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Abdominal muscular endurance in Brazilian children and adolescents: systematic review of cross-sectional studies

Resistência muscular abdominal em crianças e adolescentes do Brasil: revisão sistemática dos estudos transversais

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Abstract – The literature has demonstrated the importance of musculoskeletal fitness in the prevention of chronic noncommunicable diseases. Although current recommendations of physical activities include strengthening and muscular endurance aspects, little is known about the muscular endurance levels of children and adolescents in a national scope. The aim of this study was to systematically review the literature to identify the prevalence of Brazilian children and adolescents who meet health criteria for muscular endurance. A hierarchical search was conducted in four databases (MEDLINE; Scopus; SciELO; LILACS) using the following terms: "muscular endurance", "muscle endurance", "physical fitness", "child", "adolescent", "adults" "school" and correspondents in the Portuguese language. Overall, 2,652 articles (2,269 had their title and abstract read) were found and 70 were eligible for reading in full. Seventeen studies were reviewed and evaluated for risk of bias. Among 32,661 children and adolescents, only 40.2% of boys and 31.9% of girls presented abdominal muscular endurance adequate for health, and most studies were conducted in the southern region of Brazil. The variability in procedures for evaluating abdominal muscular endurance and cut-points used for interpretation occurred due to the use of different standardizations (PROESP/BR®, FITNESSGRAM® and AAHPERD®). Less than half of Brazilian adolescents of both sexes have adequate abdominal muscular endurance for health. Studies investigating the causes and consequences of inadequate abdominal muscular endurance may contribute to strategies for disease prevention and health promotion of children and adolescents.

Key words: Adolescent; Child; Physical fitness.

Resumo – *A literatura tem demonstrado a importância da aptidão musculoesquelética na prevenção de doenças crônicas não transmissíveis. Embora as recomendações atuais de atividades físicas incluam aspectos de fortalecimento e a resistência muscular, pouco se conhece sobre os níveis de resistência muscular de crianças e adolescentes numa abrangência nacional. O objetivo deste estudo foi revisar sistematicamente a literatura para identificar a prevalência de crianças e adolescentes brasileiros que atendem aos critérios de saúde para a resistência muscular. Foi conduzida uma busca sistemática em quatro bases de dados (MEDLINE; Scopus; SciELO; LILACS), utilizando os termos "muscular endurance", "muscle endurance", "physical fitness", "child", "adolescent", "adults", "school" e correspondentes no idioma português. Foram encontrados 2.652 artigos (2.269 tiveram seu título e resumo lidos) e 70 foram elegíveis para leitura na íntegra. Dezessete estudos foram revisados e avaliados quanto ao risco de viés. Entre 32.661 crianças e adolescentes, apenas 40,2% dos meninos e 31,9% das meninas apresentaram resistência muscular abdominal adequada para a saúde, sendo que a maior parte dos estudos foi conduzida na região Sul do Brasil. A variabilidade nos procedimentos para avaliação da resistência muscular abdominal e nos pontos de corte utilizados para interpretação ocorreu devido à utilização de diferentes padronizações (PROESP/BR®, FITNESSGRAM® e AAHPERD®). Menos da metade dos adolescentes brasileiros de ambos os sexos tem resistência muscular abdominal adequada para a saúde. Estudos que investiguem as causas e as consequências da resistência muscular abdominal inadequada podem contribuir para estratégias de prevenção de doenças e promoção da saúde de crianças e adolescentes.*

Palavras-chave: *Adolescente; Aptidão física; Criança.*

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INTRODUCTION

Physical fitness has been characterized as the ability to perform daily activities with vigor and resistance to fatigue[1] and has been considered an important health marker, also demonstrated by the strong association with cardiovascular, metabolic and motor competence outcomes in children and adolescents[2-4]. The health-related physical fitness components have been organized into cardiorespiratory, musculoskeletal, motor and body composition [2]. Although cardiorespiratory fitness has a notable importance for general health, the independent contribution of musculoskeletal fitness has been evidenced, basically by the expression of muscular strength and endurance[4]. The latter is defined by resistance to repeated muscle contractions over time or to sustain contraction for an extended period of time[4,5].

Physical activities of muscular strength and endurance have been recommended in addition to aerobic activities for children and adolescents[6]. Conversely, the absence of adequate levels of musculoskeletal fitness has been common in this population and is associated with low back pain[7] and high body adiposity[8]. In this regard, monitoring of muscular endurance is important to verify if levels are adequate or inadequate to health.

