala et al., 2019). However, CF training is defined as a high-intensity workout which is practiced quickly, repetitively with minimal or no stopping time between sets (Sprey et al., 2016),

Corresponding Author: YANKUN HAN, E-mail: hh313999@gmail.com

which brings the question whether or not this high-intensity activity benefits students' physical fitness in schools' physical education (Sibley, 2016) ?

Recently, studies showed that CF is an effective functional program for improving physical fitness in different levels of schools (Sibley, 2012; Eather et al., 2016; Kudryavtsev et al., 2018). However, Barfield et al. (2012) investigated that CF did not effectively improve the level of physical fitness of students when compared to a predefined control group. In this regard, there are disparities between studies. Unfortunately, we find that there is no systematic review filling this literature gap. Therefore, the purpose of this study is to evaluate the effects of CF intervention on students' physical fitness in PE courses via a systematic review and meta-analysis.

Methods

Search strategy. This study is based on the regulations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2015). Literatures were searched through the following online databases: Web of Science, SCOPUS, ScienceDirect, PubMed. The terms employed for online searching were "CrossFit" AND "physical education" AND "students". The outcomes from the database Web of Science were conveniently deemed as reference to identify duplicate records due to its authority in collecting journals with high impact factors.

Eligibility criteria The eligibility criteria was based on the PICO-S model (e.g. Population, Intervention, Comparison, Outcome and Study design) (Pati et al., 2018). The articles focused on studying the effects of CF intervention on students in PE courses would be included in this study. Therefore, the object of our study was defined as students who have been participating in PE courses. Moreover, the original articles should be randomized or nonrandomized trial, cross-sectional or longitudinal, quantitative or qualitative (or mixed approach) study design, to compare experimental group (CF) with control group. Given that the utilization of CF in PE is still at its infancy, our research team carried out electronic searching through databases without any time frame limitations. However, they should be with abstract and full-text available online, in English and without inclusion of gray literatures, such as, non-peer-reviewed articles, dissertations, thesis, conference papers etc.

Manual reference lists search Checking reference lists to identify and retrieve potentially relevant studies is an efficient approach to decrease the risk of bias or omission of relevant information (Horsley et al., 2011). Therefore, our research team conducted a manual reference list searching after the phase of full-text articles assessing.

Information sources According to the PICO-S search model, our research team searched articles that met eligibility criteria till Mar, 2021 which is the date of the starting manuscript. However, there were still four full text articles that were not accessible and available at the phase of full text article reviewing, even though one researcher tried to contact with those authors to solicit the original data. Unfortunately, we didn't receive a response from them. Consequently, those four articles were excluded from the current study at the phase of full-text articles assessing.

Study collection process Two members screened literatures to collect basic information, such as, author name, title, abstract, publication journal and date etc., to create a journal citation report (JCR) for the following overviewing and screening process. Duplicated articles were excluded from collection after record checking. Two reviewers then screened titles and abstracts separately. According to previous suggestions (Pati et al., 2018), they implemented an inter-rater estimation. Namely, one of them randomly sent 20% of the reviewed content to another for further reviewing till a total consensus was achieved. Otherwise, the third reviewer would be invited for further discussion until an agreement was achieved. The same procedure was used in the phase of full text article screening. Ultimately, we included six studies in this manuscript (table 1). The PRISMA flowchart was presented in Fig. 1.

Data collection and items researching Based on the process of study collection, the research team identified N = 60 records from databases. Among them, SCOPUS n = 22, Web of Science n = 9, PubMed n = 28, ScienceDirect n = 1. Consequently, N = 17 full-text articles were assessed for eligibility screening, and N = 9 were excluded. However, at the phase of manual reference lists searching, N = 6 articles were further included into this review. Finally, N = 6 for meta-analysis. (Fig. 1).

Assessment of risk of bias To assess the risk of bias, the Cochrane risk-of-bias tool (Higgins et al., 2019) was employed by two researchers independently. This tool consists of six domains: (a) selection bias (random sequence generation, allocation concealment); (b) performance bias (blinding of participants and personnel); (c) detection bias (blinding of outcome assessment); (d) attrition bias (incomplete outcome data); (e) reporting bias (selective reporting) and (f) other bias. For assessment purposes, the included articles were evaluated as one of risk of bias from choosing "low", "unclear" or "high". Before assessments, a pilot review was conducted by randomly choosing five included papers to ensure that the standards of evaluation were consistent and an agreement could be reached between the two reviewers (Higgins et al., 2019). In order to maintain accuracy, a randomly chosen 25% reviewed articles from first reviewer's assessment to further conduct judgment by the second. And any disparity would be resolved by referring to the third reviewer's suggestion. Accordingly, the assessment of accuracy was treated as acceptable.

