



Differences in Physical Fitness and Body Composition Between Active and Sedentary Adolescents: A Systematic Review and Meta-Analysis

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Abstract

Previous research analyzing the differences in physical fitness and body composition between active and sedentary adolescents aged 12–16 has not provided conclusive results. For this reason, a systematic review with meta-analysis was conducted to provide an overview of the results obtained to date. The objectives of this systematic review and meta-analysis were to investigate the differences in the physical fitness and body composition of adolescents who engaged in daily physical activity and those who were inactive. A search in PubMed, EBSCO, and Web of Sciences databases was performed. A total of 13,884 articles were reviewed and 11 were included in the meta-analysis. In the physical fitness performance, significantly higher values in cardiorespiratory fitness, hamstring and lower back flexibility, sit-ups and upper limb resistance were found in active compared to the inactive participants. In body composition, the inactive group showed significantly higher values in variables related to body fat, mainly in body fat percentage, fat mass and fat mass index compared to the active group. The results revealed that maintaining an active lifestyle through physical activity is a determining factor in improving the physical fitness and body composition of adolescents aged 12–16 years. The study design of the systematic review was previously registered in PROSPERO with code CRD42021241975. https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=241975.

Keywords Adolescents · Anthropometry · Body composition · Physical activity · Physical condition · Physical fitness

Introduction

The benefits of physical activity for different population groups have been reported in numerous studies that point out its importance for improving physical fitness and maintaining fat mass at optimal levels (Amatriain-Fernández et al. 2020). However, the research conducted so far in adolescents aged 12–16 years does not provide conclusive results when comparing the physical fitness and body composition of active and sedentary adolescents, since the differences between the two groups are small and studies

use different methodologies that make comparison difficult. Due to this lack of information and the limitations found in the scientific literature, it is difficult to draw conclusions on the importance of daily physical activity for the prevention of overweight, obesity and associated pathologies in this population. To address these shortcomings, the present investigation consists of a systematic review with a meta-analysis of the scientific literature existing to date, comparing the physical capacities (upper body strength, lower body strength, cardiorespiratory capacity) and body composition (fat mass, fat-free mass, weight) of active and sedentary adolescents aged 12–16 years, with the aim at investigating the existing differences in these parameters.

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Lifestyle and Health Risks

Sedentary lifestyles are positively associated with the risk of chronic diseases during adolescence and later stages, so that adolescents who do not engage in physical activity have a greater risk of developing cardiovascular diseases (Zheng et al. 2020), metabolic syndrome (Renninger et al. 2020), and

otorhinolaryngological diseases (Pazdro-Zastawny et al. 2020). Despite the large body of scientific evidence on the relationship between physical exercise and health, the number of hours spent by adolescents for the practice of sports is low (Fernández et al. 2017). This is evidenced by studies of large populations of adolescents, which found that only a small percentage met the minimum recommendations for moderate and vigorous physical activity, while a high percentage of adolescents exhibited sedentary behaviors for much of the day (Ferrari et al. 2020). The importance of these results is due to the fact that lack of physical activity and sedentary behaviors during adolescence are related to levels of sports practice and sedentary behaviors during adulthood (Li et al. 2016), which would increase the likelihood of diseases related to body fat accumulation, such as diabetes or cardiovascular diseases (Cristi-Montero et al. 2019). Therefore, it seems essential to increase sports practice during adolescence to prevent the onset of adiposity-related diseases such as diabetes mellitus and cardiovascular risk factors during adulthood (Cristi-Montero et al. 2019).

Influence of Physical Activity on Physical Fitness and Body Composition

Studies conducted in different populations have shown that greater physical activity is related to greater cardiorespiratory fitness (Lagestad and Mehus 2018), greater strength production or better flexibility (Lee et al. 2021), with active subjects showing better physical fitness (Thomas et al. 2020) and greater satisfaction with life (Pacífico et al. 2019). Therefore, increased physical activity, especially at a vigorous intensity, is essential for the improvement and maintenance of physical fitness (Beltran-Valls et al. 2020). Increased physical activity also is essential to produce changes in body composition, mainly decreases in body mass (Drenowatz et al. 2016), in factors associated with fat as a percentage of fat mass, waist and hip circumference, or the sum of skinfolds (Kristiansen et al. 2018), as well as increases in muscle mass (Morelli et al. 2020). All of the above-mentioned changes in fat accumulation are related to obesity, overweight, or cardiovascular risk (Ramírez-Vélez et al. 2017); they reveal physical activity to be a protective factor against these pathologies (Kallio et al. 2021).

Despite the importance of physical activity on health, and its relationship with physical fitness and body composition, previous research on the differences between active and inactive adolescents are very scarce and the evidence provided is not very clear. The instruments used, sample size, geographical location, ethnicity or sex of the participants are very heterogeneous between studies (Cho and Kim 2017; Khatun et al. 2016). Moreover, few studies analyze the differences between active and sedentary adolescents, as most of these include in their analyses the practice of sports activities, which have different demands

and involve a totally different development of physical fitness and body composition. For the above reasons, the aims of this systematic review and meta-analysis were to investigate the differences in the physical fitness and body composition of adolescents who engaged in daily physical activity and those who were inactive.

Current Study

Based on previous research conducted in other population groups and the studies mentioned in the introduction, it was hypothesized that physically active adolescents would show higher physical fitness values (upper body strength, lower body strength, flexibility, cardiorespiratory endurance) (Hypothesis 1) and better body composition (lower fat mass, higher fat-free mass, lower body skinfolds, waist circumference) (Hypothesis 2). These hypotheses would indicate that physical activity produces significant changes in physical fitness and body composition during adolescence, which would be relevant for the associated benefits later in life. These hypotheses were addressed through statistical analysis of the individual results obtained in each of the articles included in the meta-analysis to establish whether the effect of each variable was sufficient to be considered significant.

Methods

The search strategy and inclusion criteria for the present systematic review were previously recorded with the international prospective registry of systematic review PROSPERO (code: CRD42021241975). This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Liberati et al. 2009).

Search Strategy

The search for these studies concluded on February 1, 2021, and included articles from PubMed, EBSCO and Web of Science databases. The search strategy was created for Web of Science and adapted to the PubMed, and EBSCO databases. The reference lists of the articles included in the study were hand-searched for relevant additional studies. Studies that examined the relationship between the levels of physical activity practiced with physical fitness, body composition and kinanthropometric variables were included in the meta-analysis. The keywords and the search formula used in the databases are presented in Supplementary File 1.