Musculoskeletal fitness can be evaluated by laboratory tests that offer advantages such as greater validity and reproducibility, but they are not possible to be used in population studies due to the high cost and operation of instruments, and the long time required in the measurement[5]. On the other hand, field tests appear to be viable alternatives for large-sample studies, especially when performed in school settings[5,9]. Artero et al.[5] found that the most commonly used field tests for assessing musculoskeletal fitness were handgrip and arm support / flexion tests, which showed high and low quality and reproducibility scores, respectively. However, the abdominal muscular endurance test is used in most physical fitness test batteries[9,10], possibly because it represents the strength and endurance of core muscles in dynamic, easy-to-use protocols using low-cost equipment[10]. The variety of tests and protocols used to assess muscular endurance may imply divergences among studies, also assuming the limitation of the interpretation of different cut-points to meet health criteria.

Studies carried out in Brazil have shown heterogeneity in relation to the selection, size and origin of the sample of participants[11,12], in addition to the use of different muscular strength tests and cut-points for the interpretation of health suitability[13-16], which makes it difficult to summarize findings on muscular strength in Brazilian children and adolescents. In addition, there are no estimates of the number of children and adolescents in Brazil who meet the health criteria for this physical fitness component. The compilation of evidences about the Brazilian pediatric population may contribute to the standardization of field tests and to the elaboration of strategies to improve musculoskeletal fitness. Therefore, the aim of the present study was to identify the prevalence of children and adolescents in Brazil who meet the health criteria for muscular endurance.

METHODOLOGICAL PROCEDURES

Registration Protocol

The present review is registered in the International prospective register of systematic reviews (PROSPERO) under identification number CRD 42018079881.

Eligibility Criteria

The following inclusion criteria were applied: studies published as a scientific article, studies measuring muscular strength based on curl-up test (trunk flexion) or push-up test (elbow flexion test) and those presenting the classification of the localized muscle endurance according to some reference physical test battery or cut-point.

Studies published in languages other than Portuguese or English, without cross-sectional design, with sample of children and/or adolescents who were not Brazilian, studies not performed with schoolchildren, studies with athletes, those carried out on a sample with chronic diseases and medical diagnosis of diseases such as muscular dystrophies, cerebral palsy and Down syndrome were excluded. Studies that did not present prevalence and classification of localized muscle endurance according to some reference criteria, studies that focused on other physical fitness components such as aerobic endurance, flexibility and muscle power were also excluded. In addition, literature reviews, case reports, monographs, dissertations/theses were not eligible for this review. No restriction was imposed on the date of publication.

Sources of information

Searches were carried out in four databases (Medical Literature Analysis and Retrieval System Online - MEDLINE, through PubMed; Scopus; Scientific Electronic Library Online - SciELO; Latin American and Caribbean Literature in Health Sciences - LILACS, through Bireme). The search in all databases was finalized in January 2018.

Search strategy

The process of search, selection and exclusion of articles was performed by two independent reviewers, debated at consensus meetings, and in case of disagreement, a third reviewer would resolve the disagreement situation.

The descriptors used in the search were divided into three blocks and dealt with the outcome in the first block (muscular endurance, muscle endurance, physical fitness) of the population in the second block (children and adolescents: "child", "adolescent", "adult") and the place of study in the third block "school". The Boolean operators "OR" (inside the blocks), "AND" (between blocks) and the "AND NOT" operator precede the "adult" descriptor. To achieve the variations of descriptors, the truncation symbol ("") was used.

Searches were carried out with descriptors in English and Portuguese.

Selection of Studies

Initially, selected studies were filtered and duplicates were excluded by the EndNote X7® reference manager software (Philadelphia, USA). Then, titles and abstracts were read and those that did not fit the review objective were excluded. After this step, the remaining articles were read in full and checked according to the eligibility criteria of the review (Figure 1).

All eligible articles had the list of references checked and potential studies were included for reading in full. Subsequently, if these studies met the established selection criteria, they were included in the present review.

Data Collection Process

Data on studies (author/year, study site, sample, age range, aim, muscular endurance test, cut-point for the test and results) were extracted from articles by each reviewer independently and subsequently shared in consensus meeting.