Data calculation and statistical analysis the mean difference (MD), the pooled standard deviation (SD) and the number of participants (N) were used for meta-analysis. If the value of MD and pooled SD were not published in original articles then the following formulas and the Review Manager software (RevMan Version 5.4.1, The Cochrane Collaboration, 2020) were used as assistance tools for calculating data values. MD = $posttest_{mean} - pretest_{mean}$, pooled SD = $\sqrt{([(SD_1^2 + SD_1^2)]/2)}$ (Wan et al., 2014).

Meta-analysis was conducted by using RevMan-5.4.1. The random effects model was used to evaluate the effects of CF intervention on students. The outcomes from comparison between experiment and control groups were described with studies' 95% confidence intervals (CI). The heterogeneity within comparison groups was estimated based on p-value of chi-squared (Q) test. The outcome with $p \leq .1$ reflecting heterogeneity (Higgins et al., 2019). Due to a low power of chi-squared test, I^2 value also used for quantifying heterogeneity. If $I^2 \geq .5$ that indicating a substantial heterogeneity exists within studies (Higgins et al., 2019). Publication bias was estimated by using Rosenthal's fail-safe number test (Nfs-T). Nfs-T = 19S - N (S = number of studies, $p < .05$, N = number of studies, $p > .05$). Tolerance level (TL) = 5K + 10 (K = all included studies) (Kuo et al., 2018). A nonsignificant publication bias was represented by the value of Nfs-T > TL. Moreover, additional analysis, including sensitivity and subgroup analysis, was conducted to remove study (studies) with deficiency that might influence the effects in pooled group (Higgins et al., 2019).

Results

Six articles were included. Among them, the effects of CF on performance of upper body strength, lower body power, cardiopulmonary function and aerobic capacity, core strength, and BMI (body mass index, kg/m^2) were investigated. Participants ranged from secondary school to university students, and sample size covered from 28 to 141. The intervention from 5 weeks to an academic year (9-month). Most of these studies reported raw data, while some of data was needed to be calculated by aforementioned formulas and RevMan software.

A quality assessment of the included studies was depicted in Fig. 2. The symmetric measure of agreement between two reviewers was consistent with Kappa value 0.870. Among risk of bias domains, 66.67% was low risk in the random sequence generation in all of the included studies. There were 4 out of 6 that were unclear with regards to the risk in allocation concealment which represented selection bias. In terms of the following four biases: performance, detection, attrition and reporting bias displayed 100% individually. With unclear risk of other bias accounting for 66.67% in high risk in this domain.

Meta-analyses

***Effects of CF on upper-body strength*.** The random effects analysis model depicted that CF tremendously developed strength of push-ups (MD = 1.80, 95% CI = [1.08-2.52], overall effect Z = 4.91 with $p < 0.000001$) and the level of heterogeneity was significantly low with $I^2 = 0\%$ (Fig. 3). Due to Nfs-T (75) > TL (35), thus the publication bias was low and trustworthy. The performance of pull-ups, the random effects analysis model presented that CF did not positively affect its performance (MD = 0.65, 95% CI = [-2.05, 3.35], overall effect Z = 0.47 with $p = 0.64$), the degree of heterogeneity slightly high with $I^2 = 68\%$ (Fig. 4). Publication bias, in this case, Nfs-T (18) < TL (20) might be presented. In the case of the handgrip test, the random effects analysis model showed a significant statistic influence of intervention exercise in development of handgrip strength (MD = 2.42, 95% CI = [1.04, 3.81], overall effect Z = 3.42 with $p = 0.0006$), the level of heterogeneity was extremely low with $I^2 = 0\%$ (Fig. 5). The publication bias was low, since Nfs-T (38) > TL (20).

***Effects of CF on lower-body power*.** **T**he random effects analysis model displayed that the intervention project did not increase the ability of squats (MD = 0.31, 95% CI = [-0.59, 1.20], overall effect Z = 0.67 with $p = 0.50$). the degree of heterogeneity was slightly low with $I^2 = 29\%$ (Fig. 6). And Nfs-T (57) > TL (25) indicating that publication bias was low. The ability of standing long jump was not increased via analysis forest plot (Fig. 7) (MD = 0, 95% CI = [-0.2, 0.19], overall effect Z = 0.04, $p = 0.97$). Besides, the situation of heterogeneity was nonideal ($I^2 = 86\%$). However, publication bias was low with Nfs-T (38) > TL (20).