The inclusion criteria were: (a) cross-sectional and observational studies; (b) adolescents aged 12–16 years old;

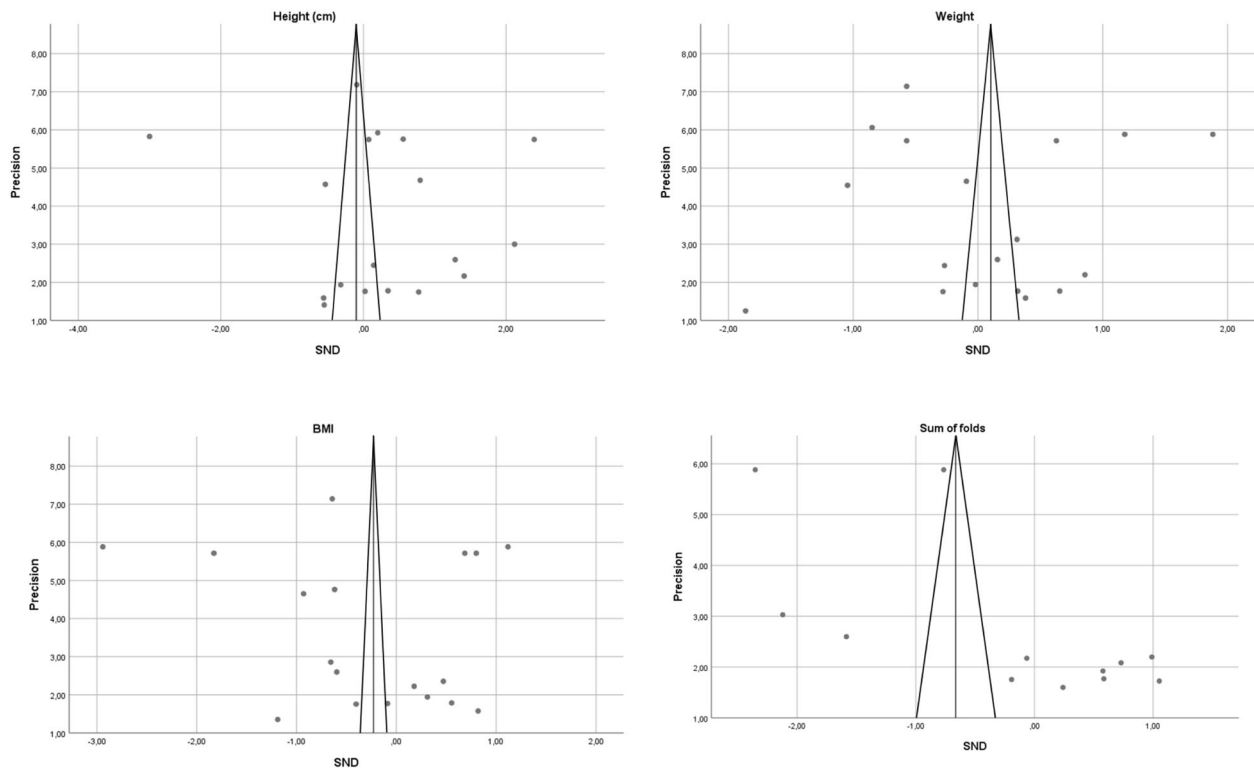


Fig. 1 Funnel Plot. This is the risk of bias for the variable's height, weight, body mass index, and fold sum of the articles included in the systematic review and meta-analysis. This graph represents with each point the articles that analyze the variables mentioned, as well as the

effect measured for that variable in each article. The dispersion in the variables analyzed is high, so there may be publication bias in the articles included

(c) results divided by active and inactive group, considering active those subjects who performed physical activity more than twice a week, and inactive those who did not practice physical activity during the week (Cho & Kim, 2017); (d) written in English; (e) outcome measurements based on physical fitness, body composition, kinanthropometric variables, or these variables combined. The exclusion criteria were: (a) studies in which the active population practiced a specific sport; (b) studies conducted in adolescents with pathologies, mental or physical disorders; (c) studies whose results are divided into groups of obese and overweight subjects; and (d) improper article type (letter, meeting abstract, communication).

Data extraction and risk of bias

The search was independently carried out by two reviewers (A. M.-O. and R. V.-C.), who examined the titles and abstracts of the articles, after reviewing the full texts to determine the articles to be included in the meta-analysis. A third reviewer (L. A.-C.) was consulted to resolve any disagreements regarding the inclusion of certain articles. To determine the inter-rater reliability of the reviewers, Cohen's Kappa (McHugh 2012) was calculated, showing a strong level of agreement (Kappa = 0.899).

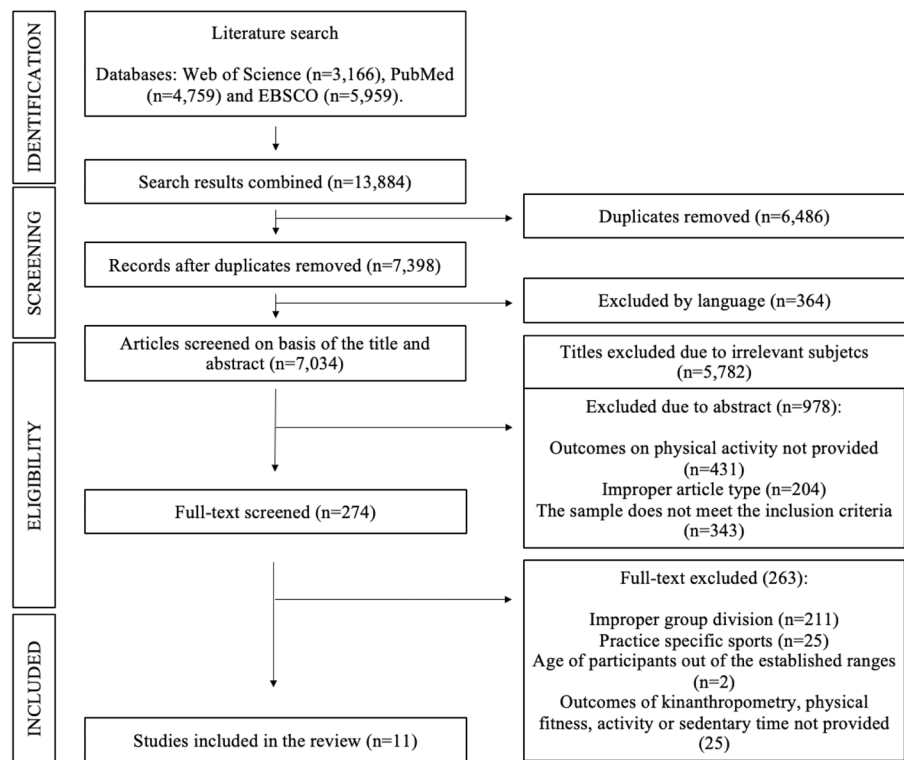
Quality assessment and risk of bias

To assess the quality of the studies included, the Strengthening Reporting of Observational Studies in Epidemiology (STROBE) statement was used (Von Elm et al. 2008). Two reviewers (A. M.-O. and R. V.-C.) were responsible for the quality assessment of the studies. A third reviewer was consulted to resolve any disagreements (L. A.-C.). Egger's (Egger et al. 1997) bias statistics and Rosenthal's (Rosenthal 1979) fail-safe N were used to assess the risk of bias, and funnel plots were created (Fig. 1). When a meta-analysis is based on a small number of studies, the capacity of Egger's test to detect bias is limited (Sterne et al. 2011). Therefore, this test must be performed when there are at least ten studies included in the meta-analysis (Egger et al. 1997).

