OXYGEN UPTAKE AND INDICATORS OF OBESITY: META-ANALYSIS INCLUDING 17,604 ADOLESCENTS

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CONSUMO DE OXIGÊNIO E INDICADORES DE OBESIDADE: METANÁLISE INCLUINDO 17.604 ADOLESCENTES

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ABSTRACT

Introduction: Low aerobic fitness levels are associated with excess body adiposity in adolescents. However, studies that have analyzed this association in adolescents have used different methods and measures to evaluate aerobic fitness, making it difficult to compare the results. Objective: To conduct a systematic review with meta-analysis of studies that have analyzed the association between aerobic fitness and anthropometric body adiposity indicators in adolescents aged 10-19 years. Methods: A systematic search was performed in May 2016, updated in March 2017, in the following electronic databases: LILACS (BIREME), Embase, MEDLINE (PubMed), Web of Science (Web of Knowledge), Scopus, and SPORTDiscus. Results: Twenty-three studies were selected. The meta-analysis indicated that as the aerobic fitness levels increased, the BMI, waist circumference and body fat percentage values of the adolescents decreased. Conclusion: There is a negative association between aerobic fitness (evaluated by measuring maximum oxygen uptake in the 20-meter Shuttle Run test) and the body fat percentage, BMI and waist circumference of adolescents and a negative association between aerobic fitness (assessed by measuring the number of laps in the 20-meter Shuttle Run test) and body fat percentage. However, caution is required in the interpretation of data due to the heterogeneity of the studies analyzed. ***Level of Evidence II; Systematic review of studies with level II of evidence.***

Keywords: Anthropometry; Aptitude; Health; Physical fitness.

RESUMO

Introdução: Os baixos níveis de aptidão aeróbica estão associados ao excesso de adiposidade corporal em adolescentes. Porém, os estudos que analisaram essa associação em adolescentes, utilizaram diferentes métodos e medidas para avaliar a aptidão aeróbica, o que dificulta a comparação dos resultados. Objetivos: Realizar uma revisão sistemática com metanálise de estudos que analisaram a associação entre aptidão aeróbica e indicadores antropométricos de adiposidade corporal em adolescentes de 10 a 19 anos. Métodos: Realizou-se busca sistemática em maio de 2016, atualizada em março de 2017, nas seguintes bases de dados eletrônicas: LILACS (BIREME), Embase, MEDLINE (PubMed), Web of Science (Web of Knowledge), Scopus e SPORTDiscus. Resultados: Foram selecionados 23 estudos. A metanálise indicou que à medida que aumentavam os níveis de aptidão aeróbica, diminuíam os valores de IMC, do perímetro da cintura e do percentual de gordura corporal dos adolescentes. Conclusões: Existe uma associação negativa entre aptidão aeróbica (avaliada pela medida da captação de oxigênio no teste de corrida de vaivém de 20 metros [20m Shuttle Run]) e percentual de gordura, IMC e perímetro da cintura dos adolescentes e associação negativa entre aptidão aeróbica (avaliada pela contagem de voltas no teste de vai e vem de 20 metros) e percentual de gordura corporal. Contudo, é necessária cautela na interpretação dos dados devido à heterogeneidade dos estudos analisados. ***Nível de evidência II; Revisão sistemática de Estudos de Nível II***

Descritores: *Antropometria; Aptidão; Saúde; Aptidão física.*

RESUMEN

Introducción: La evidencia sugiere que los niveles bajos de aptitud aeróbica están asociados a un exceso de adiposidad corporal en los adolescentes. Sin embargo, los estudios que analizaron esta asociación en adolescentes utilizaron diferentes métodos y medidas para evaluar la aptitud aeróbica, lo que dificulta la comparación de los resultados encontrados. Objetivo: Realizar una revisión sistemática con metanálisis de estudios que evaluaron la asociación entre aptitud aeróbica e indicadores antropométricos de adiposidad corporal en adolescentes de 10 a 19 años. Método: Se realizó una búsqueda sistemática en mayo de 2016, actualizada em marzo de 2017, en las bases de datos electrónicas: LILACS (BIREME), Embase, MEDLINE (PubMed), Web of Science (Web of Knowledge), Scopus y SPORTDiscus. Esta revisión incluyó estudios transversales con adolescentes de 10 a 19 años que analizaron la asociación entre la aptitud aeróbica (con diferentes métodos de evaluación) y los indicadores antropométricos de la adiposidad corporal (utilizando la antropometría como método). Resultados: Se seleccionaron 23 estudios. El metanálisis indicó que a medida que aumentaban los niveles de aptitud aeróbica, el IMC, la circunferencia de la cintura y el porcentaje de grasa corporal de los adolescentes disminuían. Conclusión: Existe una asociación negativa entre la aptitud aeróbica

