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SYSTEMATIC REVIEW

Physical Activity in Overweight and Obese Adolescents: Systematic Review of the Effects on Physical Fitness Components and Cardiovascular Risk Factors

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Abstract
Background The increasing prevalence of obesity in the pediatric age range has become a major concern. Studies have investigated the role of physical activity (PA) to prevent obesity in this population. However, previous reviews did not focus on the effects of PA in overweight/obese adolescents on physical fitness and risk factors for cardiovascular disease altogether.
Objective The present systematic review analyzed trials investigating the effect of PA on aerobic capacity, muscle strength, body composition, hemodynamic variables, biochemical markers, and endothelial function in obese/overweight adolescents.
Methods PubMed, LILACS, Web of Science, Scopus (including Embase), and SPORTDiscus databases were searched for relevant reports without time limits. Inclusion criteria included studies published in English, with overweight and obese adolescents aged 12–17 years. The review was registered (Number CRD42013004632) on PROSPERO, the International Prospective Register of Systematic Reviews.
Results The results indicated that PA is associated with significant and beneficial changes in fat percentage, waist circumference, systolic blood pressure, insulin, low-density lipoprotein cholesterol, and total cholesterol, as well as with small non-significant changes in diastolic blood pressure, glucose, and high-density lipoprotein cholesterol.
Conclusion Although limited, results from controlled trials suggest that PA intervention may improve physical fitness and risk factors for cardiovascular disease in adolescents who are overweight or obese.

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1 Introduction

Obesity is closely related to the risk of developing cardiovascular diseases (CVD) [1] and is currently considered as a serious public health concern [1, 2]. Epidemiological studies have shown a rapid increase in the prevalence of overweight and obesity not only in adults, but also in children and adolescents, thus increasing the risk of developing early CVD and co-morbidities [3, 4]. According to the World Health Organization, approximately 20 % of children and adolescents in Western countries are overweight or obese [5]. Evidence also suggests that childhood obesity may persist throughout life, compromising the quality of life and its expectancy [6–8].

Adipose tissue produces and secretes peptides and proteins called adipocytokines, which are involved in inflammation and immune response [9]. In obesity, the concentrations of various adipocytokines are high and have been associated with hypertension (angiotensinogen), inhibition of fibrinolysis (plasminogen activator inhibitor-1), insulin resistance (tumor necrosis factor-α, interleukin-6, and resistin) [10], and the onset or progression of atherosclerotic lesions (C-reactive protein) [11]. Conversely, adiponectin, which has anti-inflammatory and anti-atherogenic properties, is inversely associated with body mass index (BMI) and percentage of body fat [12]. Several mechanisms suggest a causal relationship between obesity and atherosclerosis. These factors are also related to endothelial dysfunction, as evidenced not only in adults but also in children and adolescents [6, 7]. Ruiz et al. [13] demonstrated that low-grade inflammation was negatively associated with cardiovascular fitness and positively related with percentage of body fat in prepubertal obese children. Steene-Johannessen et al. [14] have also analyzed low-grade systemic inflammation present in young people with increased waist circumference, and suggested that inflammatory markers such as C-reactive protein (CRP), hepatocyte growth factor, and plasminogen activator inhibitor-1 are related to metabolic risk profile observed in obese children and adolescents.

Given these trends, early intervention to positively impact weight and behaviors that contribute to obesity and co-morbidities is important. Multiple strategies to combat childhood obesity appear to be effective in the prevention of obesity in adulthood [15, 16]. Diet and physical activity (PA), including unsupervised/spontaneous and supervised training programs as previously and classically defined [17], are two of the most common strategies in the treatment and prevention of obesity. Considered as an important strategy to increase energy expenditure [18], regular PA is associated with improvements in body composition [19], cardiorespiratory fitness [20], metabolic syndrome components [21], hemodynamic variables [22], and psychological and socio-affective aspects [23], but the strength of the results varies among studies. Despite several reviews and meta-analyses on the efficacy of PA interventions on obesity and its co-morbidities [24, 25], systematic reviews on the effectiveness of PA interventions to induce changes in body composition, physical fitness components, and CVD risk factors among overweight and obese adolescents remain sparse. Although findings from previous reviews [26–28] suggest that PA interventions may be globally effective to improve these factors in children and adolescents, there is still no conclusive evidence.

The present systematic review moves beyond previous studies in two ways. First, given that previous reviews did not analyze physical fitness components and CVD risk factors together, they could not provide a comprehensive understanding of the overall effects of PA. This would be important to identify trends related to the possible effects of these types of interventions. Second, to our knowledge, only one study has reviewed the efficacy of PA interventions on endothelial function and inflammatory markers in adolescents [11] and no studies have analyzed these factors with other desirable outcomes in adolescents who are obese.

Therefore, it is important to update the emerging evidence in this area, analyzing the results of intervention studies that evaluated the efficacy of PA on a wide range of markers of physical fitness and CVD risk factors in overweight and obese adolescents. Thus, the objective of this study was to systematically review the effect of PA interventions on body composition, physical fitness components, hemodynamic variables, biochemical markers, endothelial function, and low-grade inflammation in overweight and obese adolescents (aged 12–17 years).

2 Methods

A literature review was conducted in parallel by F.V. and I.D. in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [29] and registered on PROSPERO, the International Prospective Register of Systematic Reviews, as Number CRD42013004632. An extensive search of online electronic databases was conducted in the PubMed, LILACS, Web of Science, Scopus (including Embase), and SPORTDiscus without time limits. Text words, key words, and subject headings used in the searches included: *(adolescent) AND (prevent OR intervention) AND (physical activity) AND (obesity OR overweight OR (weight gain)) OR ((increase OR gain OR change) AND (BMI OR body mass index OR fat mass))*. The inclusion criteria included studies published in English, with overweight and obese adolescents (aged 12–17 years), as defined from BMI percentiles for age and sex. Studies were also eligible for inclusion in the present review if they had applied any type of PA intervention, alone or combined with other kind of intervention, regardless of their duration. Repeated publications for the same studies were excluded. In the presence of any doubt about study inclusion, a final consensus decision was taken after the full text was jointly reviewed.