Risk of bias

The risk of bias was assessed based on the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies of the National Heart, Lung, and Blood Institute [17]. It is an instrument for the evaluation of cross-sectional and cohort studies, with 14 questions regarding the internal validity of studies. Through the instrument, it is possible to check selection, information, measurement and/or confusion biases. For each criterion evaluated, scores of 0 "no" and 1 "yes" were assigned, and at the end of the study classification, a total score was assigned to each study based on the number of positive responses to the questionnaire in relation to the total number of questions[18]. Questionnaire questions that could not be answered by the available information and/or that were not applicable to the study and / or aspects that had not been reported were excluded from the calculation to determine the final risk of bias score[18]. Based on the final score, studies were classified as: low (score ≥0.70), moderate (≥0.50); and high (<0.50) risk of bias.

Summarization Measures

The main summarization measure of results was the percentage of children and adolescents who met the criteria recommended for health according to cut-points used.

RESULTS

The initial search resulted in 2,652 articles, of which 383 were duplicate articles and were consequently excluded in the EndNote X7® reference manager (Philadelphia, USA), remaining 2,269 for titles and abstracts. After reading titles and abstracts, 70 studies were identified to read the text in full and to apply the previously established inclusion/exclusion criteria. After the additional step of analyzing the lists of references, 12 other

studies that met the inclusion criteria were found. After the identification, selection and eligibility stages, 17 articles were considered as the result of this review (Figure 1).

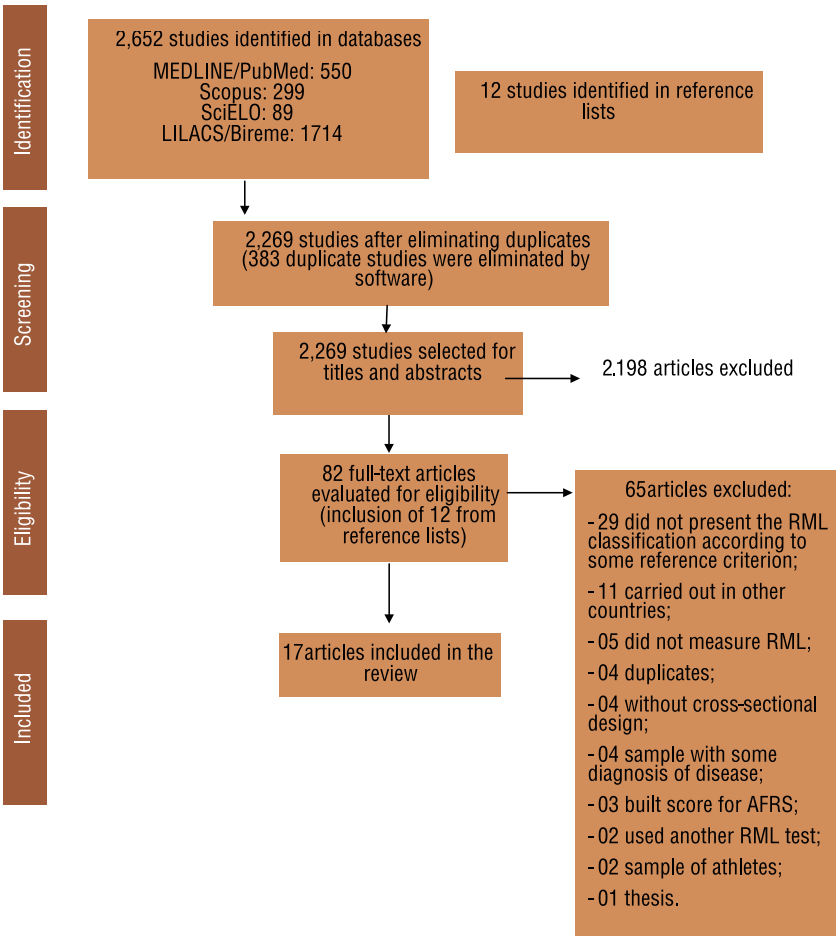

Figure 1. Flowchart of the process of search, selection and exclusion of studies.

Studies were found from 1995 to 2017, and the period of greatest publications was 2005 and 2016, with three publications each year (Figure 2).