Statistical Analysis

The statistical analysis and meta-analysis were performed using the Comprehensive Meta-Analysis program (version 3, Englewood, Bergen County, NJ, USA). The meta-analysis was done for continuous data by using the mean and standard deviation of each variable and according to the level of physical activity (active or inactive). This information was directly extracted from the studies. The analysis was

Fig. 2 PRISMA diagram of study selection. This diagram has four distinct phases. Identification: the articles found in the databases that included the search keywords were collected; screening: repeated articles and those that were not written in English were excluded; eligibility: the abstracts were reviewed and, after this first filter, the complete articles; included: the articles that met all the inclusion criteria were selected



performed when at least three groups were included for the same variable. When a study included more than one group separated by sex or country, all groups were included in the analyses. For studies that did not include the necessary data, the standard deviation (SD) was calculated and imputed when possible, using standard errors and confidence intervals. The Dersimonian–Laird (Cohen) pooling method was used, and heterogeneity was assessed using the Cochrane Q test (χ^2), Higgins I^2 , and significance (p) to determine the appropriateness of the application of a fixed or random-effect model for the pooled analysis (Ioannidis 2008). A meta-analysis with a random-effects model was performed to infer the pooled estimated standardized mean difference (SMD) (Higgins and Thompson 2004; Knapp and Hartung 2003). Dersimonian–Laird (Cohen) was interpreted using Cohen’s (Cohen 1988) as small (0 to 0.2), medium (0.3 to 0.7), and large (> 0.8). The significant differences were determined at a level of $p < 0.05$.

Results

Data Search and Characteristics of the Studies

A total of 13,884 articles were reviewed, of which 11 were included in the meta-analysis (Fig. 2).

The characteristics of the studies that were included in the meta-analysis are shown in Table 1. The quality of the

selected studies, assessed with the STROBE scale, are listed in Table 2. All studies followed a cross-sectional design (STROBE scale range 14–21), involving a total of 5938 subjects (3167 active; 2771 inactive). The mean sample size was 539.82 ± 801.74 (range 31–2799). Seven studies were carried out with males and females (63.64%) (Agata & Monyeke, 2018; Duncan et al., 2014; Gea-García et al., 2020; Huang & Malina, 2002; Khatun et al., 2016; Pacífico et al., 2019; Sivrikaya et al., 2019), two only with females (18.18%) (Cho and Kim 2017; De Milander 2011), and two only with males (18.18%) (Güvenç et al. 2011; Mukhopadhyay et al. 2005).

To measure the physical activity level of adolescents, two studies used the international physical activity questionnaire (one study used the short version and one study used the children’s version) (Agata and Monyeke 2018; Gea-García et al. 2020), two studies used surveys or interviews (Cho and Kim 2017; Khatun et al. 2016), one study used the Activity Gram questionnaire (De Milander 2011), one study used the Al-Hazaa and Al-Ahmadi questionnaire (Duncan et al. 2014), one study used heart rate recording to establish physical activity (Güvenç et al. 2011), one study used the Bouchard activity record (Huang & Malina, 2002), one study used the physical activity questionnaire for adolescents (Pacífico et al. 2019), one study designed an ad-hoc questionnaire (Mukhopadhyay et al. 2005), and lastly, one study did not specify how to measure the level of physical activity (Sivrikaya et al. 2019).

Table 1 Results obtained for physical activity variables, physical fitness, and body composition activity from the studies included in the systematic review and meta-analysis

Author	Sex (n)	Physical activity level	Age (X ± SD)	Physical activity measure	Physical condition assessed	Body composition measurements
Agata & Monyekei (2018)	M (90)	Active (83) Inactive (7)	14.90 ± 0.80	International Physical Activity Questionnaire Short Form Version (IPAQ-SF)	Lower body explosive strength, upper limb resistance, abdominal strength and endurance, cardiovascular fitness, hamstring and lower back flexibility	Height, body mass, sum of two skinfolds (triceps, and subscapular), BMI, and body fat percentage (Slaughter et al. (1988) equation)
	F (148)	Active (125) Inactive (23)				
Cho & Kim (2017)	F (31)	Active (16) Inactive (15)	12.30 ± 1.20 12.70 ± 0.90	Survey/Interview	Handgrip strength, abdominal strength and endurance, and hamstring and lower back flexibility	Height, body mass, BMI, fat mass, and fat-free mass (method: body composition analyzer Inbody 720)
De Milander (2011)	F (94)	Active (48) Inactive (46)	12 to 13	Activity Gram	Cardiovascular fitness, upper limb resistance, abdominal strength and endurance, hamstring and lower back flexibility	Height, body mass, BMI, and body fat percentage (anthropometry)
Duncan et al. (2014)	M (797)	Active (426) Inactive (371)	16.50 ± 1.00 16.60 ± 0.98	Al-Hazzaa & Al-Ahmadi (2003) questionnaire	–	Height, body mass, BMI, waist girth, and WHtR.
	F (851)	Active (168) Inactive (683)	16.40 ± 0.93 16.50 ± 0.95			
	M (585)	Active (483) Inactive (102)	15.20 ± 0.98 15.20 ± 0.88			
	F (566)	Active (374) Inactive (192)	15.20 ± 0.94 15.20 ± 0.95			
Gea-García et al. (2020)	M (164)	Active (151) Inactive (172)	12.39 ± 1.03	Physical Activity Questionnaire for Children (PAQ-C)	Cardiovascular fitness, speed and agility, handgrip strength, lower body explosive strength, hamstring and lower back flexibility, and abdominal strength and endurance	Height, body mass, arm span, BMI, and body fat percentage (method: bioelectrical impedance)
	F (161)					
Güvenç et al. (2011)	M (147)	Active (73) Inactive (74)	13.00 ± 1.50 12.90 ± 1.40	HR monitoring	Cardiovascular fitness and aerobic endurance	Height, body mass, sum of eight skinfolds (biceps, triceps, subscapular, chest, iliac crest, abdominal, thigh, and calf), body fat percentage (Slaughter et al. (1988) equation), and fat-free mass (body mass*body fat percentage)
Huang & Malina (2002)	M (68)	Active (34) Inactive (34)	13.60 ± 0.80	Activity record (Bouchard et al. 1983)	Cardiovascular fitness, abdominal strength and endurance, and hamstring and lower back flexibility	Sum of four skinfolds (triceps, subscapular, iliac crest and calf)
	F (72)	Active (36) Inactive (36)	13.60 ± 0.90			
Khatun et al. (2016)	M (522)	Active (282) Inactive (240)	13.44 ± 2.20	Survey/interview	–	Height, body mass, BMI, sum of five skinfolds (biceps, triceps, subscapular, iliac crest, and calf), body fat percentage (Slaughter et al. (1988) equation), fat mass, fat-free mass, fat mass index, and fat-free mass index (VanTallie et al., 1990)
	F (546)	Active (304) Inactive (242)	13.29 ± 2.13			
Mukhopadhyay et al. (2005)	M (528)	Active (313) Inactive (215)	13.40 ± 2.00 13.20 ± 2.10	Ad-hoc questionnaire	–	Height, body mass, BMI, fat mass, fat mass index, ten skinfolds (subscapular, iliac crest, midaxillary, chest, abdominal, triceps, biceps, forearm, thigh, and calf), and body fat percentage (Slaughter et al. (1988) equation)
Pacifico et al. (2019)	M (90)	Active (36) Inactive (54)	16.35 ± 0.65	Physical Activity Questionnaire for Adolescents	Cardiovascular fitness, abdominal strength and endurance, hamstring and lower back flexibility, upper limb resistance	BMI