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(evaluada por el test Shuttle Run 20 metros mediante el consumo máximo de oxígeno) y el porcentaje de grasa, IMC y circunferencia de cintura de los adolescentes y una asociación negativa entre la aptitud aeróbica evaluada por el test Shuttle Run 20 metros según el número de vueltas y el porcentaje de grasa corporal. Sin embargo, se requiere precaución al interpretar los datos debido a la heterogeneidad de los estudios analizados. ***Nivel de evidencia II; Revisión sistemática de estudios de nivel II***

Descriptores: *Antropometría; Aptitud; Salud; Aptitud física.*

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INTRODUCTION

Adequate aerobic fitness levels are important health marker in children and adolescents and are strongly associated with the prevention of diseases.[1,2] On the other hand, the low aerobic fitness levels are associated with metabolic syndrome and increase of cardiovascular risk factors that can manifest even in adolescence.[1]

Recent estimates indicate that more than three million Brazilian students aged 13-17 years are overweight.[3] The world projection for 2025 is that approximately 75 million children and adolescents are overweight and obese.[4] In Latin America, approximately 21 million adolescents (between 2008 and 2013) and one-third of adolescents in the United States (in 2003 and 2004) presented body fat above normal levels.[5] These data are worrisome because excess weight is a risk factor for cardiovascular and pulmonary diseases, diabetes mellitus, biliary disorders and some cancers,[6] increasing the chances of premature mortality.[1]

One of the ways to identify excess weight is through anthropometry.[7] Widely used in epidemiological research, anthropometry is considered easy to apply, to have low cost and good validity indexes when compared to more precise methods.[7] For being non-invasive methods that systematically measure body size and dimensions, anthropometric indicators are well accepted and widely used in population research, helping to detect changes in body pattern, health conditions, performance and functional capacity.[8]

The fact that aerobic fitness levels in adolescents are gradually decreasing[9] is even more worrying when associated with excess body adiposity. Studies have identified that one of the possible explanations for the various cardiovascular changes and the onset of chronic diseases in overweight individuals may be related to low aerobic fitness levels.[1,2] These data seem to be independent of the anthropometric index used,[10] since adequate aerobic fitness levels are associated with greater amount of fat-free mass. Thus, early body fat discrimination is an alternative to identify high fat concentration and to identify groups considered to be at health risk.[11]

Many studies have analyzed the relationship between aerobic fitness and anthropometric indicators in the young population and in general found a negative association among variables.[10,12-23] However, studies have used different methods and measures to evaluate aerobic fitness, such as direct and indirect tests and presented the results as absolute VO_2max, relative VO_2max and VO_2peak.[20-22] This fact implies in the comparison of the results found by studies, because in indirect methods, for example, mathematical formulas are used to predict VO_2max[2]. In addition, studies that investigated the relationship between aerobic fitness and anthropometric indicators in the same sample have made use of four[13], or at most three indicators,[10,15-18,24-27] which limits the identification of magnitude of association between body fat distributed in different body parts and aerobic fitness. Thus, investigating the degree of association between fat distributed in different body regions and aerobic fitness may help in identifying fat sites that are more sensitive to modifications with improved aerobic fitness.

This study aimed to perform a systematic review with meta-analysis including studies that have analyzed the association between aerobic fitness and anthropometric body adiposity indicators in adolescents aged 10-19 years.

