Effects of exercise intervention on health-related physical fitness and blood pressure in preschool children: A systematic review and meta-analysis of randomized controlled trials

Running head: Exercise and health parameters in preschoolers

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Key points

- Physical exercise whether combined or not with additional interventions, favors small improvements on health-related physical fitness components in preschoolers.

- Physical exercise-alone favors larger significant reductions in body mass index and waist circumference compared with physical exercise combined with another intervention.

- Changes in cardiorespiratory fitness, lower-body muscular strength and speed-agility are related with body composition changes in preschoolers.

ABSTRACT

Background: No previous systematic review has quantitatively examined the effect of physical exercise interventions on health-related physical fitness and blood pressure in children younger than 6 years old.

Objective: to evaluate the effects of exercise interventions on health-related physical fitness (i.e., physical fitness components and body composition) and blood pressure in preschoolers.

Methods: We searched four databases. Only randomized controlled trials (RCTs), evaluating the effectiveness of exercise intervention on weight-related outcomes, blood pressure, and physical fitness components in preschoolers (1-5.99 years old) were included. The effect sizes were reported as Hedges' g using random-effects models.

Results: A total of 19 RCTs were included. Exercise interventions favored reductions in body mass index (g=−0.17; 95% confidence interval [CI], −0.31 to −0.03), waist circumference (g=−0.25; 95%CI, −0.47 to −0.03), and body fat percentage (g=−0.31; 95%CI, −0.60 to −0.23); as well as improvement in cardiorespiratory fitness (g=0.25; 95%CI, 0.08 to 0.42), muscular strength (g=0.25; 95%CI, 0.09 to 0.40), and speed-agility (g=−0.51; 95%CI, −0.78 to −0.24). Blood pressure was not reduced. The subgroup analysis reveals that physical exercise-alone favored larger reductions in body mass index and waist circumference compared with physical exercise combined with another intervention. Also, changes in cardiorespiratory fitness, lower-body muscular strength and speed-agility were associated with larger decreases on body composition.

Conclusion: Physical exercise whether combined or not with additional intervention has a small effect on both body weight and physical fitness in preschoolers. Also, it seems that interventions to prevent obesity should be directed towards improving physical fitness of preschoolers.

1. Introduction

The early years are a critical period for physical, social and cognitive development [1] and for establishing healthy behavior patterns, which may persist into childhood [2] and adulthood [3]. While the evidence for the early years is relatively new, a growing body of research suggests that regular physical activity participation in preschool-aged children is vital for the normal growth and development, providing immediate and long-term benefits for physical and psychological well-being [4]. Nevertheless, the depth and breadth of the evidence for this age group remains relatively small compared to the one for older children and adolescents.

Recently, the World Health Organization recommended that typically developing children aged 3-to-5 years old should be physically active every day for at least three hours [5]. In spite of the benefits seen to regular physical activity, many preschoolers do not meet this recommendation [6]. Evidence from previous reviews suggests that physical exercise interventions, mainly focused on gross motor skills, are associated with health benefits such as cognitive and motor development, psychosocial health, physical fitness, cardiometabolic outcomes, skeletal health [7,8] and weight-related outcomes [9]. Another recent meta-analysis suggested that physical exercise interventions improve fundamental motor skills among preschoolers [10]. Despite the conclusions of the 2018 Physical Activity Guidelines Advisory Committee suggested that higher amounts of physical activity were found to be associated with beneficial effects on adiposity and bone health [11], no study to our knowledge has meta-analyzed these results in children of the early years (aged 1–5.99 years old). Due to heterogeneity between studies in terms of results, we used a meta-analytic approach to provide a comprehensive synthesis of the effectiveness of the effects of physical exercise interventions on health-related physical fitness and blood pressure in preschoolers.

Therefore, the aim of this meta-analysis was to evaluate the effects of exercise interventions on health-related physical fitness and blood pressure in preschoolers.

2. Methods

2.1. Protocol and registration

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement Checklist [12] and is registered in the PROSPERO International Prospective Register of Systematic Reviews (identifier CRD42019130107).