Table 1 (continued)

Author	Sex (n)	Physical activity level	Age (X ± SD)	Physical activity measure	Physical condition assessed	Body composition measurements
Sivrikaya et al. (2019)	F (145) M (191) F (144)	Active (47) Inactive (98) Height, body mass, BMI, and sum of five skinfolds (subscapular, triceps, biceps, iliac crest, and abdominal)	16.19 ± 0.67 Active (104) Active (64)	12 to 14	-	-
Inactive (80)						

X mean, SD standard deviation, M males, F females, BMI body mass index, WHtR waist to height ratio

Physical Fitness Test Results

Seven of the 11 articles finally included in the meta-analysis utilized physical fitness tests, using a total of 12 different tests, although eight variables were not included in the meta-analysis because they were not analyzed in three studies or more.

To assess the strength and endurance of the abdominal and hip-flexor muscles, sit-ups and curl-ups were the most common tests used in the research studies included in the meta-analysis and were found in a total of four articles (36.36%) (Agata & Monyeki, 2018; Cho & Kim, 2017; Gea-García et al., 2020; Huang & Malina, 2002) and two articles (18.18%) (De Milander 2011; Pacífico et al. 2019), respectively. Considering the sit-ups, two of the four articles (50.00%) found statistically significant differences when comparing active and inactive subjects (Agata and Monyeki 2018; Gea-García et al. 2020), while for the curl-ups, one of the two studies (50.0%) showed significant differences (Pacífico et al. 2019). It should be noted that Pacífico et al. (2019) found significant differences in the curl-up, but did not indicate the duration of the test or the criterion considered for ending it.

To assess hamstring and lower back flexibility, the sit-and-reach test was used in five studies (45.45%), with significant differences found in one of them (20.0%) (Huang & Malina, 2002). The trunk flexion test was used in two studies, of which only one showed significant differences (Cho and Kim 2017).

Cardiovascular fitness and aerobic endurance were measured in six studies using the 20-m shuttle run test, Wingate anaerobic test, progressive aerobic cardiovascular endurance run test (PACER test), and the one mile run, with significant differences found in five of the tests (Agata & Monyeki, 2018; De Milander, 2011; Güvenç et al., 2011; Huang & Malina, 2002; Pacífico et al., 2019). Upper limb resistance was analyzed in three studies (27.27%), using the push-up test in two of them (66.67%), with one of them showing significant differences (50.0%) (De Milander 2011), while the unique study which evaluated this parameter with the bent arm hang test (33.3%) did not find significant differences (Agata and Monyeki 2018).

Table 3 shows the results of the meta-analysis of the comparison of the active and inactive subjects groups (SMD standardized mean difference; 95% CI: 95% confidence interval; z test for overall effect; p significance). A positive SMD value indicates that the results of the active group were higher than those of the inactive group. The results of the meta-analysis showed that the active subjects showed significantly higher values in cardiovascular fitness and aerobic endurance (SMD = 2.22; $p < 0.001$), hamstring and lower back flexibility (SMD = 1.13; $p = 0.025$), abdominal strength and endurance (SMD = 0.50; $p < 0.001$) and upper

Table 2 Analysis of the quality of the articles included in the systematic review according to the STROBE scale

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	100%	Total	
Agata & Monyeki (2018)	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	81.82	18
Cho & Kim (2017)	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	0	0	1	0	1	0	0	0	63.64	14
De Milander (2011)	1	1	1	0	1	0	1	1	0	0	1	1	0	1	1	0	1	1	1	1	1	0	0	68.18	15
Duncan et al. (2014)	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	95.45	21
Gea-García et al. (2020)	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	86.36	19
Güvenç et al. (2011)	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	81.82	18
Huang & Malina (2002)	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	0	1	0	0	0	68.18	15
Khatun et al. (2016)	1	1	1	0	1	0	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	68.18	15
Mukhopadhyay et al. (2005)	1	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	63.64	14
Pacifico et al. (2019)	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	1	81.82	18
Sivrikaya et al. (2019)	1	1	1	0	0	1	1	1	0	1	1	1	1	0	1	0	1	1	1	1	0	0	0	68.18	15
Mean of total scores:																								75.23	16.55

Within the table: 1: criterion met; 0: criterion not met; **In the table header:** 1: title and abstract; 2: context/rationale; 3: objectives; 4: study design; 5: context; 6: participants; 7: variables; 8: data sources/measures; 9: biases; 10: sample size; 11: quantitative variables; 12: statistical methods; 13: participants included in each phase of the results; 14: descriptive data; 15: outcome variable data; 16: main results; 17: other analyses; 18: key results discussed in the discussion; 19: limitations; 20: interpretation; 21: generability; 22: funding

limb resistance (SMD = 0.50; $p < 0.001$), as compared to the inactive subjects. Figure 3 represents the forest plots of the physical fitness tests that were statistically significant between active and inactive subjects. Forest plots of cardiovascular fitness and aerobic endurance, hamstring and lower back flexibility, abdominal strength and endurance, and upper limb resistance were included.

Body Composition Results

A total of 12 body composition and kinanthropometric variables were analyzed in the 11 studies included in the meta-analysis. Ten body composition and anthropometric variables were analyzed in three studies or more and were therefore included in the meta-analysis.

Of the 11 studies included in the meta-analysis, nine analyzed adolescent height and body mass (81.82%). For height, only three studies (27.27%) found significant differences between groups (Duncan et al. 2014; Güvenç et al. 2011; Khatun et al. 2016), while for body mass, the differences were significant in four of the nine studies (44.44%) (Cho and Kim 2017; Duncan et al. 2014; Gea-García et al. 2020; Khatun et al. 2016). Body mass index was calculated in eight studies (72.73%) and differences were significant between active and inactive adolescents in five of them (62.50%) (Cho and Kim 2017; Duncan et al. 2014; Gea-García et al. 2020; Khatun et al. 2016; Mukhopadhyay et al. 2005). Five articles measured the sum of skinfolds (45.45%), and six measured the percentage of fat mass of the participants (54.55%). Regarding the sum of skinfolds, differences between active and inactive subjects were significant in four of the five studies that included this variable (80.00%) (Agata and Monyeki 2018; Güvenç et al. 2011; Khatun et al. 2016; Sivrikaya et al. 2019), while five of six studies (83.33%) showed significant differences in the percentage of fat (Agata and Monyeki 2018; Cho and Kim 2017; Güvenç et al. 2011; Khatun et al. 2016; Mukhopadhyay et al. 2005). Fat mass and fat-free mass were included in three studies (27.27%), with all three (100.00%) showing differences in fat mass (Cho and Kim 2017; Khatun et al. 2016; Mukhopadhyay et al. 2005), while two (66.67%) in fat-free mass (Güvenç et al. 2011; Khatun et al. 2016). Two studies calculated the fat mass index (18.18%), and both found significant differences between adolescents in the active and inactive groups (Khatun et al. 2016; Mukhopadhyay et al. 2005). Waist girth and waist to height ratio were analyzed in one research (Duncan et al. 2014), but differences were not significant between active and inactive adolescents on these variables.