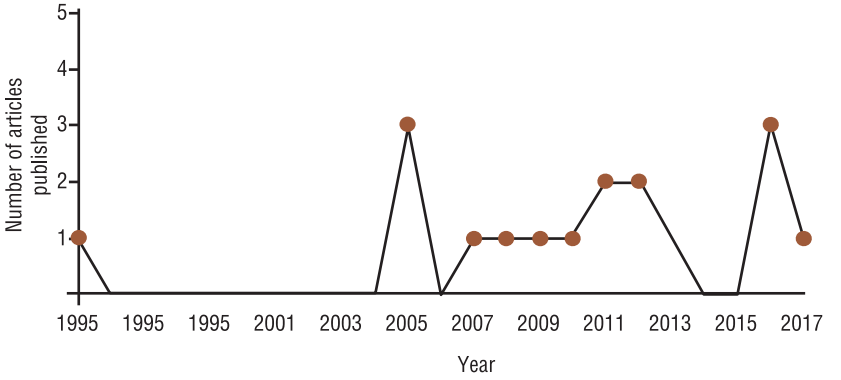

Figure 2. Timeline of publications with a sample of children and adolescents in Brazil that dealt with localized muscle endurance.

The mapping of the Brazilian regions that developed studies on local-

ized muscle endurance shows the predominance of investigations in the southern region of the country (n = 10), followed by the southeastern (n = 3), northeastern (n = 2) and midwestern (n=10) regions, with one study covering all regions. The age of subjects investigated ranged from 6 to 18 years. Most studies investigated both sexes (n = 16), while one investigation addressed only males (Table 1).

In most studies, the test used to measure muscular endurance was the curl-up test (abdominal muscular endurance) (n = 16), only one study used the curl-up test and the arm flexion test in the same sample (Table 1). Of the 17 studies included in this review, seven studies performed the curl-up test following the protocol established by the PROESP/BR battery[15,19-25]. Another seven studies used the protocol established by AAHPERD[11,12,14,16,26-29], two studies used the test as proposed by FITNESSGRAM[13,30-31] and one study[33] used protocol described by Guedes et al.[32]. Of studies that used the PROESP/BR[15,19-25] standardization, six titled the curl-up test of 60s[15,20-23,25] and one study titled it curl-up test[24]. One study that followed the protocol suggested by AAHPERD referred to the test as curl-up of 60s[27], another five studies referred as a modified curl-up test of 60s[11,12,16,28-29] and another study as curl-up test[14]. The tests that followed the FITNESSGRAM battery[30] were denominated as modified curl-up test[13] and curl-up test[31], and the study that followed the protocol of Guedes et al.[32] called it modified curl-up test (Table 1).

With regard to the aims of studies, eleven studies aimed at descriptively evaluating the health-related physical fitness of children and adolescen ts[11,12,14-16,20,21,25,28,31,33] and other five studies[13,22 -24,27] evaluated the association of physical fitness with other variables (socioeconomic and cultural level, place of residence (rural and urban), anthropometric characteristics (body fatness) and professionals involved in physical education classes) (Table 1).

A total of 32,661 subjects aged 6-18 years participated in studies that used the curl-up test (abdominal endurance). Of this amount, 40.2% of boys and 31.9% of girls were classified with abdominal muscle endurance levels adequate for health. Table 2 shows the results of each study, which classified localized muscle endurance as adequate or inadequate for health. In two studies, information was not stratified by sex[23,24]. The cut-points used in studies to classify localized muscle endurance as adequate or inadequate were those from PROESP/BR[19], FITNESSGRAM[30] and AAHPERD[26].

Table 3 shows the risk of bias assessment of each study included in the systematic review. It was observed that of the 17 studies included in the review, 14 presented low risk of bias[11,13-16,20-22,24,25,27,28,31,33] and three presented moderate risk of bias[12,23,19].

DISCUSSION

The main finding of this review was that less than half of children and adolescents in Brazil presented adequate abdominal muscular endurance according to the reference criteria adopted. This low prevalence of Brazilian

Table 1. Characterization of samples from studies included in the systematic review of literature, 2018