Study quality was assessed using the Physiotherapy Evidence Database (PEDro) scale (http://www.pedro.fhs.usyd.edu.au), which has been shown to have good reliability and validity [30]. The PEDro scale has 11 possible

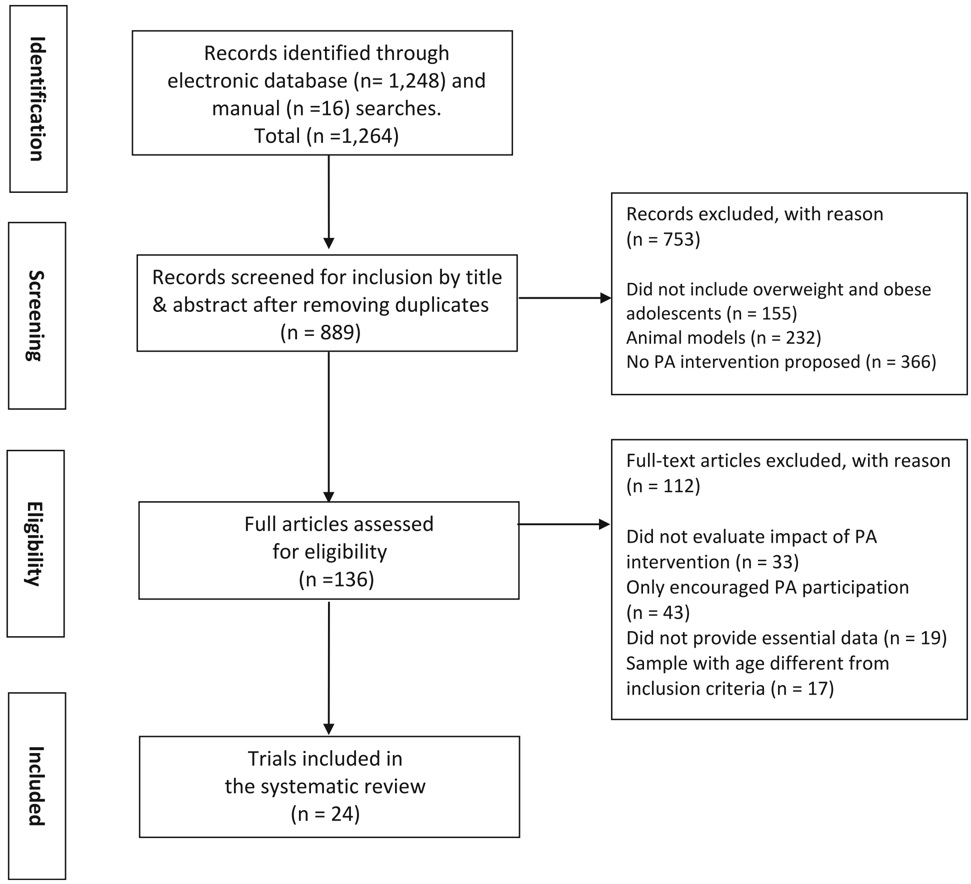

Fig. 1 Flow diagram, illustrating the details of the search strategy, screening of potentially qualifying reports (*n*), selection of the included trials, and reasons for study exclusion. *PA* physical activity

points that examine external validity (criterion 1) and internal validity (criteria 2–9) of controlled trials and whether there is sufficient statistical information for interpreting results (criteria 10–11). The items of the scale are: (i) eligibility criteria were specified; (ii) subjects were randomly allocated to groups; (iii) allocation was concealed; (iv) groups were similar at baseline; (v) subjects were blinded; (vi) therapists who administered the treatment were blinded; (vii) assessors were blinded; (viii) measures of key outcomes were obtained from more than 85 % of subjects; (ix) data were analysed by intention to treat; (x) statistical comparisons between groups were conducted; and (xi) point measures and measures of variability were provided. The first criterion is not included in the final score. Moreover, because of the nature of PA interventions, patient and therapy blinding and allocation is unlikely, therefore the total score a trial could receive was 8 points. A cut-off point of 6 on the PEDro scale was used to indicate high-quality studies, as this has been reported to be sufficient to determine high quality vs. low quality in previous studies [30, 31]. The studies were evaluated by two experienced investigators and in the event of disagreement a third reviewer was invited.

3 Results

The electronic search identified 1,248 potentially relevant studies and the manual search of reference lists identified another 16. A total of 24 studies met all the inclusion criteria for this review. A total of 1,635 participants underwent PA programs and completed their respective studies. In all studies, a significance level of 0.05 was set for the type I error. Figure 1 summarizes the selection process of the included studies.

Table 1 presents the characteristics of the 24 studies included in the systemic review. Seventeen studies were classified as ‘high-quality’ studies (range 6–8 in the PEDro scale score), and seven as ‘low-quality’ studies (range 4–5 in the PEDro scale score). In most low-quality studies, the following methodological limitations were found: (i) subjects were not randomly allocated to groups; (ii) the allocation was not concealed; and (iii) subjects, therapists, or evaluators were not blinded. Fifteen of the 24 studies were PA-only intervention [32–46] and nine studies were PA plus another kind of intervention (lifestyle or dietary) [47–55]. Fifteen studies included both girls and boys [34, 35, 37, 40, 42–44, 46, 48–54], five included only girls [38, 43, 49, 50, 53], and four included only boys [34, 50, 54]. No difference

Table 1 Characteristics of the studies that examined the effect of physical activity on overweight and obesity in adolescence