2.2. Information sources and search

The electronic search of Ovid MEDLINE, EMBASE, Cochrane Controlled Trials Registry, and SPORTDiscus was combined with hand searches of existing literature were performed from inception to March 28, 2019. The search strategy applied was the following: 1) "exercise" OR "physical* activ*" OR "active play" OR "active games" OR sport* OR "motor activit*" OR "locomotor activit*"; 2) preschool* OR pre-school* OR infan* OR baby OR babies OR toddler* OR "young child*" OR child* OR "early childhood" OR "early years"; 3) intervention* OR trial OR "randomi*ed controlled trial" OR "controlled trial" OR RCT OR experiment*; 4) obes* OR "obesity" OR "body mass index" OR "BMI" OR "waist circumference" OR "body fat" OR "fat mass"; 5) "blood pressure" OR "triglyceride" OR "lipids" OR "cholesterol" OR "glycemia" OR "glucose" OR "insulin" OR "cardiometabolic risk factors" OR "metabolic syndrome"; 6) fit* OR "fitness" OR "cardiorespiratory fitness" OR "CRF" OR "strength" OR "muscular strength" OR "agility"; 7) 1 AND 2 AND 3 AND 4 OR 5 OR 6. Also, the reference lists of the included studies were checked to find potential studies that could also be used in this review.

2.3. Eligibility criteria and study selection

The criteria for study inclusion were: (i) apparently healthy (i.e., general population, including samples of children with overweight/obesity but not samples of children exclusively with a diagnosed medical condition), preschoolers (mean age: 1 to 5.99 years); (ii) randomized controlled trials (RCTs) in which the control group received no structured type of physical exercise or dietary restriction intervention (i.e. usual care of regular school curriculum); (iii) supervised exercise interventions (e.g. not home-based exercise or free play); and (iv) an assessment of at least one of the following parameters: health-related physical fitness (i.e., physical fitness components and body composition) and blood pressure. We utilized the following exclusion criteria: studies describing lifestyle interventions not including a well-defined structured physical exercise intervention, studies including subjects older than 6 years, and studies not providing an adequate control group for comparison. Titles, abstracts and full text were assessed for eligibility independently by two authors (AG-H and RR-V) for potential inclusion. If necessary, a third researcher (M-I) was consulted. Finally, RCTs were limited to those published in English.

2.4. Data collection process

For each study, data were extracted for characteristics of the study population including: (i) first author's last name; (ii) year of publication; (iii) characteristics of participants, sample size and age; (iv) characteristics of physical exercise (type, frequency, and duration); (v) outcomes; and (vi) differences in the means of two time points or post-intervention mean values with corresponding standard deviations. When there was insufficient information, the respective corresponding author was contacted.

2.5. Risk of bias of individual studies

The risk of bias was evaluated using the Physiotherapy Evidence Database (PEDro) criteria [13], an 11-item scale designed for measuring the methodological quality of RCTs.

2.6. Summary measures

All analyses were carried out using Comprehensive Meta-analysis Software (2nd version, Biostat, Englewood, NJ, USA) to calculate the standardized mean difference, which was expressed as Hedges' g to correct for possible small sample bias [14]. Hedges' g of the each parameter from baseline to follow-up between groups [15] was calculated and pooled using the random-effects model (DerSimonian–Laird approach). Data were pooled if outcomes were reported by at least three studies. The pooled effect size for Hedges' g was classified as small ($0 \leq g \leq 0.50$), moderate ($0.50< g \leq 0.80$) and large (>0.80) [16].

2.7. Synthesis of results

The percentage of total variation across the studies due to heterogeneity (Cochran's Q-statistic) was used to calculate the I^2 statistic [17], considering I^2 values of <25%, 25–75%, and >75% as small, moderate, and high heterogeneity, respectively [18].

2.8. Risk of bias across studies

Each study was deleted from the model once in order to analyze the influence of each study on the overall results. Egger regression tests were performed to detect small study effects and possible publication bias [19].

2.9. Additional analysis

Whenever it was possible, a subgroup analysis was conducted according to type of the intervention, that is, physical exercise-alone with or without another intervention. Additionally, random-effects meta-regression analyses were used to evaluate whether the results in weight-related outcomes differed with physical fitness changes (as Hedges' g).

3. Results

3.1. Study selection

The electronic search strategy retrieved 2,479 records. After removal of duplicate references, and screening of titles and abstracts, we excluded 2,162 articles. Of the remaining 317 articles, and after full-text screening and checking the reference lists of included studies and previous reviews for additional relevant articles, a total of 61 studies were read in full. The reasons for exclusion based on full text were (1) inappropriate study design (8 articles); (2) inappropriate study population (3 articles); and (3) inappropriate outcome measurement (31 articles). Finally, 19 were included in the final meta-analysis [20–38]. The PRISMA flow diagram is shown in Fig. 1.