METHOD

The method used in the systematic review and meta-analysis were consistent with the norms of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[28]

In this systematic review with meta-analysis, there was no physical test restriction to measure aerobic fitness, since the use of a specific test may exclude important results of this outcome. In addition, the applicability of different tests is very common in aerobic fitness studies. It is understood that this fact allows obtaining mixed results; therefore, it was tested whether the different measures of aerobic fitness would result in different findings on the association between aerobic fitness and anthropometric body adiposity indicators. The aerobic fitness indicators included in this systematic review were: maximal oxygen uptake (VO_2max), absolute VO_2max ($l.min^{-1}$), relative VO_2max ($ml.kg^{-1}.min^{-1}$), peak oxygen uptake (VO_2peak), number of laps in the 20-m Shuttle Run test, aerobic fitness score and aerobic power ($W.kg^{-1}$ or Kg.m.min).

The systematic search was performed in the following electronic databases: LILACS (BIREME), Embase, MEDLINE (PubMed), Web of Science (Web of Knowledge), Scopus and SPORTDiscus. The search was initially performed in May 2016 and updated in March 2017. Studies that analyzed the association between aerobic fitness and anthropometric body adiposity indicators until the date of the search were included. The year of publication of articles was disregarded in order to cover as many studies as possible. Boolean operators AND and OR, parentheses, quotation marks and asterisks were used in each database. Parentheses were used to combine search terms by outcome, exposure and population categories. Quotation marks were used to search for exact terms or expressions. Asterisk was used to search for all words derived from the same prefix. Descriptors came from DEC's (Health Sciences Descriptors), MESH (Medical Subject Headings) and words related to the subject.

The research groups were: Outcome (aerobic fitness) ("Aptitude" OR "Aptitude Tests" OR "Physical Fitness" OR "Physical fitness" OR "aerobic capacity" OR "aerobic fitness" OR "cardiorespiratory capacity" OR "Cardiovascular fitness" OR "cardiorespiratory fitness" OR "aerobic power" OR "aerobic endurance" OR "cardiorespiratory endurance" OR "oxygen consumption" OR "maximum oxygen consumption" OR "maximal oxygen uptake" OR "VO2 maximal" AND Exposure (anthropometric indicators) "fats" OR "fat body" OR "body mass index" OR "BMI" OR "obesity" OR "adiposity" OR "body size" OR "excess weight" OR "overweight" OR "body composition" OR "Body fat distribution" OR "Anthropometry" OR "Anthropometric indicators" OR "skinfolds" OR "waist" OR "central obesity" OR "abdominal obesity" OR "waist to height ratio" OR "Conicity index" OR "circumference" OR "Body Weight" OR" "Body Height" AND Population (adolescents) "adolescent" OR "adolescence" OR "student" OR "youth" OR "teen" OR "teenager".

We used only one descriptor for skinfold and circumference in order to broaden the search, considering that all titles indexed with these keywords would be identified, regardless of the type of skinfold or circumference used in the survey.

Searches were conducted in the online databases with descriptors in English language and the results were exported to EndNote® reference manager software version X7 (Thomson Reuters, New York, USA).

The entire process of selection and evaluation of articles was analyzed by two reviewers using a systematic method. First, the titles of articles were read. The abstracts were then analyzed according to the inclusion criteria. After reviewing abstracts, the full text of articles was obtained, read and included if they met the inclusion criteria. In case of disagreement among reviewers about the inclusion and exclusion criteria, a third reviewer was asked to evaluate the article, reaching final consensus.

The selection criteria of studies were: (a) being original research article; (b) including adolescents aged 10-19 years;[29] (c) having cross-sectional design; (d) having sample of 50 or more adolescents, in order to guarantee statistical power;[30] (e) including at least two anthropometric body adiposity indicators in order to compare which anthropometric indicator had greater magnitude of association with aerobic fitness; (f) studies that used only anthropometry to measure anthropometric indicators.