The results of the differences between active and sedentary subjects are shown in Table 3, including standardized mean differences (SMD), 95% confidence interval (95% CI), overall size effect (z), and significance (p). A positive SMD

Table 3 Statistical differences and effect size in physical fitness and body composition variables between active and inactive subjects

	Number of studies	Number of active and inactive groups compared	Active vs inactive			
			SMD	95% CI	<i>z</i>	<i>p</i>
Height (cm)	9	18	0.10	−0.05 to 0.25	1.30	0.195
Body mass (kg)	9	18	0.02	−0.09 to 0.13	0.31	0.757
BMI (kg/m ²)	8	18	−0.07	−0.20 to 0.06	1.07	0.284
Sum of skinfolds (mm)	5	12	−0.03	−0.26 to 0.19	0.29	0.770
% BF	6	7	−0.39	−0.53 to −0.26	5.75	<0.001
Fat mass (kg)	3	4	−0.42	−0.77 to −0.07	2.38	0.017
Fat-free mass (kg)	3	4	0.04	−0.60 to 0.69	0.14	0.891
Fat mass index	2	3	−0.30	−0.40 to −0.20	5.93	<0.001
Waist circumference (cm)	1	4	−0.04	−0.13 to 0.04	1.00	0.319
WHR (%)	1	4	−0.06	−0.22 to 0.09	0.84	0.403
Cardiovascular fitness and aerobic endurance (ml/kg/min)	6	8	2.22	1.26 to 3.17	4.55	<0.001
Hamstring and lower back flexibility (cm)	6	8	1.13	0.14 to 2.12	2.24	0.025
Abdominal strength and endurance (repetitions)	6	8	0.50	0.28 to 0.71	4.49	<0.001
Upper limb resistance (repetitions)	3	4	0.50	0.30 to 0.69	4.93	<0.001

SMD standardized mean difference, *CI* confidence interval, *p* significance value, *BMI* body mass index, *% BF* body fat percentage, *WHR* waist to height ratio, *VO₂ max.* maximal oxygen consumption, *SUP* sit-ups

value indicates a higher value for active subjects than inactive subjects. The meta-analysis showed significant differences between subjects in the active and inactive groups in the variables body fat percentage (SMD = −0.39; $p < 0.001$), fat mass (SMD = −0.42; $p = 0.017$), and fat mass index (SMD = −0.30; $p < 0.001$), with the inactive subjects obtaining higher values in all variables. Body mass, body mass index, sum of skinfolds, fat-free mass, waist circumference, and waist-to-height ratio did not show significant differences between the groups. The forest plots of the variables that were significant, body fat percentage, fat mass index, and fat mass (kg), are shown in Fig. 4. Egger's test did no evidence publication of bias according to height (SE = −0.101; 95% CI = −0.404; 0.259; $p = 0.691$), body mass (SE = 0.103; 95% CI = −0.185; 0.277; $p = 0.684$) or body mass index (SE = −0.229; 95% CI = −0.394; 0.151; $p = 0.360$), although it reported light evidence of publication of bias according to sum of skinfolds (SE = −0.664; 95% CI = −0.932; 0.108; $p = 0.018$).

Discussion

Research has revealed a lack of consensus on the influence exerted by physical activity on body composition and physical fitness in adolescents aged 12–16 years. In an attempt to address this situation, the present systematic review with meta-analysis was carried out, including the scientific literature published to date in which the

differences in body composition and physical fitness between active and sedentary adolescents had been analyzed. The results showed that active adolescents who engaged in regular physical activity had better body composition (lower percentage of fat, lower fat mass, and lower fat mass index) and better physical fitness (better cardiovascular endurance, better hamstring and lower back flexibility, greater abdominal strength, and endurance and greater upper limb strength) than sedentary adolescents.

These results have made it possible to respond to the first objective set at the beginning of the research, which was to investigate the existing differences in the physical fitness of adolescents according to whether or not they practiced physical activity. An important result of the present meta-analysis was that the group of active adolescents showed significantly higher values of cardiorespiratory fitness, finding significant differences in this variable in five of the studies that included it, in favor of the active subjects (Agata & Monyeki, 2018; De Milander, 2011; Güvenç et al., 2011; Huang & Malina, 2002; Pacífico et al., 2019). Previous research has found that the type of sport practiced or type of training performed can affect the development of cardiorespiratory fitness from childhood to adulthood (Rakovac et al. 2018), adolescence being a key stage for the development of cardiorespiratory capacity and having a great impact on the later stages of life of the subjects (Lazic et al. 2019). In this sense, one of the cardiovascular adaptations produced by the practice of systematic exercise is the development of the atria and ventricles of the heart