Study	PEDro scale	Obesity status [BMI—kg/m^2, percentile or fat percentage]	Year	Sample size	Country	Sex	Age, years (mean ± SD or range)	Physical activity	Duration (weeks)
Flores [32]	5	≥25	1995	110	USA	F	12–13	Dance → 3x/W—1 h	12
Neumark-Sztainer et al. [33]	6	≥85th	2003	201	USA	F	15.4 ± 1.1	Varied activities → 4x/W—1 h	32
Bayne-Smith et al. [47]	6	≥20 %	2004	442	USA	F	16.2 ± 1.2	Circuit training → 5x/S—20 min and others	12
Watts et al. [34]	5	≥85th	2004	19	Australia	M/F	14.3 ± 1.5	Circuit training → 3x/W 1 h	8
Carrel et al. [35]	6	≥95th	2005	50	USA	M/F	12–14	Strength → 3x/W—45 min	36
Balagopal et al. [48]	7	≥30	2005	21	USA	M/F	16 ± 0.4	Aerobic activities → 3x/W—45 min and others	12
Nassis et al. [36]	4	≥85th	2005	19	Greece	F	13.1 ± 1.8	Circuit training + sports → 3x/W—40 min	12
Meyer et al. [37]	5	≥97th	2006	67	Germany	M/F	14.7 ± 2.2	Sports and walking → 3x/W—1 h	24
Melnyk et al. [49]	6	≥25	2007	23	USA	M/F	15.4 ± 0.5	Sports → 2x/W—1 h and others	8
Kim et al. [38]	6	≥25	2007	40	Korea	M	16.9 ± 0.1	Jump roping → 5x/W—40 min	6
McMurray et al. [43]	5	≥85th	2007	58	USA	M/F	15.2 ± 0.5	Exercise bike → 3x/W—1 h	12
Johnston et al. [50]	6	≥85th	2007	60	USA	M/F	12.3 ± 0.7	Circuit training and sports → 4x/W—40 min and others	12
Wong et al. [39]	7	≥25	2008	24	Singapore	M	13.8 ± 1.1	Circuit training and sports → 2x/W—55 min	12
Foschini et al. [51]	6	≥95th	2009	32	Brazil	M/F	16.5 ± 1.7	Aerobic activity and strength → 3x/W—30 min and others	12
Tjonna et al. [52]	8	≥30	2009	62	Norway	M/F	14 ± 0.6	Interval running → 2x/W—4x 4 min	12 and 48
								Multidisciplinary treatment in hospital and others	12 and 48
Lee et al. [55]	6	≥25	2010	18	Korea	F	16.7 ± 0.7	Running → 4x/W—50 min and others	12
Van der Heijden et al. [40]	5	≥95th	2010	12	USA	M/F	15.5 ± 0.5	Strength → 2x/W—1 h and others	12
Ben Ounis et al. [53]	6	≥97th	2010	28	Tunisia	M/F	13.2 ± 0.7	Running, jumping, and sports with ball → 4x/W—90 min and others	8
Johnston et al. [54]	7	≥85th	2010	60	USA	M/F	12.3 ± 0.7	Circuit training and sports → 4x/W—40 min and others	24
Shih et al. [41]	5	≥23	2010	106	China	M	15.8 ± 0.1	Running → 5x/W—40 min	12
Buchan et al. [42]	7	≥20	2011	57	England	M/F	16.4 ± 0.7	Running → 3x/W – 20 min	7
Davis et al. [44]	6	≥85th	2011	38	USA	M/F	15.8 ± 1.1	Circuit training → 2x/W—1 h	16

Table 1 continued

Study	PEDro scale	Obesity status [BMI—kg/m^2, percentile or fat percentage]	Year	Sample size	Country	Sex	Age, years (mean ± SD or range)	Physical activity	Duration (weeks)
Lee et al. [45]	7	≥95th	2012	45	USA	M	14.9 ± 1.7	Strength → 3x/W—1 h	12
								Aerobic → 3x/W—1 h	
Farah et al. [46]	7	≥95th	2013	43	Brazil	M/F	15.2 ± 0.4	High-intensity training → 3x/W	24
								Low-intensity training → 3x/W	

PEDro scale physiotherapy evidence database scale, *F* female, *M* male, *M/F* male and female, *x* times, *W* weeks, *H* hour, *min* minutes, *Others* other methods of intervention beyond the physical activity, *BMI* body mass index, *SD* standard deviation

whatsoever could be identified between sexes in the reviewed studies, girls and boys seeming to respond similarly to PA, at least for the variables presently analyzed.

Seventeen studies had a follow-up not exceeding 3 months [32, 34, 36, 38–43, 45, 47–51, 53, 55], while only seven studies provided longer follow-ups [33, 35, 37, 44, 46, 52, 54]. This fact may be because of the difficulty in maintaining the participants for a longer period of time, as a result of the difficulty in keeping the team, the lack of interest of researchers for a long-term monitoring, or the choice of unattractive activities leading to high drop-out during the study. Furthermore, the short duration of follow-up might also reflect the reality of school or holiday calendars in many countries.

With regard to the experimental designs, ten studies could be classified as controlled trials [33, 37, 38, 45, 47, 48, 50, 53–55] and four adopted a within-group vs. post-intervention design [32, 34, 36, 39–41]. The other studies compared two groups performing different activities or interventions [42–44, 46, 51, 52]. Among the controlled trials, in four studies, subjects were not randomly assigned into intervention and control groups [36, 40, 41, 43]. Studies that combined PA with other types of interventions did not report additional effects as a result of those treatments upon the observed outcomes [47–55].

3.1 Effect of Physical Activity on Body Mass Index and Physical Fitness Variables

Table 2 summarizes the effects of interventions tested in the reviewed studies on BMI and other physical fitness variables. Twenty-two studies quantified the impact of PA on BMI [32–42, 45–55]. Fifteen of these studies were effective in reducing the BMI [32, 37–39, 41, 42, 45, 46, 48–51, 53–55], six studies did not report any significant change [33–36, 47, 52], and only one study showed a BMI increase after the intervention [40]. Of the 19 studies that measured the percentage of body fat [34–41, 45–48, 50–55], 12 found a decrease [35, 38, 41, 42, 45–48, 51–54] and seven reported no change [34, 36, 37, 39, 40, 50, 55]. Nine out of 10 studies that measured waist circumference showed significant improvements after the intervention programs [36–38, 41, 42, 45, 46, 52, 55]. Fifteen studies presented results for both BMI and fat percentage [34–39, 41, 44, 46, 47, 49–52, 54]. From these, six trials reported a decrease in body fat after PA [37, 41, 44, 47, 51, 52], whereas nine did not find any significant differences [34–36, 38, 39, 46, 49, 50, 54]. One study investigated the impact of PA on tricipital skinfold thickness [54], which decreased after the intervention.