Effects of CF on Core strength. The level of core strength was reflected by curl up exercises. The forest plot showed that CF did not improve this ability in students (MD = -0.06, 95% CI = [-2.79, 2.68], overall effect Z = 0.04 with $p = 0.97$). However, the level of heterogeneity ($I^2 = 21\%$) (Fig. 8) was minimal. But the publication bias might be displayed Nfs-T (17) < TL (25).

Effects of CF on BMI changing. The random effects analysis model presented that effectiveness of CF on BMI was null (MD = -0.53, 95% CI = [-1.59, 0.52], overall effect Z = 0.99, $p = 0.32$). The degree of heterogeneity was low with $I^2 = 13\%$ (Fig. 9). The publication bias might be displayed, Nfs-T (17) < TL (25).

Effects of CF on cardiopulmonary function and aerobic capacity. By assessing VO_2max, the forest plot showed that CF did not statistically improve the capacity of VO_2max (MD = 1.39, 95% CI = [-1.22, 4], overall effect Z = 1.04, $p = 0.30$), and the extent of heterogeneity was substantial, $I^2 = 84\%$ (Fig. 10). The publication bias might be displayed, Nfs-T (18) < TL (20). Except to reflect aerobic ability, the shuttle run test was also used in the physical fitness test in physical education to assess the ability of speed and agility. In the current study, the outcome of the test was statistically negative (MD = 3.14, 95% CI = [-8.84, 15.65], overall effect Z = 0.55, $p = 0.59$) and the scale of heterogeneity was substantial, $I^2 = 89\%$ (Fig. 11). The publication bias was high Nfs-T (18) < TL (20).

Discussion

Since the inception of CF, different participants have been invited to investigate the effectiveness of this novel functional program, including students. However, no study focuses on systematic evaluation of effects of CF on students in PE courses. Therefore, this is the first study that aims to investigate the effects of CF on students in PE courses through systematic review and meta-analysis. The outcomes indicated that the six included studies examined four out of ten general physical skills (strength, respiratory capacity, speed, agility) of CF program and without evaluation of remaining aspects (stamina, flexibility, and power, coordination, balance, and accuracy). Among these findings, the forest plots indicated that the functional program significantly increases push-ups and handgrip performance. Although the results are without statistical significance, the current study suggested that CF could also positively influence the performance of pull-ups, squats, VO_2max and shuttle run, but not curl up exercises, stand long jump, BMI.

CF is a fitness program (Glassman, 2002), one of its purposes is to improve health-related fitness (Dawson, 2015). Based on the ten general physical skills (above), fundamental movements are developed, such as squats, shoulder press, push press. These fundamental movements are the movements of people's daily life, such as, pulling/pushing ourselves up/down. It is a natural effort to prepare for basic needs of life. From this point of view, therefore, we can understand why the performance of push-up (MD = 1.80, 95% CI = [1.08-2.52], Z = 4.91, $p < 0.000001$) and handgrip strength test (MD = 2.42, 95% CI = [1.04, 3.81], Z = 3.42, p = 0.0006) has statistical significance. Through a 4-week PE season, Ward et al. (2017) found that CF effectively increased performance of 96 primary students in push-ups (z =2.26, p = .024). Kokorev (2016) examined the effectiveness of CF on improvement of physical fitness of 140 (70 men and 70 women) university students, found that the physical fitness of participants was significantly improved ($p<0.05$) and either the performance of push-ups on horizontal bars for male or back push-ups on bench for female was statistically improved ($p<0.05$). Moreover, Dmytro et al. (2018) demonstrated that the functionality of heart positively adapted the changes with linear reduction after CF intervention on students during a PE session. The amelioration of heart rate showed positive correlation with muscle activity, reflected by the performance of push-ups on cross bars which was significantly changed (30.5%, $p<0.05$). The CF training system could positively influence upper body strength development on all targeted students.