Author	Region	City	State	M%	Age (years)	Muscular endurance measurement	Aim
Bergman et al.[20]	Southern	Canoas	RS	M: 50.8%	7 to 17	Curl-up (60s)	To analyze the development of health-related physical fitness of children and adolescents, verifying the differences between sexes and determining the occurrence of children and adolescents who are respectively below, within or above the healthy physical fitness zones.
Burgos et al.[21]	Southern	Santa Cruz do Sul	RS	M: 52.3%	7 to 17	Curl-up (60s)	To evaluate and characterize the profile of health-related physical fitness of children and adolescents of Santa Cruz do Sul-RS
Castro et al.[27]	Northeastern	Aracaju	SE	M: 56.1%	15 to 18	Curl-up (60s)	To verify the association between health-related physical fitness components and academic performance in adolescents
Dórea et al.[28]	Northeastern	Jequié	BA	M: 53.2%	7 to 12	Curl-up mod. (60s)	To analyze health-related physical fitness in schoolchildren from Jequié, BA, Brazil
Glaner et al.[14]	Southern	Porto Alegre	RS	M:100%	10 to 18	Curl-up	To compare health-related physical fitness among male adolescents residing in rural and urban areas and to analyze it in relation to the referenced criteria established by AAHPERD (1988).
Guedes et al.[33]	Southern	Londrina	PR	M: 49%	7 to 17	Curl-up mod.	To identify the proportion of children and adolescents belonging to the school population of the city of Londrina-Paraná who meet criteria related to health, based on information on physical fitness indexes
Guedes et al.[13]	Southeastern	Montes Claros	MG	M:48.8%	6 to 18	Curl-up mod.; push-up	To investigate the association between socio-demographic and behavioral behavior factors and health patterns based on scores of physical fitness components in a sample of Brazilian schoolchildren
Luguetti et al.[15]	Southeastern	São Paulo	SP	M: 50.5%	7 to 16	Curl-up (60s)	To measure physical fitness indicators in children and adolescents according to chronological age and sex and to classify their performance through normative tables of PROESP / BR
Minatto et al.[31]	Southern	São Bonifácio	SC	M:52.3%	10 to 17	Curl-up	To identify the physical fitness and health profile of Brazilian adolescents from a small German colonization city, as well as to describe the prevalence of adolescents with low physical fitness according to sex and age
Pelegrini et al.[12]	All regions	-	-	M: 54.8%	7 to 10	Curl-up mod. (60s)	To analyze the physical fitness of Brazilian schoolchildren, according to an evaluation referenced by health criteria.
Pereira et al.[22]	Southern	Uruguaiana	RS	M: 49.1	10 to 17	Curl-up (60s)	To identify the prevalence and factors associated with low physical fitness in adolescents.
Petroski et al.[16]	Southeastern	Januária	MG	M: 42.4	14 to 17	Curl-up mod. (60s)	Assessing health-related physical fitness in adolescents of a city with medium / low human development index.
Ronque et al.[29]	Southern	Londrina	PR	M: 53.6	7 to 10	Curl-up mod. (60s)	To analyze body adiposity and motor performance in children of high socioeconomic level, according to an evaluation referenced by health criteria.

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Author	Region	City	State	M%	Age (years)	Muscular endurance measurement	Aim
Sehn et al.[23]	Southern	Santa Cruz do Sul	RS	M: 46.1%	7 to 17	Curl-up (60s)	To verify the existence of association between socio-demographic factors and health-related physical fitness levels in schoolchildren.
Serassuelo Junior et al.[11]	Southern	Cambé	PR	M: 45.9%	11 to 12	Curl-up mod. (60s)	To analyze the health-related physical fitness in schoolchildren of low socio-economic level in the city of Cambé / PR
Tornquist et al.[24]	Southern	Santa Cruz do Sul	RS	M: 53.1	9.07 (dp1.54)	Curl-up	To verify possible differences in health-related physical fitness levels among students in the initial grades who participate in Physical Education classes taught by a qualified professional (municipal and private schools) and students in which classes are taught by a single teacher (state schools).
Werk et al.[25]	Midwestern	Campo Grande	MT	M: 43.9%	7 to 10	Curl-up (60s)	To analyze the health-related physical fitness level of children aged 7-10 years and the differences between sexes.

RS: Rio Grande do Sul; SE: Sergipe; BA: Bahia; PR: Paraná; MG: Minas Gerais, SP: São Paulo; SC: santa Catarina; MT: Mato Grosso; M%: percentage of male participants; 60s: 60 seconds; sd: standard deviation.

Table 2. Prevalence of subjects classified as having adequate muscular endurance according to some reference criteria from the curl-up test.