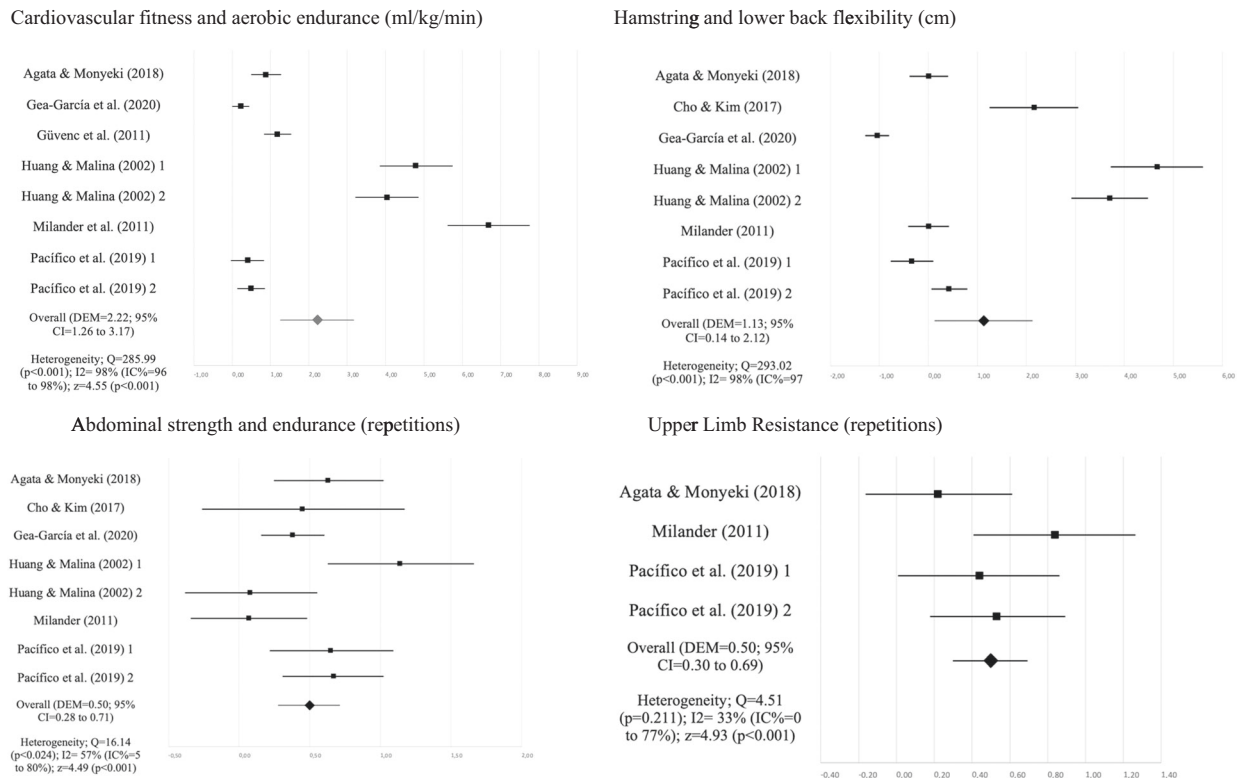


Fig. 3 Forest plots for active and inactive subjects for physical fitness tests. Each square represents the mean value for the variable studied in each article, and the horizontal bars are the standard deviation for that

variable in that study. The diamond at the bottom of each graph represents the mean value and standard deviation for all items

(Castanheira et al. 2017), which would explain the differences found in the present investigation.

Of note is the great heterogeneity of the tests used to estimate cardiorespiratory fitness among the studies included in the present meta-analysis, which included four different tests with the 20-m shuttle run test (Agata and Monyeki 2018; Gea-García et al. 2020), one mile run (De Milander, 2011; Huang & Malina, 2002), Wingate anaerobic test (Güvenc et al. 2011) and PACER test (Pacifico et al. 2019). All four tests have been previously validated in adolescents (Batista et al. 2017), but only in one of these studies (Gea-García et al. 2020), it was indicated that the equation of Léger et al. (1988) had been used to calculate cardiorespiratory fitness. These aspects should be considered in future research.

Another result of the present meta-analysis is that the active group showed significantly greater hamstring and lower back flexibility than the inactive group; when analyzing the results of the different articles individually, it was found that there were differences in this variable in two of the six studies (Cho & Kim, 2017; Huang & Malina, 2002). Previous research has shown that the hamstring and lower back flexibility of adolescents is mainly influenced by the type of sports practiced. For example, the practice of sports

in which the technical movements involve hamstring muscle extensibility can induce a traction stimulus that increases hamstring and lower back extensibility. Furthermore, specific stretching programs are included in the training of these sport modalities to achieve the range of motion which allows performing these specific movements with a good technique (Vaquero-Cristóbal, Molina-Castillo, et al. 2020). However, the studies included in the meta-analysis did not indicate the type of physical activity performed by the active subjects, which makes it difficult to establish whether the reason for the differences between active and inactive subjects or between the studies that found significant differences in this capacity and those that did not, is due to the fact that the active participants practiced a certain type of sports. Therefore, the results should be taken with caution, especially considering that the sample sizes of four studies were less than 50 subjects per group (Cho & Kim, 2017; De Milander, 2011; Huang & Malina, 2002; Pacifico et al., 2019), and that in one of the studies, a group of two hundred and eight active subjects was compared with a group of 30 sedentary subjects (Agata and Monyeki 2018).

Another variable where the meta-analysis showed that active subjects had significantly higher values than inactive subjects was the strength and endurance of the abdominal

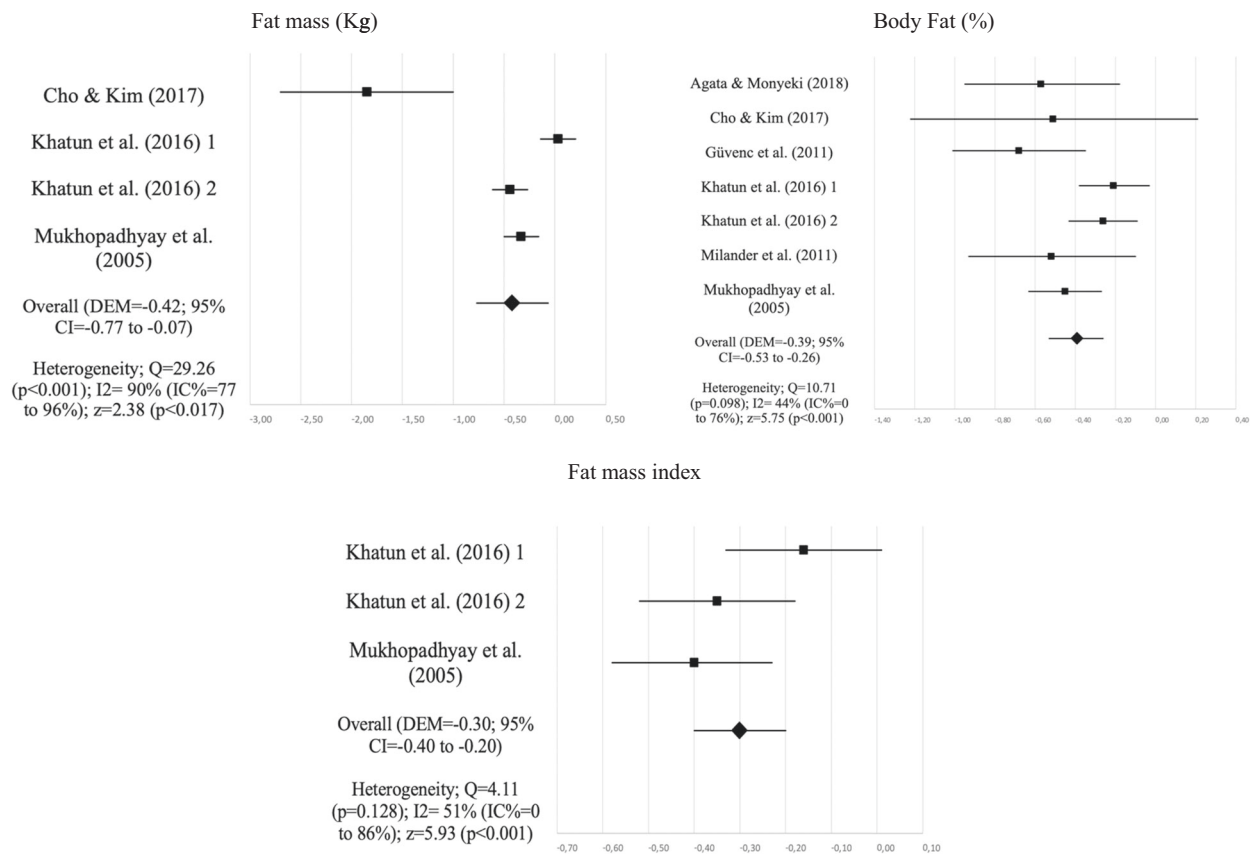


Fig. 4 Forest plots for active and inactive subjects for body composition variables. Each square represents the mean value for the variable studied in each article, and the horizontal bars the standard deviation

for that variable in that study. The diamond at the bottom of each graph represents the mean value and standard deviation for all items

and hip-flexor muscles. To assess this capacity, the sit-up test was used in four studies, where subjects had to perform a full sit-up and remain seated, of which two studies showed differences between groups (Agata and Monyeki 2018; Gea-García et al. 2020); while the curl-up test was used in two studies, where subjects had to separate the upper back from the floor, of which one study showed differences between groups (Pacífico et al. 2019). The rectus abdominis and obliques are the main muscles involved during sit-ups and curl-ups (Escamilla et al. 2006). Previous studies have shown that the systematic practice of physical activity and sports is associated to an increase in the resistance of the abdominal muscles (Wang et al. 2018), suggesting that adolescents who engage in moderate to vigorous physical activity on a daily basis develop abdominal muscles to a greater extent than those who are sedentary.