Fig.1 about here

3.2. Study characteristics

Table 1 summarizes the study characteristics. The final analysis included a total of 7,843 preschoolers (47.9% girls). Most studies included apparently healthy preschoolers, but two studies included overweight and/or obese children [28,32]. Participants enrolled in exercise cohorts were predominantly from the Germany (n = 4) [31,32,36,38], with studies from USA (n = 3) [20,21,35], Australia (n = 2) [29,37], Israel (n = 2) [27,34], Switzerland (n = 2) [24,33], China (n = 1) [28], Scotland (n = 1) [25], Spain (n = 2) [22,30], and Thailand (n = 1) [23]. All studies included boys and girls. Sample sizes across studies ranged from 41 [33] to 1,474 [22].

The primary mode of the physical exercise interventions incorporated primarily gross motor skills (e.g., walking, running, jumping, ball skills, dancing), while the control group was either usual care or regular school curriculum. Ten studies also included parental [22,32,35], or nutritional information [21,31,32,34,35] and/or changes to the environment in the schools [22,24,31] to promote higher free physical activity. The duration of the interventions varied from 6 weeks [33] to 96 weeks [38]. In all of the studies, children of the control group maintained their regular school curriculum.

The outcome measures were: body mass index, body mass index z-score, waist circumference, skinfolds thickness, body fat, obesity prevalence, blood pressure (systolic and diastolic blood pressure), and cardiorespiratory fitness assessed with the shuttle-run test or a 10x20-meter test [22,24,28,30], lower-body muscular strength assessed with the standing long-jump test, and speed-agility assessed with the 10-meter x 4 shuttle run test [22,28], an obstacle course test [24,26], a 20-meter test [30] or a 6-m test [38]. Further information for all individual RCTs are summarized in Tables 1.

Table 1 about here

3.3. Risk of bias within studies

The average total bias score was 5.1 with a range from 4 to 8. Only four studies scored a high quality score (i.e. ≥7) [24–26,37] (Table 1 and Electronic Supplementary Material Table S1). Low scores corresponded to studies that failed to concealed allocation, blind subjects and therapists and/or conduct intention-to-treat analysis. However, it is important to keep in mind that an important methodological problem among exercise programs occurs because is not possible to blind subjects to the treatment they receive and therapists.

3.4. Summary of evidence

The results of the meta-analysis showed that when compared with the control group, exercise interventions resulted in significant reductions in body mass index (g=−0.17; 95% confidence interval [CI], −0.31 to −0.03), waist circumference (g=−0.25; 95%CI, −0.47 to −0.03), and body fat percentage (g=−0.31; 95%CI, −0.60 to −0.23); as well as increases in cardiorespiratory fitness (g=0.25; 95%CI, 0.08 to 0.42), lower-body muscular strength (g=0.25; 95%CI, 0.09 to 0.40), and speed-agility (g=−0.51; 95%CI, −0.78 to −0.24) (Electronic Supplementary Material Table S2). The forest-plots are presented in Figs. 2-5.

Subgroup analysis revealed that physical exercise-alone favored larger significant reductions in body mass index (g=−0.26; 95%CI, −0.55 to −0.02; I^2=83.19%), waist circumference (g=−0.53; 95%CI, −1.15 to −0.08; I^2=77.86%) and increased lower-body muscular strength (g=−0.44; 95%CI, 0.19 to 0.69). Regarding physical exercise combined with additional intervention, results showed a reduction in body fat (g=−0.11; 95%CI, −0.19 to −0.02; I^2=0%) and in speed-agility (g=−0.13; 95%CI, −0.21 to −0.06; I^2=0%). Also, these interventions increased cardiorespiratory fitness (g=0.18; 95%CI, 0.09 to 0.28; I^2=13.7%) and lower-body muscular strength (g=0.15; 95%CI, 0.01 to 0.29; I^2=80.7%) (Electronic Supplementary Material Table S2).

Finally, the meta-regression analyses show that there was a greater decrease in body mass index, waist circumference, and body fat in preschoolers who achieved greater cardiorespiratory fitness (ß=−0.78 to −1.33), lower-body muscular strength (ß=−0.64 to −1.22) and speed-agility (ß=0.94 to 0.99) changes (Table 2).

Table 2 about here

3.5. Risk of bias across studies

Egger's linear regression tests provided evidence for a potential publication bias for three outcomes: body mass index (p=0.031), lower-body muscular strength (p=0.023), and speed-agility (p=0.017). In the sensitivity analysis, with each study deleted once from the model, the results remained the same across all deletions.