Monographs, dissertations, theses, abstracts, chapters or books and point of view / opinion of experts were not included in the review, as well as studies including adolescents with some type of disease and / or mental and / or physical problem (anemia, cognitive problems, diabetes, depression, asthma, bronchitis, metabolic syndrome, physical disability), or adolescents from specific groups (athletes and obese individuals); articles without full access (after searching databases and contacting authors by e-mail); articles published in a language other than English, Spanish or Portuguese (no articles were found in Spanish, Portuguese and English only); studies that presented only descriptive statistics of data to identify differences between aerobic fitness and anthropometric body adiposity indicators; studies that have analyzed body composition using techniques other than anthropometric indicators (X-ray absorptiometry (DXA), Plestimography or Bioimpedance).

Two reviewers independently assessed the methodological quality of studies using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.[31] This instrument of methodological analysis is indicated to help the internal validity (potential risk of selection, information or confusion) of cross-sectional studies and cohorts. In the case of disagreements between the two reviewers, a third reviewer analyzed the criteria in question for consensus between them. Score from 13 to 14 was considered good, from nine to 12 moderate and below nine poor.[31,32]

All statistical analyses were performed with the use of Data Analysis and Statistical Software – STATA®, version 13.0 (StataCorp, Texas, USA). The combined correlation coefficients between anthropometric parameters and aerobic fitness were calculated according to the correlation coefficient values *r* provided in each article. To reduce the possibility of bias due to different tests and measurements used to assess aerobic fitness, we conducted separate meta-analyzes for each type of test and measurement used. Correlation coefficients were converted by the Fisher's *r*-to-*z* transformation to obtain approximately normally distributed *z*-values to further calculate the 95% CI. Then, combined correlation coefficients and respective 95% CI were converted back to correlation units using the method described by Borenstein et al..[33] Heterogeneity was considered significant when $p < 0.1$ on the chi-square test or $I^2 > 50\%$. Sensitivity analysis was performed to assess the influence of each study on the pooled correlation coefficient by omitting each study individually. Publication bias analysis and meta-regression models were not assessed because the minimum number of studies for the implementation of this test in each analysis (≥10) was not achieved.[34]

We adopted the p value < 0.05 for statistical significance and the respective cut-off points of the combined correlation coefficients to indicate the strength of association: $r \leq 0.20$ - poor correlation; $0.20 \leq r \leq 0.40$ - average correlation; $0.40 \leq r \leq 0.60$ moderate correlation; $0.60 \leq r \leq 0.80$ - substantial correlation; and $r \geq 0.81$ - strong correlation.[35]

RESULTS

The initial literature search carried out on May 2016 identified a total of 32,159 publications in databases. In the search update on March 2017, 4,075 other articles were found. After the removal of duplicate studies and the reading of titles and abstracts, 178 studies were read in their entirety. At the end of the search, 23 articles were included in the systematic review (all articles belonging to the search of year 2016)[10,12-22,24-27,36-42]. No search article of year 2017 was included. Of the 23 studies included in the systematic review,[43] only 10 had sufficient data for the meta-analysis. The selection process of studies is presented in Figure 1.

Data availability

Every data set that supports the results of this study was provided to the OSFHOME repository and can be accessed at https://osf.io/wp5xc/[43]

The methodological quality of most studies (n = 14), was evaluated as poor.[10,12-14,16,17,20,24,25,36,39-42] All other studies (n = 9)[15,18,19,21, 22, 26, 27, 37, 38] obtained moderate methodological quality. No study presented high methodological quality.

A total of 13 studies opted for the 20-meter Shuttle Run test to measure aerobic fitness.[10,12-15,17-20,25,26,36,37] Maximal and submaximal exertion tests in cycle ergometer,[27,38,39,41] treadmill progressive test,[40,42] 9 minute walk / run test,[16,22,24] 12-minute walk / run[16] and the step-mCAFT test[21] were also used.