The discrepancies in the protocol followed when performing the sit-up and curl-up tests lead to consider them as different tests. During the sit-up, an individual almost completely sits up, while in the curl-up, there is an angle of about 30°. This could be one of the reasons for the differences found between the studies, but the following aspects

should also be considered. While some of the studies included in the systematic review with meta-analysis used protocols of 30" duration (Agata and Monyeki 2018; Cho and Kim 2017; Gea-García et al. 2020), others opted for 60" (Huang & Malina, 2002). There was also no homogeneity in foot support and knee flexion degrees, varying between keeping the feet in contact with the ground with the knees at 140°, and keeping the feet in the air with knee and hip flexion at 90° (Cho & Kim, 2017; Gea-García et al., 2020; Huang & Malina, 2002); or in the execution of each repetition, with some articles requesting that both knees be touched simultaneously with the elbows (Cho and Kim 2017) and in others to touch the opposite knee alternately with the elbow (Huang & Malina, 2002). The muscle activation is different depending on the trunk elevation performed, with greater or lesser pelvic and thoracic involvement (Cordo et al. 2003), which could be the reason for the differences found. Therefore, future research is needed to standardize the way of performing this test in order to corroborate the results of the present meta-analysis.

Another finding of the present study was that the active group showed significantly greater upper limb resistance

than the inactive group. This variable was analyzed in three studies, and the differences between the active and inactive groups were significant in one of the two studies that used the push-ups test (De Milander 2011), while in the research in which this variable was evaluated by means of the bent arm hang test, no significant differences were found (Agata and Monyeki 2018). The discrepancies between the results of these studies could be due to the fact that the push-ups test is a push test that mainly involves the pectoral muscles, although differences are found depending on the placement of the hands, wrists and elbows (Kim et al. 2016), with greater activation during push-ups performed with the narrow base hand position, with the 50% and 100% palmar widths as compared with the 150% palmar width (Kyung-Hwan 2017), while the bent arm hang test is a traction test that mainly activates the muscles of the shoulder girdle and is commonly used with climbers (Baláš et al. 2012). The different types of contraction produced in both tests could be the origin of the differences found. The push up is a dynamic exercise and the bent arm hang is an isometric exercise, and therefore they have different physiological demands and require different mechanisms for improvement (Warnock et al. 2019). In addition, it should be taken into account that the bent arm hang test and its modifications have methodological limitations. They appear to be a reliable measure of relative isometric strength, but not of absolute strength or muscular endurance (Clemons 2014); it is a difficult and unreliable test in children (Sekeljic et al. 2015); and depend on the weight of the subject (Artero et al. 2010). Previous studies have proposed its modification or substitution with tests such as a two-handed bicep curl so that the results are more valid (Bubanjan et al. 2017). The results obtained with respect to the physical fitness of the active and inactive subjects allow to affirm the first hypothesis put forward at the beginning of the research since the active subjects presented greater cardiorespiratory fitness, the flexibility of the hamstrings and lower back, number of abdominals and strength of the upper limb.

The results also allowed to answer the second objective of the research, which was to analyze the existing differences in body composition and kinanthropometry variables of adolescents according to whether or not they practiced physical activity. The main result was that the active group showed significantly lower body fat percentage, fat mass and fat mass index than the inactive group. The latter variable calculates fat mass as a function of height, providing greater accuracy to body composition (Fedewa et al. 2020). After analyzing the results of the included articles individually, it was observed that 83.33% of the studies that estimated body fat percentage (Agata and Monyeki 2018; Cho and Kim 2017; Güvenç et al. 2011; Khatun et al. 2016; Mukhopadhyay et al. 2005) and 100% of those that estimated body fat mass (Cho and Kim 2017; Khatun et al.

2016; Mukhopadhyay et al. 2005) or fat mass index (Khatun et al. 2016; Mukhopadhyay et al. 2005), found significant differences between active and inactive individuals. This could be due to the fact that the practice of moderate to vigorous-intensity physical exercise produces body changes related to long-term fat loss (Espinoza-Salinas et al. 2020), while sedentary behaviors are related to fat accumulation, especially in the abdominal area (Golubic et al. 2015).

One aspect to consider when analyzing variables related to body fat is the method and formulas used for its estimation, as previous research has shown significant differences according to these (Vaquero-Cristóbal, Albaladejo-Saura, et al. 2020). In the present meta-analysis, some heterogeneity was found, as two articles analyzed these variables with bioelectrical impedance (Cho and Kim 2017; Gea-García et al. 2020), while seven articles analyzed the percentage of fat through kinanthropometry, based on the measurement of skinfolds, muscle perimeters, and waist and hip circumferences mainly (Agata & Monyeki, 2018; De Milander, 2011; Güvenç et al., 2011; Huang & Malina, 2002; Khatun et al., 2016; Mukhopadhyay et al., 2005; Sivrikaya et al., 2019), with four of the studies (Agata and Monyeki 2018; Güvenç et al. 2011; Khatun et al. 2016; Mukhopadhyay et al. 2005), using the formula by Slaughter et al. (1988) which is the most commonly used formula for the assessment of adolescents (Alvero-Cruz et al. 2010).

In the present meta-analysis, no significant differences were found in fat-free mass between active and inactive subjects, and this could be due to the small number of studies that included this parameter. In fact, only three studies included it, with two of them finding differences in fat-free mass (Güvenç et al. 2011; Khatun et al. 2016). A second reason could be that this variable was estimated with bioelectrical impedance, and this method has been shown to have limitations in its validity with adolescents because the preconditions must be rigorously controlled for the measurements to be valid and reliable (Brewer et al. 2019), and the research does not indicate that these aspects have been taken into consideration. A third reason is that this component does not represent muscle mass, despite the fact that on many occasions this association is incorrectly made, since it represents mass that does not correspond to fat mass, but does not correspond in its entirety to muscle mass (Jensen et al. 2019). Therefore, future research is needed to analyze the differences in muscle mass between active and inactive adolescents, as an independent parameter.