4. Discussion

The main finding of this systematic review and meta-analysis is that physical exercise favors small improvements on health-related physical fitness components, i.e. body mass index, waist circumference, body fat, cardiorespiratory fitness, lower-body muscular strength, and speed-agility in preschoolers. Overall, the effects on body mass index and waist circumference seem to be slightly larger with interventions using physical exercise-alone. Also, changes in cardiorespiratory fitness, lower-body muscular strength, and speed-agility were related with larger effects size in body mass index, waist circumference, and body fat. That said, the results of the present meta-analysis should be interpreted with caution because of: (i) the relatively small number of RCTs pooled in each parameter; (ii) the variety of exercise programs used (type, frequency, and duration) and other interventions; (iii) the outcome measures; (iv) the role of potential confounders; and (v) the quality of the RCTs.

Obesity is a major health problem in children, including preschoolers. Globally, in 2016 the number of overweight children under the age of five was estimated to be over 41 million [39]. Recent reviews suggest that intensive behavioral interventions might be a promising approach to reduce preschool obesity [9,40,41]. Also, a recent review found moderate evidence for effectiveness in both physical activity-only and combined diet and physical activity interventions among children and adolescents (aged 2–19 years old) [42]. Along this line, our meta-analysis revealed that exercise interventions focused on gross motor skills, combined or not with another intervention (nutrition, parental information, among others), are effective for reducing weight-related outcomes such as body mass index, waist circumference, and body fat, but the results indicated that the effect size of these interventions is small ($g = -0.17$ to -0.24). Specifically, largest changes have been noted among obese preschoolers [28,32] regardless of the characteristics of the exercise program. In this study population, Pate et al. [11] concluded that there is strong evidence indicating that higher amounts of physical activity are associated with better weight status/reduced risk for increases in weight and adiposity in children age 3 to 6 years old. Several biologically plausible mechanisms could explain the effects of exercise in modulating adipose tissue and body composition changes [43]. Exercise can be therapeutic in reducing body fat by increasing energy expenditure, stimulating lipid oxidation, and inhibiting lipid synthesis in the liver through the activation of the AMP-activated protein kinase pathway and free fatty acid flux to the liver [44]. Another way in which exercise may be beneficial for patients with excess adiposity is in attenuating the inflammatory state mediated via a reduction in visceral fat mass [45] and/or by induction of an anti-inflammatory environment [46], increasing interleukin (IL)-6, IL-10 and IL1-ra.

Overall, our present results are in line with those reported in children and adolescents population in other studies, even including combined physical activity and diet [47,48]. Therefore, given the increase in BMI in many countries over the last three decades [39], these intervention effects could be considered slightly trivial. Indeed, our meta-analysis did not show reductions in overweight/obese prevalence, however, we included only three studies [22,27,34] and therefore the results must be interpreted with caution. There is some evidence from RCTs that preschoolers at special risk (e.g. migrant, minority, overweight, or low–socioeconomic status) can benefit most from these interventions [28,32,35]. Our subgroup analysis revealed that physical exercise-alone interventions resulted in larger body mass index and waist circumference reductions relative to the overall results, which is in contrast to another review that suggested that, for example parental involvement accentuates the beneficial effects of interventions [49]. A recent longitudinal study recommends promoting vigorous-intensity physical activity at young ages as it has long-term beneficial effects on childhood body composition and physical fitness [50].

Because impaired cardiometabolic health during childhood is associated with future cardiovascular diseases [51], improvements in this parameter in early life are likely to be important for the prevention of cardiovascular events. Although several studies show benefits of physical activity on the cardiometabolic risk profile of children [52], several recent meta-analyses have reported controversial results [49,53,54] and very little is known about preschoolers. In our systematic review, only five studies analyzed blood pressure among preschoolers [22,26,28,36,38]. In line with a Cochrane review in children and adolescents published in 2012 [54], our pooled analysis did not show significant reductions in systolic or diastolic blood pressure. These results could be because most of the preschoolers included in the RCTs had normal blood pressure levels, and thus, small reductions on blood pressure should be expected in this population [55]. It has been suggested that the health effects of physical exercise become more apparent or manifested in youth who are already somewhat at risk (i.e. hypertension and/or excess of adiposity) [55]. For example, Tan et al. [28] reported largest effects on blood pressure ($g = -1.15$ and -0.43 in systolic and diastolic blood pressure, respectively) among preschoolers with obesity, confirming the findings of a previous meta-analysis among obese children [56]. By contrast, two other meta-analyses in children and adolescents reported improvements in blood pressure [49,53], albeit with small reductions and large heterogeneity, likely due to the age range included in both studies (between 3 to 12 years old).