Nine studies adopted the BMI as the criterion for obesity classification [32, 38, 39, 41, 42, 48, 49, 52, 55]. Five out of these applied a cut-off point of BMI > 25 kg/m^2 [31, 37, 38, 44, 48], two used BMI > 30 kg/m^2 [47, 51], one used BMI > 23 kg/m^2 [40], and one used BMI > 20 kg/m^2 [41]. Nonetheless, no differences related to these cut-off points were noticed with regard to the impact of PA on BMI: eight studies found a decrease after intervention [32, 38, 39, 41, 42, 48, 49, 55], while only one did not observe alteration [52]. The same trend was repeated for other variables; for instance, fat percentage decreased [40, 41, 44, 47], cardiorespiratory fitness improved [41, 44], and insulin did not change [37, 40] in studies that used different BMI cut-off points.

Fourteen studies considered weight percentiles estimated for age and sex [33–37, 40, 43–46, 50, 51, 53, 54], and one adopted the fat percentage as reference [47]. Overall, the results of these studies were similar and not affected by the criteria used to define obesity or overweight. For instance, 12 out of 14 studies that used weight percentiles as a criterion to define obesity observed the impact of PA on BMI—seven reported a decrease [37, 45, 46, 50, 51, 53, 54], in four no change was detected [33–36], and one found an increase [40]. Five studies observed the impact of PA on waist circumference—four detected a decrease [36, 37, 45, 46], and in only one no change was found [34].

High-quality studies reported better results on BMI and physical fitness variables than lower quality studies.

Table 2 Effect of physical activity interventions on physical fitness and hemodynamic variables

Study	PEDro scale	Body composition			Cardiorespiratory fitness	Muscle strength	SBP	DBP	HR
		BMI	Fat %	Waist circumference					
Flores [32]	5	↓	NE	NE	↔	NE	NE	NE	↓
Neumark-Sztainer et al. [33]	6	↔	NE	NE	↔	NE	NE	NE	NE
Bayne-Smith et al. [47]	6	↔	↓	NE	↔	NE	↓	↓	NE
Watts et al. [34]	5	↔	↔ (↓Tr. ↓ Ab.)	↔	NE	↑	NE	NE	↔
Carrel et al. [35]	6	↔	↓	NE	↑	NE	NE	NE	NE
Balagopal et al. [48]	7	↓	↓	NE	NE	NE	NE	NE	NE
Nassis et al. [36]	4	↔	↔	↓	NE	NE	NE	NE	↓
Meyer et al. [37]	5	↓	↔	↓	NE	NE	↓	↔	NE
Melnyk et al. [49]	6	↓	NE	NE	NE	NE	NE	NE	NE
Kim et al. [38]	6	↓	↓	↓	NE	NE	↔	↔	↔
Johnston et al. [50]	6	↓	↔	NE	NE	NE	↔	↔	NE
Wong et al. [39]	7	↓	↔	NE	NE	NE	↓	↔	↓
Foschini et al. [51]	6	↓	↓	NE	↑	↑	↓	↓	NE
Tjonna et al. [52]	8	↔	↓	↓	↑	↑	↓	↓	NE
Lee et al. [55]	6	↓	↔	↓	↑	NE	NE	NE	NE
Van der Heijden et al. [40]	5	↑	↔	NE	NE	↑	NE	NE	NE
Ben Ounis et al. [53]	6	↓	↓	NE	NE	NE	NE	NE	NE
Johnston et al. [54]	7	↓	↓	NE	NE	NE	↔	↔	↔
Shih et al. [41]	5	↓	↓	↓	NE	NE	NE	NE	NE
Buchan et al. [42]	7	↓	↓	↓	↑	↑	↓	↔	NE
Lee et al. [45]	7	↓(st) ↔(at)	↓(st) ↓(at)	↓(st) ↓(at)	↑(st) ↑(at)	↑(st) ↔(at)	NE	NE	NE
Farah et al. [46]	7	↓	↓	↓	↑	NE	↓	↔	↔

PEDro scale physiotherapy evidence database scale, *BMI* body mass index, ↓ significant decrease in the mean value, ↔ no significant change in the mean value, ↑ significant increase in the mean value, *Tr.* percentage of fat in the trunk, *Ab.* percentage of fat in the abdomen, *NE* not evaluated, *st* strength training, *at* aerobic training, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HR* heart rate

Twelve and eleven high-quality studies reported decreases in BMI [38, 39, 42, 45, 46, 48–51, 53–55] and fat percentage [35, 38, 42, 45–48, 51–54], respectively, while in only four studies no significant change was found [33, 35, 47, 52]. Results from low-quality studies were inconsistent, reporting an increase, decrease, or stability of BMI and fat percentage after PA intervention.

Only ten studies assessed changes in cardiorespiratory fitness [32, 33, 35, 42, 45–47, 51, 52, 55]. Seven of these studies showed an improvement in cardiorespiratory fitness [35, 42, 45, 46, 51, 52, 55], while three did not report any significant difference pre- and post-intervention [32, 33, 47]. With regard to muscle strength effect, all six studies showed an improvement after PA intervention [34, 40, 42, 51, 52, 55]. No difference between low- and high-quality studies could be detected for results associated with physical fitness variables.