Although the performance of pull-ups, squats, VO_2max and shuttle runs in present study demonstrated a positive trend, the outcomes were without statistical significance. They were inconsistent with previous studies. Through a 2.5-month study, Dmytro et al. (2018) found the level of fitness was significantly improved, including pull-ups (29.2%, $p < 0.01$) and shuttle runs (-8.3%, $p < 0.01$). Reflecting the improvement of ability of back strength, speed, coordination and dexterity. In a CF-based high-intensity power training session, Smith et al. (2013) found that the VO_2max of participants (male and female) showed significant enhancement ($p < 0.05$). Moreover, they claimed that the capacity of VO_2max had a positive relation with level of body composition. Through a systematic review, Meyer et al. (2017) inferred that in the perspective of increasing VO_2max, strength and endurance, CF could play an effective role. This standpoint was supported by Kokorev et al. (2017), the outcomes in their study not only displayed the lung vital capacity was increased ($p < 0.05$) but also the performance of squats ($p < 0.05$). However, when it comes to the shuttle run test the study failed to prove effects of CF on students ($p > 0.5$) which was consistent with our study. The reasons that caused these differences between studies might be a), different participants. Compared with beginners, CF may tend to bring much more improvement in performance to non-novices (Butcher et al., 2015). While, in the present study, the participants were students in different levels of schools. Most of them did not experience systematic training, let alone the style of high intensity functional training. In contrary, the adult participants in other studies had advantages in physiology. b), different protocol. The purpose of studies on students were to promote health-related fitness. Therefore, from the perspective of safety, the experimental protocol in these kinds of studies were designed with lower intensity, which hardly produce effectiveness in a short time. Accordingly, whether CF is usable as a learning support to solve the problems aforementioned or not depends on how it is employed in PE courses.

Compared with control groups, experimental groups in the current study demonstrated a null trend on performance of core strength (MD = -0.06, 95% CI = [-2.79, 2.68], Z = 0.04 p = 0.97), standing long jump (MD = 0, 95% CI = [-0.2, 0.19], Z = 0.04, p = 0.97) and BMI (MD = -0.53, 95% CI = [-1.59, 0.52], Z = 0.99, p = 0.32). The results were supported by Barfield et al. (2012), in their study of the effectiveness of CF on changing BMI as a disadvantage to control group. Another meta-analysis study also demonstrated that CF failed to change BMI, bodyfat and waist circumference (Claudino et al., 2018). However, Smith et al. (2013) found that the recruited 43 adult participants were significantly changed in their BMI after 10 weeks of CF-intervention. The disparity between studies, might have resulted from subjects. It is well known that a popular phenomenon among students includes sedentary behavior, screen time based sedentary behavior, in particular (Deyab et al., 2019; Chen et al., 2020; Uddin et al., 2020). Screen based sedentary behavior significantly impacted abilities such as core strength, flexibility. In the national fitness test, Wang (2019) found that the ability of strength and power was disadvantaged among physical inactive students whose test outcomes were far away from the national fitness test standard. Additionally, screen time based sedentary behavior, such as online entertainment (chatting, watching videos), electronic games, aggravated the trend of physical inactivity, in turn, the competence of speed, power and endurance were detrimental and obesity risks increased (Wang, 2019). Unfortunately, there is not a study to assess the effects of CF on screen-time based sedentary behavior. Further research is warranted and encouraged in this domain.

Conclusion

The current study is the first study that investigates effects of CF on students' physical fitness in physical education in different level of schools. This study has been based on the included six studies that investigated the effects of CrossFit on upper-body strength, lower-body power, core strength, BMI, cardiopulmonary function and aerobic capacity. Outcomes from meta-analysis suggested that the effects of CF intervention program on improvement of upper body strength with statistical significance through testing push-ups and handgrip, pull-ups with positively influence. CF could also positively influence lower-body power by positively influence performance of squats rather than standing long jump. Although there was no statistical significance, positive trend also showed in improvement of cardiopulmonary function and aerobic capacity by comparing VO_2max, shuttle run performance between included studies. While, effects of CF intervention on core strength and BMI showed null effects which were reflected by the curl up exercise, weight and height respectively. Although there are different examining standards when it comes to health-related physical fitness tests on students in different regions and countries, the difference is nuanced in testing items. However, this meta-analysis verified that studies did not completely report physical fitness tests and examined related ability which is a knowledge gap in literatures for further study.

An increasing number of people practice CF worldwide, thus schools are hesitating to incorporate this functional program into PE curriculum due to its high-intensity. However, the outcomes of this study suggest that CF is an effective program to improve students' physical fitness and is trustworthy to introduce CF into PE. Therefore, leaders in education can be confident that there will be positive effects on students by using CF into PE courses. This study also can be a reference for students for noting the advantage of CF on improvement of physical fitness when doing physical activity. Moreover, PE teachers also can design effective plans for courses.

NOTE:
All of figures and tables were used in this study were uploaded into Mendeley Data. For further information please see (Han, 2021) and visit Mendeley Data.

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