Finally, our meta-analytic approach suggests that physical exercise interventions are an effective strategy for improving physical fitness in preschoolers, although the magnitude of the effect was small. A recent meta-analysis published on children aged 3-12 years [57] reported a similar effect size on cardiorespiratory fitness ($g = 0.22$). Likewise, Smith et al. [58] confirmed that physical activity, mainly vigorous intensity, is positively related with muscular strength in children and adolescents. Overall, evidence seems to indicate that the promotion of physical activity interventions is successful in improving physical fitness. According to a meta-analysis published by Van Capelle et al. [10] physical activity interventions improve fundamental motor skills in preschoolers, which appear to be related to higher levels of physical activity and sports participation

[59]. Although this physical fitness improvement may appear relatively weak, its importance should not be overlooked due to the large number of studies showing that physical fitness during childhood is related to better health later in life [60,61]. In this regard, the meta-regression analysis showed that changes in physical fitness (i.e. cardiorespiratory fitness, lower-body muscular strength, and agility) were related with larger effects size in body mass index, waist circumference, and body fat. Although information in preschools is sparse, a recent longitudinal study published by Henriksson et al. [62] confirmed the importance of physical fitness early in life, suggesting that better physical fitness at 4.5 years of age is associated with lower fat mass and higher fat-free mass one year later.

The present meta-analysis had several limitations. First, our search strategy was restricted to articles in English. Second, few RCTs described in detail the implementation conditions of their interventions – for example, the intensity of the physical activity, who is the one responsible to carry out the program, and the compliance rate. Third, the results of the present meta-analysis should be interpreted with caution because of heterogeneity on the assessment of physical fitness tests and the devices used to measure blood pressure. Fourth, due to limited sample sizes and heterogeneity, it was not possible to conduct sensitivity analyses in terms of intervention setting (i.e. duration of the intervention, frequency) and sex. Fifth, most of the studies were conducted in high-income countries and therefore may not be generalizable to lower-income countries. Sixth, regarding to cardiometabolic parameters, only pooled results for blood pressure had been analyzed. Seventh, most studies did not report intensity of physical activity. Finally, most studies did not adjust the outcome variable of interest for baseline values, which could restrict the interpretation of the temporal sequence and causality. Also, few studies assessed factors that might confound the relationship between physical exercise and health-related physical fitness outcomes, for example, diet and sleep behaviors.

5. Conclusion

Our meta-analytic approach provides evidence supporting that physical exercise focused on gross motor skills, combined or not with additional interventions, reduces body mass index, waist circumference and body fat and improves physical fitness components among preschoolers. Our results also indicate that changes in cardiorespiratory fitness, lower-body muscular strength and speed-agility were related with body composition in preschoolers. Future physical exercise interventions, preferably of vigorous intensity, with more rigorous methodological standards and conducted in low-incomes countries are recommended to confirm our results and to assess other cardiometabolic parameters such as lipids and glycemic indicators, in addition to body composition measures, in order to fully capture the health benefits in preschoolers.

Data availability statement

The data that support the findings of this review are available on request from the corresponding author (Antonio García-Hermoso).

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Compliance with Ethical Standards

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Conflicts of Interest

Antonio Garcia Hermoso, Alicia M. Alonso-Martinez, Robinson Ramírez-Vélez and Mikel Izquierdo declare that they have no conflicts of interest relevant to the content of this review.

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Figure legends

Figure 1. PRISMA flow diagram.

Figure 2. Forest plot showing the effect size (Hedges′ g) of physical exercise programs on body mass index (a), body mass index z-score (b) and waist circumference (c) between intervention and control groups for each study. B, boys; G, girls. The red diamonds represent the overall point estimate and 95% confidence intervals from all individual studies included in each meta-analysis.

Figure 3. Forest plot showing the effect size (Hedges′ g) of physical exercise programs on skinfolds thickness (a), body fat (b) and overweight/obesity (c) between intervention and control groups for each study. B, boys; G, girls. The red diamonds represent the overall point estimate and 95% confidence intervals from all individual studies included in each meta-analysis.

Figure 4. Forest plot showing the effect size (Hedges′ g) of physical exercise programs on cardiorespiratory fitness (a), lower-body muscular strength (b) and speed-agility (c) between intervention and control groups for each study. B, boys; G, girls. The red diamonds represent the overall point estimate and 95% confidence intervals from all individual studies included in each meta-analysis.

Figure 5. Forest plot showing the effect size (Hedges′ g) of physical exercise programs on systolic (a) and diastolic blood pressure (b) between intervention and control groups for each study. The red diamonds represent the overall point estimate and 95%

confidence intervals from all individual studies included in each meta-analysis.