3.2 Effect of Physical Activity on Hemodynamic Variables

Table 3 exhibits the effects of PA interventions on blood pressure (BP) and heart rate (HR). Data on resting BP were available from ten studies [37–39, 42, 46, 47, 50–52, 54]. Seven of the nine studies showed significant decreases in systolic BP (SBP) after the intervention [37, 39, 42, 46, 47, 51, 52], while three studies did not report significant changes [38, 50, 54]. Ten studies examined the diastolic BP (DBP) [37–39, 42, 46, 47, 50–52, 54]. Three of them observed a reduction in their values [47, 51, 52], but the other seven did not report significant changes [37–39, 42, 46, 50, 54]. Only seven studies measured the HR at rest or during submaximal exercise [32, 34, 36, 38, 39, 46, 54]. Four of them showed a reduction owing to the intervention [32, 36, 39, 46], while the other three did not find any

Table 3 Effects of physical activity intervention on biochemical, endothelial function, and inflammatory variables

Study	PEDro scale	Insulin	Glucose	HDL	LDL	Total cholesterol	CRP	IL-6	Adiponectin	Fibrinogen	Endothelial function
Bayne-Smith et al. [47]	6	NE	NE	NE	NE	↔	NE	NE	NE	NE	NE
Watts et al. [34]	5	↔	NE	NE	NE	↔	NE	NE	NE	NE	↑FMD
Balagopal et al. [48]	7	NE	NE	NE	NE	NE	↓	↓	NE	↓	NE
Carrel et al. [35]	6	↓	↔	NE	NE	NE	NE	NE	NE	NE	NE
Nassis et al. [36]	4	↓	↔	NE	NE	NE	↔	↔	↔	NE	NE
Meyer et al. [37]	5	↓	NE	↔	↓	↓	↑	NE	NE	↑	↑FMD
Kim et al. [38]	6	↔	↓	↔	↔	↔	↔	↔	↑	NE	NE
Johnston et al. [50]	6	↔	↔	↔	↓	↓	NE	NE	NE	NE	NE
Wong et al. [39]	7	NE	↔	↔	↔	↔	↔	NE	NE	NE	NE
Foschini et al. [51]	6	↓	↔	↔	↓	↓	NE	NE	NE	NE	NE
Tjonna et al. [52]	8	↓	↓	↔	NE	NE	NE	NE	↑	NE	↑FMD
Ben Ounis et al. [53]	6	NE	NE	NE	NE	NE	↓	↓	NE	NE	NE
Lee et al. [55]	6	↓	↑	↔	NE	↓	NE	NE	NE	NE	NE
Van der Heijden et al. [40]	5	↔	↔	↔	↔	↔	NE	NE	NE	NE	NE
Johnston et al. [54]	7	NE	NE	↔	↓	↓	NE	NE	NE	NE	NE
Shih et al. [41]	5	NE	NE	NE	NE	NE	↓	↓	NE	NE	NE
Lee et al. [45]	7	↔(st)	↔(st)	NE	NE	NE	NE	NE	NE	NE	NE
Farah et al. [46]	7	↔	NE	NE	NE	NE	NE	NE	NE	NE	NE

PEDro scale physiotherapy evidence database scale, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, ↓ significant decrease in the mean value, ↔ no significant change in the mean value, ↑ significant increase in the mean value, *NE* not evaluated, *st* strength training, *CRP* C-reactive protein, *IL-6* interleukin-6, *FMD* flow-mediated dilation

significant differences [34, 38, 54]. No clear tendency was detected with regard to different outcomes when comparing high- with low-quality studies, as classified by the PEDro scale.

3.3 Effect of Physical Activity on Biochemical Markers

Studies investigating the effects of PA on biochemical markers are shown in Table 3. Of the 12 studies that measured insulin level [34–38, 40, 45, 46, 50–52, 55], six reported a decrease [35–37, 51, 52, 55] and five did not detect any significant changes [34, 38, 40, 45, 50]. Plasma glucose levels were measured in ten studies [35, 36, 38–40, 45, 50–52, 55], most of them reporting significant improvements. Nine studies examined the response of high-density lipoprotein cholesterol (HDL) to PA interventions and no significant change was reported [37–40, 50–52, 54]. However, of the seven studies that measured low-density lipoprotein cholesterol (LDL) levels [37–40, 50, 51, 54], four showed a significant decrease [37, 50, 51, 54], while three did not report significant changes [38–40]. Five studies showed a decrease in the total cholesterol level [37, 50, 51, 54, 55], but the other five studies did not observe any significant changes [34, 38–40, 47]. Most studies that observed biochemical markers were classified as being high quality by the PEDro scale, therefore it was not possible to ascertain differences between high- and low-quality studies.

3.4 Effect of Physical Activity on Endothelial Function and Inflammatory Markers

As shown in Table 3, few studies have investigated the effects of PA on inflammatory markers in overweight and obese adolescents. Of the seven studies that evaluated C-reactive protein (CRP) levels [36–39, 41, 48, 53], three showed a reduction [41, 48, 53], three did not report significant changes [36, 38, 39], and only one study reported an increase after the intervention [36–38]. Five studies have examined the response of interleukin-6 (IL-6) to PA [36, 38, 41, 48, 53], three of them showing a significant decrease in their levels [41, 48, 53] and two reporting no significant change [36, 38]. Three studies evaluated the adiponectin levels [36, 38, 52], two of them detecting an increase in the basal levels [38, 52]. Among the two studies that measured the fibrinogen levels [37, 48], one reported a reduction [48], but one showed an increase after the intervention [37]. Only three studies assessed the endothelial function in obese adolescents after PA interventions

[34, 37, 52]. In all cases, the endothelial function measured by flow-mediated dilation (FMD) of the brachial artery showed an improvement after PA intervention. Positive effects of PA on endothelial function and inflammatory markers have been reported by studies of different quality levels.