Author	Age range/Sample that performed the muscle endurance test	Percentage of subjects classified as having adequate abdominal muscular endurance	Reference for the classification of curl-up test
Bergman et al.[20]	7-17 years (n=3447 boys; n=3347 girls)	47% of boys (n=1620) and 34% of girls (n=1138)	FITNESSGRAM
Burgos et al.[21]	7-17 years (n=871 boys; n=793 girls)	63.3% of boys (n=543) and 71.2% of girls (n=06)	PROESP/BR
Castro et al.[27]	15-18 years (n=183 boys; n=143 girls)	9.8% of boys (n=18) and 4.2% of girls (n=11)	AAHPERD
Dórea et al.[28]	7-12 years (n=182 boys; n= 160 girls)	11.0% of boys (n=20) and 7.0% of girls (n=04)	AAHPERD
Glaner et al.[14]	10.50 to 17.49 years (n=721 boys)	24.8% of boys (n=179)	AAHPERD
Guedes et al.[33]	7-17 years (n=2103 boys; n=2189 girls)	39.5% of boys (n=831) and 31.0% of girls (n=679)	AAHPERD
Guedes et al.[13]	6-18 years (n=1,392 boys; n=1,457 girls)	Abdominal: 33.2% of boys (n=462) and 21.8% of girls (n=318); Arm flexion: 48.7% of boys (n=678); 30.7% of girls (n=447).	FITNESSGRAM
Luguetti et al.[15]	7-16 years (n=1,590 boys; n=1555 girls)	64% of boys (n=1,018) and 57% of girls (n=886)	PROESP/BR
Minatto et al.[31]	10-17 years (n=145 boys; n=132 girls)	62.1% of boys (n=90) and 54.5% of girls (n=72)	FITNESSGRAM
Pelegrini et al.[12]	7-10 years (n=4,114 boys; n=3,393 girls)	30% of boys (n=1,243); 30% of girls (n=1,018)	AAHPERD
Pereira et al.[22]	10-17 years (n=714 boys; n=741 girls)	71.7% of boys (n=523); 73.5% of girls (n=563)	PROESP/BR
Petroski et al.[16]	14-17 years (n=266 boys; n=361 girls)	2.3% of boys (n=06); 1.0% of girls (n=03)	AAHPERD
Ronque et al.[29]	7-10 years (n=274 boys and n=237 girls)	67% of boys (n= 184) and 64% of girls (n= 152)	AAHPERD
Sehn et al.[23]	7-17 years (n=461 boys; n=539 girls).	51.5% (n=567) (did not present stratification by sex)	PROESP/BR

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Author	Age range/Sample that performed the muscle endurance test	Percentage of subjects classified as having adequate abdominal muscular endurance	Reference for the classification of curl-up test
Serassuelo Junior et al.[11]	11-12 years (n=108 boys; n=127 girls)	10.2% of boys (n=11) and 8.0% of girls (n=10)	AAHPERD
Tornquist et al.[24]	7-17 years (n=333 boys; n=293 girls)	43.0% (n=269) (did not present stratification by sex)	PROESP/BR
Werk et al.[25]	7-10 years (n=129 boys; n=161 girls)	72% of boys (n=93); 78% of girls (n=126)	PROESP/BR
Total*†§	6-18 years (n=32661) (n=17,033 boys; n=15,628 girls)	40.2% of boys (n=6,841) and 31.9% of girls (n=4,986)	

* for the calculation of the percentage of subjects with adequate muscular endurance, the following equation was considered: (number of subjects classified as having adequate muscular endurance/total number of subjects in the studies considered) * 100; †: the calculation only considered the information of the abdominal muscular endurance test of the studies found; §: the calculation for sex-stratified information only considered studies that presented information stratified by sex, thus, two studies were not included for this calculation (e.g., Sehn et al., and Tornquist et al.).

Table 3. Risk of bias assessment of studies included in the systematic literature review, 2018.

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Final score*	Classification
Bergman et al.[20]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias
Burgos et al.[21]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias
Castro et al.[27]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0,70	Low risk of bias
Dórea et al.[28]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0,70	Low risk of bias
Glaner et al.[14]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0,70	Low risk of bias
Guedes et al.[33]	1	1	ND	1	1	0	NA	NA	1	NA	1	0	NA	1	0,77	Low risk of bias
Guedes et al.[13]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	1	0,80	Low risk of bias
Luguetti et al.[15]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias
Minatto et al.[31]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias
Pelegrini et al.[12]	1	1	ND	ND	0	0	NA	NA	1	NA	1	0	NA	0	0,50	Moderate risk of bias
Pereira et al.[22]	1	1	1	ND	1	0	NA	NA	1	NA	1	0	NA	1	0,77	Low risk of bias
Petroski et al.[16]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0,70	Low risk of bias
Ronque et al.[29]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0,50	Moderate risk of bias
Sehn et al.[23]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0,50	Moderate risk of bias
Serassuelo Junior et al.[11]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias
Tornquist et al.[24]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0,70	Low risk of bias
Werk et al.[25]	1	1	ND	1	0	0	NA	NA	1	NA	1	0	NA	0	0,55	Low risk of bias