The most used outcome indicator was the relative VO_2max (ml.kg^{-1}.min^{-1}).[10,12,13,17,18,20,21,36,37,40,42] The absolute VO_2max (l.kg^{-1}.min-1) was estimated in two studies[41,42] and the VO_2peak (relative and absolute) in

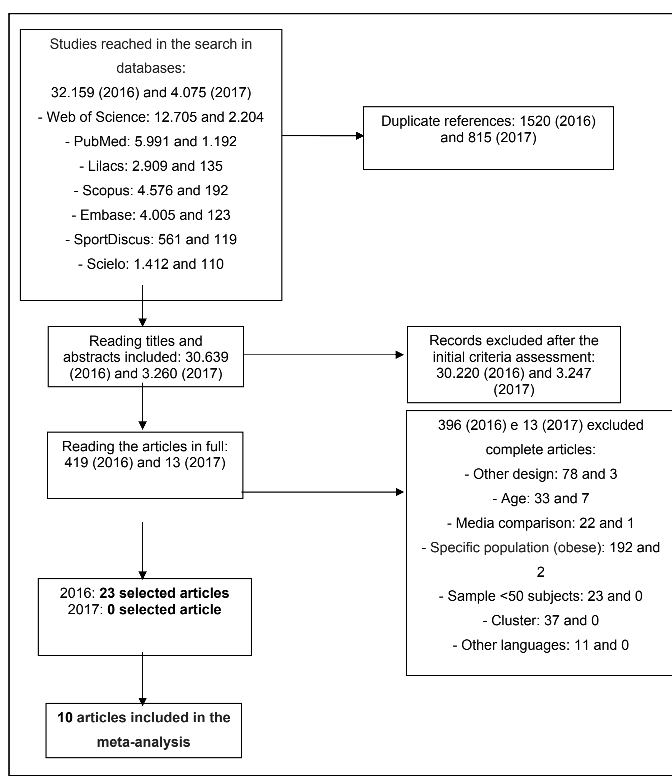

Figure 1. Flowchart of selection of the association studies between aerobic fitness and anthropometric indicators of body adiposity in adolescentes.

one study.[19] The distance in meters was evaluated in three studies.[16,22,24] A total of five studies used the number of laps in a given test[10,14,15,25,26] and three studies used power as indicator.[27,38,39]

A total of 18 studies investigated BMI as one of the anthropometric body adiposity indicators possibly associated with aerobic fitness.[10,12-18,20-22,24-27,36,38,40] Skinfolds were analyzed in 16 studies,[13,15-22,24-27,36,39,41] and three of them[13,15,26] used the sum of the triceps and subscapular skinfolds to analyze body fat percentage by the equation of Slaughter et al.,[44] two[10, 36] used the sum of the triceps and subscapular skinfolds to analyze body fat percentage using the equation of Boileau et al.;[45] one study[24] used the sum of the triceps and subscapular skinfolds to analyze body fat percentage using the equation of Lohman;[46,47] one study[19] used the sum of triceps and medial calf skinfolds to identify body fat percentage by means of the equation of Slaughter et al.;[44] one study[16] evaluated body fat percentage by the sum of triceps, subscapular and medial calf skinfolds using the equation of Slaughter et al.[44] one study[20] used these same skinfolds to include the values in the equation of Eston et al.[48] and one study[42] did not report the skinfolds used.

Another anthropometric indicator used was the sum of the skinfolds evaluated by 10 different studies. The sum of triceps and subscapular skinfold thickness was analyzed by three studies.[10,21,22] Two studies analyzed the sum of triceps, biceps, subscapular and suprailiac skinfolds.[27,39] One study analyzed the sum of triceps and medial calf skinfolds,[25] one study analyzed the sum of the triceps, biceps and medial calf skinfolds,[17] one study analyzed the sum of the triceps, subscapular and medial calf skinfolds,[16] one study analyzed the sum of the triceps, biceps, subscapular, suprailiac, supraspinatus, abdominal, thigh and medial calf skinfolds[41] and one study analyzed the sum of triceps, biceps, subscapular, suprailiac, thigh and medial calf skinfolds.[18]

Waist circumference was investigated by 11 studies.[12-14,17,18,24,26,27,37,39,40] Body mass was used as an anthropometric indicator in six of the 23 studies included in the systematic review.[15,19,25,38,41,42] Only two studies used the waist-to-height ratio.[27, 37]

The studies included in the meta-analysis used one method (20-m Shuttle Run Test) and two different measures (VO_2max and number of laps performed) to evaluate aerobic fitness. We performed pooled analyzes of studies that used the same test and the same measure to avoid possible biases.