3.5 Effects of Intensity, Frequency, Duration, and Type of Activity

As exhibited in Table 1, only five studies applied interventions with less than two training sessions per week [39, 40, 44, 49, 52]. In most studies, the weekly frequency was three times [32, 34, 36, 42–44, 48, 51, 54]. In 13 studies, the duration of training sessions was shorter than 1 h [35, 36, 38, 39, 41, 42, 47, 48, 50–52, 54, 55], while in nine studies, sessions were from 1 to 1.5 h [32–34, 37, 40, 43, 49, 53, 55]. With reference to PA intensity, only four studies applied high-intensity programs [40, 42, 47, 52], while in six studies the intensity was reported as low to moderate [37, 41, 45, 46, 48, 55]. However, the isolated and combined effects of frequency, duration, and intensity of PA programs in obese and overweight adolescents seem not to have been addressed, therefore information about optimal dose-response relationships regarding fitness, hemodynamic, and inflammatory markers are not available.

The predominant type of PA within the different interventions was running, either performed continuously with low intensity [37, 41, 45, 46, 48, 55] or intermittently with high intensity [40, 42, 52, 53]. Nine other studies applied cycle ergometer exercise [34, 36, 38, 39, 43, 44, 49–51], four observed the effects of school activities [33, 35, 47, 54], and only one with dance [32]. Of the four studies performed in schools, three did not report significant changes [33, 35, 47] and one showed a decrease in BMI [54]. Three studies found reduction in fat percentage [35, 47, 54] and one reported an increase in cardio-respiratory fitness [35]. Only two studies measured BP, one of them showing a decrease [47] and the other one no changes [54]. HR [54], glucose [35], cholesterol [47], and insulin [35] were assessed by only one study, and only insulin levels were reported to decrease after PA.

Conversely, 18 out of the 20 studies investigating the effects of PA intervention out of school reported data about the BMI. Of these, 14 [32, 37–39, 41, 42, 44–46, 48–51, 53] reported a decrease, three did not find differences [34, 36, 52], and one reported an increase in BMI owing to PA [39]. A reduction in fat percentage and waist circumference vs. no change was found in 9 out of 16 [38, 41, 42, 45, 46, 48, 51–53 vs. 34, 36–38, 40, 44, 50] and 9 out of 10 [36–38, 41, 42, 44–46, 51 vs. 34] studies, respectively. Beneficial effects were reported with regard to BP by six out of eight studies [37, 39, 42, 46, 51, 52 vs. 38, 50]. Seven studies assessed cardio-respiratory fitness and six of them [42, 44–46, 51, 52] reported an increase, whereas in just one no alteration could be detected [32]. Muscle strength increased in all studies that reported this variable [34, 40, 42, 45, 51, 52]. With regard to biochemical markers, 11 studies analyzed the insulin level—in six it remained stable [34, 38, 40, 45, 46, 50], while a decrease was reported by the other five [36, 37, 44, 51, 52].

Glucose level decreased in two studies [38, 52], increased in one [44], and remained unaltered in six [36, 39, 40, 45, 50, 51] community-based trials. PA was shown to be an ineffective method for changing HDL by the eight trials [37–40, 44, 50–52]. Three [37, 50, 51] out of six studies showed a decrease in LDL and four [37, 44, 50, 51] out of eight studies a reduction in total cholesterol vs. no change in respectively three [37, 50, 51] and four [34, 38–40] studies. CRP was assessed in seven studies, three observing a reduction after PA [41, 48, 53], three not finding changes [36, 38, 39], and one reporting an increase [37]. Five studies observed IL-6; three of them reported a decrease [41, 48, 53] and two did not observe significant changes [36, 38]. Adiponectin was evaluated by three studies and, in two, an increase owing to PA was reported [38, 52], while in one no alteration was found [36]. Only two studies measured fibrinogen, and results were mixed—one study found an increase [37] and the other a decrease [48] in its levels. Finally, all three studies that evaluated endothelial function reported an improvement owing to PA intervention [34, 37, 52].

4 Discussion

This systematic review appraised the peer-reviewed literature published without date restriction that reported the effects of PA interventions on body composition, physical fitness components, hemodynamic variables, biochemical markers, endothelial function, and low-grade inflammation in overweight and obese adolescents. There is accumulated evidence suggesting that PA is an effective strategy to prevent and treat obesity and its co-morbidities. Such evidence is fairly consistent, as demonstrated by a relatively large number of studies [15, 56–58]. While the 24 studies included in this review varied widely in their objectives, designs, mode, and setting of intervention delivery, PA appears to promote beneficial effects in obese adolescents [15, 21, 59]. It is worthy to point out that very often the studies reported results that not always reflected their main purpose. This is important because studies designed to test one outcome generally do better on that specific variable than on other outcomes, which may introduce a measurement bias. For instance, Nassis et al. [36] did not observe a significant decrease in BMI, body fat, and inflammatory markers, but the main objective of the study was to investigate the effect of exercise on insulin sensitivity. Other studies [34, 38] aimed to observe responses related to vascular dysfunction and insulin sensitivity, but reported secondary outcomes on BP and HR.

The present review aimed to scrutinize studies with adolescents aged 12–17 years because this is a critical age in terms of adherence to PA [16], which contributes to the onset of overweight and obesity [23]. Conversely, as mentioned in Sect. 1, much of the available data with this population are controversial and have not been yet summarized by previous reviews. Notwithstanding, it is important to notice that most studies did not provide information about the biological age of adolescents enrolled in the PA programs [32, 33, 35, 37–39, 42, 44, 47, 49, 50, 52, 54, 55]. It is therefore difficult to analyze the effects of maturation on their results, although it is well accepted that adolescents who are obese are frequently more advanced in biological maturation than non-obese adolescents of similar chronological age [60].

Moreover, it is also likely that many subjects within the age range of 15–17 years are already biologically adult, and youth in the midst of pubertal maturation and growth spurt might respond differently to PA intervention than late adolescents who are approaching or who are biologically mature [61]. Unfortunately, just a few studies have controlled the pubertal status or any other indicator of biological maturation and all of them reported only that subjects were at the post-puberty stage [34, 36, 40, 41, 43, 45, 46, 48, 51, 53]. Therefore, it must be acknowledged that to compare studies including adolescents with different maturation stages can be problematic. Consequently, to use chronological age cut-off points was the only alternative, because of the lack of data about biological age in the reviewed studies.