An expected result of the present investigation is that no significant differences in height were found between the active and inactive groups. Height is strongly dependent on genetics, and the influence of environmental variables is very limited (Jelenkovic et al. 2020), which could explain the results of the present investigation. However, it was

surprising that there were no significant differences in body mass and body mass index. This could be because, although both parameters are frequently used to assess body composition, it is not possible to distinguish between changes in fat and muscle masses by only using these parameters (Herrero and Cabañas 2009). The lack of changes in body mass and body mass index, which associates body mass to height, may be a consequence of the exercise-induced decrease in fat mass being compensated by an increase in muscle mass (Vaquero-Cristóbal et al. 2016). In addition, other studies have shown that fat mass and muscle mass are also influenced by factors such as energy intake (González Jiménez 2013).

No differences were found in the sum of skinfolds between the active and inactive group, despite the fact that skinfolds are the basis of fat mass estimation using kinanthropometry (Vaquero-Cristóbal, Albaladejo-Saura, et al. 2020). Also, the analysis of the individual results in these articles showed that the differences between active and inactive subjects were significant in four of the five studies which included skinfolds (Agata and Monyeki 2018; Güvenç et al. 2011; Khatun et al. 2016; Sivrikaya et al. 2019). The absence of significant results in this variable between the active and inactive group could be due to the heterogeneity in the number of skinfolds included in the sum, ranging from two to eight and including different skinfolds (Agata & Monyeki, 2018; Güvenç et al., 2011; Huang & Malina, 2002; Khatun et al., 2016; Sivrikaya et al., 2019), the protocol followed to perform the measurements (Agata & Monyeki, 2018; Güvenç et al., 2011; Huang & Malina, 2002; Khatun et al., 2016; Sivrikaya et al., 2019), or the plicometers used (Güvenç et al., 2011; Huang & Malina, 2002; Sivrikaya et al., 2019). Therefore, it is necessary to contrast the results of the present meta-analysis in future studies in which all of these aspects are standardized.

Anthropometric indices, such as waist girths and waist to height ratio, are commonly used to assess assessing obesity during childhood and adolescence because of their simplicity, low cost, and strong correlation with the body fat percentage (Herrero and Cabañas 2009). The present meta-analysis found that there were no significant differences between the active and inactive groups in waist girth and waist to height ratio. Only one study of those included in the meta-analysis analyzed these variables (Duncan et al. 2014), and although the sample was large (2799) and included adolescent boys and girls, the results were limited to the geographical areas in which the research was conducted (Great Britain and Saudi Arabia). This last aspect is relevant because the interaction of genetic and environmental factors seems to influence certain elements of body composition, as is the case of waist girth (Arya et al. 2018). In addition, it would be necessary to know other aspects such as television viewing hours or parental lifestyle habits, as they are positively associated with adolescent waist girth (Bruce

et al. 2021); or the body composition of adolescents when they were still children, as previous research has shown that the waist-to-height ratio of girls was higher than expected during adolescence, the higher the body mass index was during childhood (Biro et al. 2010). The results obtained in the present systematic review regarding the differences in body composition between active and inactive subjects confirm the second hypothesis. However, of all the variables included, only the percentage of body fat, fat mass and fat mass index showed statistically significant differences, so it is necessary to continue to investigate the reasons why certain parameters of adolescent body composition are modified by the practice of physical activity.

The results obtained in the systematic review and meta-analysis reaffirm the importance of physical activity for the adolescent population. Although the number of physical fitness and body composition variables included in the meta-analysis was not very large, the results provided significant differences in physical fitness and body composition variables between physically active and inactive adolescents. This work provides a solid starting point to encourage the promotion of physical activity by sports and educational organizations, with the aim at increasing the level of physical activity among adolescents and reducing the risk of suffering any type of chronic disease that may appear during adolescence or adulthood. Although future research is needed to analyze more variables on which modifications can occur with the practice of physical activity, this study was necessary to obtain conclusions supported by statistical values with which to make professionals working with adolescents aware of the importance of physical activity in their development.

During the systematic review and meta-analysis, some limitations were observed in the available scientific literature. Firstly, the protocols used to assess physical fitness tests, body composition and anthropometric variables were different. Secondly, the sample sizes used in some of the articles were small, which makes their comparison, and the final interpretation of the meta-analysis results difficult. And thirdly, the samples used in the investigations included a disparate number of boys and girls, and some of them even included participants of only one sex, which makes it difficult to draw conclusions for adolescents as a whole.

With respect to the strengths of the present review, it should be noted that it was carried out in accordance with the PRISMA and STROBE declarations, that the number of studies included at the beginning of the review was very high, that it included meta-analyses that provided statistically relevant data on the effects found in the articles reviewed, and provides an overview of the scientific articles published to date that address the influence of physical activity on physical fitness and body composition in adolescents. Although these strengths make the article strong,

some limitations should be noted. Firstly, research in a language other than English was not included, nor were unpublished articles or scientific productions other than articles (abstracts of meetings, conferences, etc.). Secondly, the selection of studies that divided their sample between active and inactive adolescents left out numerous articles that compared adolescents who practiced specific sports with those who did not. Thirdly, this review includes only cross-sectional studies, while interventions and longitudinal studies could provide other relevant data. And, fourthly, some of the studies used included samples from different countries, which implies the comparison of adolescents with different ethnicities, social classes and customs that were not considered, which could influence the results obtained.

Conclusion

Research conducted to date on the differences between active and sedentary adolescents aged 12–16 years did not provide consistent results that would allow conclusions to be drawn. For this reason, this systematic review with meta-analysis was needed to establish the differences between adolescents in both groups. The results obtained show that being an active adolescent is associated with better physical fitness, as shown by the statistically higher values in cardiovascular fitness and aerobic endurance, hamstring, and lower back flexibility, abdominal strength and endurance, and upper limb resistance, as compared to inactive adolescents. A relationship was also found between being active during adolescence and better body composition in all parameters related to fat mass, with inactive adolescents showing significantly higher values in all the variables related to fat mass. However, no differences were found in the other anthropometric and derived parameters, perhaps due to the different sample sizes, and the instruments and methodologies used in the studies. The results obtained allow to affirm that physical activity is necessary to achieve changes in the physical fitness and body composition of adolescents from 12–16 years of age, this being relevant to emphasize the promotion of youth sports in all educational and sports centers. The fact that adolescents develop in the best physical and psychological conditions is fundamental for them to become healthy adults with full autonomy to develop their duties during adulthood. Therefore, it is necessary to emphasize that all organizations and professionals working with adolescents give daily physical activity the importance that this research reflects.

Authors' Contributions A.M.-O. participated in design of the study, data collection, and helped to draft the first version of the manuscript; N.G.-G. participated in the design of the study, data collection and performed statistical analysis; L.A.-C. participated in the design of the study, data collection and helped to draft the final version of the

manuscript, and R.V.-C. participated in design of the study, data collection, and helped to draft the first version of the manuscript. All authors read and approved the final manuscript.

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Data Sharing and Declaration The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Ethical Approval The ethics committee of the Catholic University of Murcia approved the research (code CE022102).

Informed Consent The use of informed consent was not necessary because no individuals participated in the research.

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Citations with an * were included in the meta-analysis.

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