Meta-analysis revealed that BMI for boys or girls was negatively and moderately associated with aerobic fitness when assessed by the 20-m Shuttle Run Test and measured by VO_2max[43] Meta-analysis of studies that assessed BMI and included adolescents of both sexes showed no significant association.[43]

For body fat percentage in both sexes and for boys, the meta-analysis showed a negative and moderate association between this outcome and aerobic fitness when assessed by the 20-m Shuttle Run Test and measured by VO_2max[43] while this relationship was weaker when assessed by the 20-m Shuttle Run Test and measured by the number of laps performed. [43] Meta-analysis of studies that included only girls showed no significant association.[43]

The combined correlation between waist circumference and aerobic fitness when assessed by the 20-m Shuttle Run Test and measured by VO_2max was -0.50 (95% CI: -0.65 to -0.31, $p<0.001$) for boys and -0.45 (95% CI: -0.66 to -0.16, $p=0.003$) for girls, characterizing a negative and moderate relationship.[43] Meta-analysis of studies that assessed waist circumference and included adolescents of both sexes showed no significant association. [43]

For body weight in both sexes, the meta-analysis showed no significant association.[43] No study included in this meta-analysis that correlated body weight and aerobic fitness performed stratified analyzes by sex or included only boys or girls in their studies.

Heterogeneity ($I^2 > 50\%$ or chi^2 test < 0.1) was observed in all analyses performed.[43] It is not possible to conduct a sensitivity analysis in majority of the analyses performed due to the small number of studies (n=2). Sensitivity analysis that could be performed showed that the removal of a single study resulted in significant changes in combined correlation coefficients for two outcomes analyzed. [43] When the studies of Awotidebe et al.[13] or Coelho and Silva et al.[15] are removed, statistical significance is lost for the relationship between body fat percentage and aerobic fitness for both sexes when assessed by the 20-m Shuttle Run Test and measured by the number of laps performed. When the studies of Bim & Nardo Jr.[36] or Minasian et al.[20] are removed, statistical significance is reached for the relationship between body fat percentage and aerobic fitness for girls when assessed by the 20-m Shuttle Run Test and measured by VO_2max. For other sensitivity analyses, the removal of a single study did not result in significant differences. [43]

DISCUSSION

The present systematic review identified 23 studies (considering the inclusion and exclusion criteria) that analyzed the association between aerobic fitness and anthropometric body adiposity indicators in adolescents aged 10-19 years. The results of the meta-analysis showed that as the aerobic fitness levels increased (20-meter Shuttle Run test measured by VO_2max), BMI and waist circumference values decreased. The body fat percentage presented a negative association regardless of the type of measurement used in the 20-m Shuttle Run Test (VO_2max or number of laps).

Excess body fat is important inducer of systemic inflammation and this fact contributes to cardiovascular diseases linked to obesity.[11] Increased serum C-reactive protein (CRP) levels have been reported in obese individuals[49] and have been reported as associated with anthropometric indicators such as BMI.[50] One of the most important and strong contributors to increased serum CRP levels is visceral adiposity,[51] since adipokines stimulate the hepatic synthesis of CRP.[11] Studies have shown that CRP is positively associated with trunk adiposity measures such as waist circumference[52] and body fat percentage,[53] which were associated in this study.

As a consequence, CRP levels are closely linked to aerobic fitness levels.[54] A study has shown that the higher the aerobic fitness level, the lower the CRP level. The relationship between aerobic fitness and CRP is explained by the action that physical exercise exerts on adipose tissue, that is, the practice of physical exercise leads to improvement in aerobic fitness and reduction in the inflammatory process caused by body adiposity.[55] This enhancement in aerobic fitness reduces inflammation of visceral adipose tissue because it causes reduction in adipocyte size, reduction in macrophage infiltration, increased peripheral blood flow, increased mitochondrial function, facilitated oxidation of fatty acids, decreased oxidative stress, and improved resistance to cell stress.[11]

Of the different tests to measure aerobic fitness, the 20-meter Shuttle Run test was the field test used by all studies included in the meta-analysis.[10,13-15,17-20,25,36] This test is one of the most suitable to measure aerobic fitness indirectly[11] and allows analyzing performance by different parameters (number of laps, predicted VO_2max, stages) of aerobic fitness. The doubt about which estimate (VO_2max or number of laps) should be used is frequent among researchers[56] and was observed in this review.