4.1 Body Composition, Cardiorespiratory Fitness, and Muscle Strength

Body composition measurements were analyzed in 22 studies included in this systematic review. All of them except one reported a favorable change in at least one body composition variable. Nonetheless, a meta-analysis by Harris et al. [62] could not confirm the effectiveness of school-based PA programs on body composition, cardiorespiratory fitness, and muscle strength. Hills et al. [63] suggested that different anthropometric assessment methods and cut-off points for determining overweight and obesity in adolescents may contribute to such inconsistent results. A recent review ratified this opinion, proposing that the ineffectiveness of some PA interventions in children and adolescents could be because of a lack of strict control on the criteria and methods for assessing body composition [64].

For instance, the effects of PA upon other body composition markers such as body fat have been investigated by a significant number of studies, but their results are still inconclusive. This could be partially explained by the relatively short intervention periods [65], but also by the great variability of techniques applied to determine body fat [66]. However, in agreement with this systematic review, previous studies using randomized controlled designs and sophisticated assessment, such as dual-energy X-ray absorptiometry, have reported a significant decrease in body composition after PA interventions [67, 68]. Another potential source of bias, particularly with regard to BMI, is the fact that depending on the maturation stage it can be potentially influenced by differential growth in height and weight [5]. However, because in most studies included in the present review the duration of PA intervention was no longer than 12 weeks, it is unlikely that differences in the rate at which height and weight increased would have significantly changed their results.

Although PA programs may likely induce favorable changes in body composition, it is important to mention that not all studies ratified such a premise. In this sense, the relationship between sample size within each study and the observed outcomes shall be taken into account. For instance, the majority of studies (15 studies) have shown a significant reduction in BMI after the intervention program, while seven studies did not observe the same effect. However, these seven studies represented over 55 % of the total sample of all studies included in the present review. Additionally, the sample sizes in studies assessing the effect of combined diet and PA (9 studies) and only PA (15 studies) were 47 and 53 %, respectively. Therefore, we have to be cautious about the independent effect of PA on body composition.

In most of the reviewed studies, aerobic exercise was considered an effective strategy to increase cardiorespiratory fitness in obese adolescents [34, 36]. However, cardiorespiratory fitness assessment in this population is usually performed through submaximal tests, which may explain the difficulty of comparing the available data. Only two studies included in this systematic review reported an increase in cardiorespiratory fitness in children and adolescents by assessing their maximal oxygen uptake [35]. However, regardless of the assessment methods used, current evidence suggests that PA intervention programs may improve the cardiorespiratory fitness in children who are overweight and obese [69]. Only a few studies have investigated the effect of PA programs on the muscle strength of obese adolescents, and their results are generally favorable, either after programs including resistance training [56] or after team sports [70, 71]. A previous systematic review [72] concurs with these results, suggesting that it is quite plausible that adolescents who are obese increase their muscle strength in response to PA programs.

4.2 Hemodynamic Variables

The effects of PA programs on hemodynamic variables in overweight and obese adolescents have not been extensively evaluated. It is well accepted that in adults the possible effects of PA on BP change depend to a large extent on pretreatment baseline levels [28]. Our results suggest that this is also the case in obese and overweight adolescents. One study [47] found a significant decrease in DBP and SBP in adolescents with relatively high baseline BP at rest. However, the same was not detected by studies with normotensive obese adolescents [38, 50]. Weight control programs that did not include PA appear to be less likely to influence hemodynamic variables. Watts [56], for example, demonstrated that dietary and PA interventions were more efficacious than dietary intervention alone in achieving declines in BP and HR.

4.3 Biochemical Markers

Current evidence suggests a significant correlation between the degree of adiposity and biochemical markers [73]. Children and adolescents who are obese tend to exhibit higher levels of total cholesterol compared with normal weight controls [74]. The present systematic review indicated that PA may induce beneficial effects on biochemical variables, such as LDL cholesterol, insulin, and glucose levels [37], while in some studies these variables remained unchanged [39]. These disparities may be related to the type, intensity, and volume of PA programs [75]. Dietary characteristics can also contribute to such inconclusive results, because the dieting pattern may have an independent action from PA and weight reduction over several biochemical markers [76].

4.4 Endothelial Function and Inflammatory Markers

As mentioned in Sect. 1, a proinflammatory state associated with disturbances in endothelial function can accelerate the atherosclerotic process [77]. An association between endothelial dysfunction, low-grade inflammation, and weight excess has been observed in children and adolescents [13, 14, 78–80], as well as an increased risk of morbidity and atherosclerotic coronary disease in adulthood [79, 81]. Such evidence reinforces the need for early detection and treatment of these risk factors. Studies examining the effect of PA on low-grade inflammation related to obesity in adolescents are scarce and do not provide consistent results. Some studies have shown that PA could reduce inflammatory markers [41, 48, 53], whereas others did not report significant differences [36–39]. A possible explanation for this discrepancy could be the relatively wide variation in the components of PA programs, such as the type of exercise, weekly frequency, intensity, and duration, among other factors.

With respect to endothelial function, we could find only three studies that evaluated it through FMD [34, 37, 52]. All of them reported improvement after intervention with PA. For this reason, it has been suggested that PA may exert a direct and beneficial effect on vascular function, likely because of the increased bioavailability of nitric oxide resulting from the shear stress during activity [82].

4.5 Effects of Intensity, Frequency, Duration, and Type of Activity

Recent recommendations [83] state that children and adolescents should engage in moderate to vigorous PA for 1 h at least 5 days per week, which should be complemented by strength activities performed three times per week. However, some studies have suggested that high-intensity exercises performed three times a week for 20 min would be enough to improve physical fitness components in adolescents [41], while others indicated that PA duration would be a major factor in the improvement of health-related markers in obese and overweight adolescents [50, 54].