The sensitivity analysis altered the statistical significance of the meta-analysis regarding the association between body fat percentage and aerobic fitness assessed by the 20-meter Shuttle Run test by the number of laps in both sexes and VO_2max for females. That is, when the study of Awotidebe et al. [13] or Coelho and Silva et al.[15] is excluded, the significance of aerobic fitness assessed by the 20-meter Shuttle Run test by the number of laps and body fat percentage is lost. In addition, when the study from Bim & Nardo Jr.[36] or Minasian et al.[20] is removed, the significance of aerobic fitness assessed by the 20-meter Shuttle Run test by means of VO_2max is reached. A possible justification is that the four studies[13,15,20,36] also estimated body fat percentage in adolescents (sum of triceps and subscapular skinfolds), different from the other studies included in this meta-analysis that evaluated body fat percentage by the sum of biceps, triceps, subscapular, suprailiac, medial calf and thigh skinfolds[18] and by the sum of triceps and medial calf skinfolds.[25] This shows that a discussion about possible homogeneity for skinfolds to be used in adolescents becomes necessary.

To our knowledge, the present meta-analysis was the first to analyze aerobic fitness and different anthropometric body adiposity indicators in adolescents (10-19 years). A systematic review was conducted with a similar theme, but examined the association between aerobic performance (exclusively through the 20-m Shuttle Run Test) and health indicators in children and adolescents of school age (5-17 years) in North America.[23] The correlation coefficients of studies included in the study by Lang et al.[23] had wide variation (r = -0.70 to r = -0.10), demonstrating that adiposity alone did not explain performance in the 20-m Shuttle Run Test.[23] It is important to emphasize that this study analyzed researches that used a specific type of field test to evaluate aerobic fitness (Shuttle Run 20 meters) and the present study made a systematic search for different methods of assessing aerobic fitness and presented the results separately. In addition, the study by Lang et al. [23] included researches of different designs (longitudinal and cross-sectional) and worked with children and adolescents (5-17 years). This review evaluated only cross-sectional surveys with adolescents aged 10-19 years. All these differences between the two studies hinder the comparison and justify the different results found.

This meta-analysis has some limitations that must be considered. First, few studies have evaluated the same anthropometric or body composition parameters using the same test and the same measurement for aerobic fitness assessment. Therefore, a cautious interpretation of results is necessary since the meta-analysis may have been underestimated or overestimated. Second, studies had a cross-sectional design, which does not allow temporal or causal relationships. Third, the studies included are heterogeneous in terms of age, sample size and cutoff points for assessing aerobic fitness and anthropometric indicators. This heterogeneity, together with potential confounding factors such as maturational stage and level of physical activity of adolescents may have partially affected the results. To compensate for these factors, the random effects analysis model was used. Due to the small number of studies, it was not possible to perform sensitivity tests in all analyses, nor meta-regression to explore the sources of heterogeneity.

Perspective

This meta-analysis presents strengths. To our knowledge, this meta-analysis is the first that gathered all the available evidence that evaluated the association between anthropometric indicators with aerobic fitness only in adolescents. Samples of studies included in the meta-analysis ranged from 78 to 12,946 individuals, while pooled analysis (systematic review) of studies included a total of 17,604 participants. Our meta-analysis therefore increased statistical power and found significant associations not observed in part of included studies. We also separated analyses according to the method and measurement used to evaluate aerobic fitness, and also stratified by sex, which demonstrates more reliable estimates.

CONCLUSION

It could be concluded that this meta-analysis showed that there is a negative association between aerobic fitness (as measured by the 20-meter Shuttle Run test through VO_2max) and body fat percentage, BMI and waist circumference of adolescents and negative association between aerobic fitness assessed by the 20-meter Shuttle Run test by means of the number of laps and body fat percentage. However, caution is required in the interpretation of data due to the heterogeneity of studies analyzed.

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