The approaches observed in the studies reviewed in this article reflect these inconsistencies. Unfortunately, research on the dose-response relationships between frequency, duration, and intensity of PA intervention and improvement of fitness, hemodynamic, and inflammatory markers in this population appears to be lacking, and should be addressed in the future. Further research is also warranted into the effects of ludic activities (as team sports) upon components of physical fitness and CVD risk factors. These activities (e.g., basketball, soccer) have been classified as of high intensity [83] and acknowledged as an alternative to increase adherence of adolescents to regular PA [84]. However, we could not find studies investigating the role of different combinations of training intensity and volume variables within this type of PA intervention on fitness and risk markers.

With regard to the type of PA, as mentioned in Sect. 3.5, continuous or intermittent running and cycle ergometer exercise were predominant, followed by a few studies with PA at schools and dance. This could be because of the fact that training variables are easier to control in this type of activity, and therefore to estimate outcomes in terms of energy expenditure or weight reduction. However, not a single study reported whether the adolescents enjoyed the PA intervention or if they had some sort of participation in defining its characteristics. The number of school-based trials was comparatively small in comparison with community-based PA interventions (only 4 out of 24 studies). However, the samples of studies developed in schools were larger and corresponded to an important percentage of the overall subjects when all included studies were considered. Differences between school and community-based studies are sometimes based on a comparison of 1 vs. 20 studies, but when the samples are considered overall the total numbers of subjects can be quite similar. Therefore, comparisons regarding the effectiveness of PA programs developed in school and community contexts are still inconclusive.

In summary, it is very difficult to synthesize information about the optimal dose-response relationship regarding intensity and volume training variables that will produce favorable effects on fitness and health-related markers in adolescents who are obese or overweight. First of all, there is a lack of research addressing this specific issue. Second, the methodological variation within studies is too low for some variables (for instance, weekly frequency), whereas with regard to others the variation is too high (for instance, intensity). In both cases, direct comparisons designed to determine which is the better combination are unlikely to be carried out, and this issue unquestionably warrants additional future research.

4.6 Limitations

Some limitations of the results from this systematic review should be mentioned. First, despite the strict inclusion criteria, it must be acknowledged that the reviewed studies were very heterogeneous. Study populations differed in several aspects (sample size, age and sex, country of recruitment, and specific BMI criteria to define overweight and obesity), as well as PA programs varied widely both in their components (intensity, duration, and frequency) and in the type of intervention. Moreover, not a single study presently reviewed reported data about the persistence of the beneficial effects once the intervention was finished, or provided a more qualitative analysis of the characteristics of PA programs. The focus was exclusively on statistical significance of differences within/between groups, which might be affected by sample size and variability. However, this type of follow-up would be crucial to define how much PA would be needed to maintain the favorable gains, as well to compare the magnitude of long-term responses as a result of different types of intervention.

Second, most of the studies did not provide information about the drop-out rates across the intervention programs. As stated in Sect. 1, one of the main purposes of any PA intervention with adolescents who are overweight or obese should be to promote the interest and enjoyment of participation [16]. Traditionally, the literature in the area of obesity prevention has focused upon PA interventions that are very monotonous, boring, and similar to those commonly used with adults [62, 85]. In fact, typical PA interventions for overweight and obese adolescents have generally incorporated a variety of aerobic and resistance activities aimed at accommodating individual differences in body mass and PA interests (e.g., rowers, cycle ergometer, circuit activities), and rarely attempted to link interests of children in team games and sport activities [86]. Involving youth in the design of interventions could be an alternative to PA programs aiming at health improvement of adolescents who are overweight or obese. Moreover, future research should acknowledge that focusing on dose-response relationships within aerobic exercise training (e.g., the exercise physiology model) might not be the appropriate model to increase enrollment of this population.

Recently published studies have suggested that team games and sport activities in addition to meeting children's interest to participate in PA can be a highly effective alternative for the prevention/reduction of childhood obesity and co-morbidities [84, 87–89]. These studies have shown that the impact of such activities on physical fitness components and body composition is similar to the impact of typical PA intervention programs. Furthermore, team games and sport activities seem to be more beneficial in improving psychological and socio-affective dimensions [70, 71, 84, 88].

However, team sports are frequently not friendly for obese adolescents and should be adapted to increase their attraction to this population. Further research is certainly warranted to investigate options that could increase the enrollment of adolescents who are obese in this type of sport. Conversely, this raises the issue of resistance training effectiveness to improve weight and health outcomes in obese adolescents [71]. Most studies about resistance training and obese adolescents are from the previous 30–40 years. Given limited success of obese individuals in team sports, resistance programs may attract them and should be further investigated with regard to different outcomes related to cardiovascular risk.

5 Conclusion

Despite the diversity of methods and intervention designs employed by the included studies, this systematic review detected important trends regarding the effects of PA programs for the treatment and prevention of overweight and obesity at an early age. Interventions including PA programs are very likely to induce favorable adaptations on body composition and physical fitness of overweight and obese adolescents. Even though the evidence in this sense remains inconclusive, our findings suggest that PA programs may also improve biochemical variables, inflammatory markers, and endothelial function in this population.

Future studies should focus on large-scale studies and especially on large randomized controlled trials using different types of activities and components of training (intensity, duration, and frequency) to confirm these findings. Another major challenge for the future is to design studies to investigate the response of specific risk factors to PA programs, rather than to assess these factors marginally as part of protocols designed with other purposes. In other words, if children exhibit normal cholesterol, BP, or any other risk factor at baseline, there is no reason to expect much change. Inclusion criteria of research aiming at disclosing the specific effects of PA over any risk factor should not consider only the body weight or body composition in the selection of subjects, but also the profile related to that given risk factor.

Another challenging aspect is the need to identify the reasons for poor compliance of children and adolescents to PA intervention programs. Most of the studies reviewed have applied typical PA programs in which control of intensity and volume could be more easily performed. Unfortunately, none of the reviewed studies assessed the level of satisfaction and compliance of adolescents to the intervention program. In addition to the potential clinical benefits, it is important to better understand what types of activities can motivate adolescents to adopt an active lifestyle, without which any initiative becomes innocuous.

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