Q1. Has the question of the research or objective in this article been clearly indicated? Q2. Has the study population been clearly specified and defined? Q3. The participation rate of eligible persons was at least 50%?; Q4. Have all subjects been selected or recruited in the same or similar populations (including the same time period)? Were the inclusion and exclusion criteria to be included in the study pre-specified and uniformly applied to all participants?; Q5. Were provided justification of sample size, power description or estimates of variation and effect? Q6. For the analyses in this article, were the exposure (s) of interest measured before the outcome (s) to be measured?; Q7. Was the deadline sufficient to reasonably expect an association between exposure and outcome if existed? Q8. For exposures that may vary in quantity or level, has the study examined different exposure levels as related to outcome (e.g., exposure categories or exposure measured as a continuous variable)? Q9. Have exposure measures (independent variables) been clearly defined, validated, trusted and consistently implemented to all study participants?; Q10. Has the exposure (s) been assessed more than once over time?; Q11. Have outcome measures (dependent variables) been clearly defined, validated, trusted and consistently implemented to all study participants?; Q12. Were the outcome evaluators blind to participants' exposure status? Q13. The loss of follow-up after the baseline was 20% or less?; Q14. Were the main confounding variables measured and statistically adjusted for their impact on the relationship between exposure (s) and outcome (s)?; ND. Cannot be determined; NR. Not reported; NA. Not applicable; 0. No; 1. Yes; ≥ 0.70: low risk of bias; ≥ 0.50: moderate risk of bias; <0.50 high risk of bias; * to determine the total score, we considered the following equation: (total of positive answers / total of questions considered for that study).

youth with adequate levels of abdominal muscular endurance differs from that found in other countries. Santos et al.[34] evaluated a sample of 22,048 Portuguese children and adolescents and found that 81.3% of girls and 83.8% of boys met the health criterion for abdominal muscular endurance. Another

study conducted with 192,848 children and adolescents from 725 schools located in urban and rural areas of the United States found that 76.4% of girls and 78.3% of boys evaluated also met the health criteria for this variable[35].

Brazil is a middle-income country with large social discrepancies and quite heterogeneous in terms of *per capita* income distribution[36]. The literature points out that socioeconomic factor can influence the physical fitness of children and adolescents[16], since families with higher schooling and economic levels have better understanding of the benefits of physical activity, and can provide the participation of children in activities and sports that require specific environments such as clubs and/or training schools[37]. In this sense, one of the differences between results presented in this review on the percentage of young people with adequate levels of abdominal muscular endurance and the results presented in Portugal[34] and the United States[35] may be the socioeconomic differences between these countries.

Four protocols were found in this review that aimed to evaluate the abdominal muscular endurance component of physical fitness[19,26,30,32]. The curl-up test recommended by PROESP/BR[19] and AAHPERD[26], and by the protocol proposed by Guedes et al.[32] used the measurement of maximum repetitions during one minute, having as difference between them the positioning of the upper limbs during the test: (1) crossed on the trunk[19,32]; (2) positioned behind the head[26]. On the other hand, the test proposed by the FITNESSGRAM[30] differed from the other tests by: (1) measuring unlimited repetitions (performed at a rate of 20 repetitions per minute until exhaustion) and/or until reaching maximum of 75 repetitions; (2) positioning of the upper limbs (extended along the body) and lower limbs (140º of knee flexion, while in the other tests, knee flexion was 90º) and (3) the amplitude of the trunk flexion required to perform of the curl-up test (until fingers reached the other end of a 75 cm wide band, whereas in the other tests, trunk flexion should be performed until forearms[19,32] and/or elbows[26] touched the thighs). In this context, some authors[30] reported that the curl-up test with the upper limbs positioned next to the body generates less compression in the lumbar region. In addition, other authors[38] reported that sixty seconds would not be the best procedure to measure abdominal muscular endurance, but rather the muscle power, suggesting that longer time, such as that provided by curl-up tests with unlimited duration, would be more appropriate for the evaluation of this variable[38].

Regarding the cut-points used to assess the health-related physical fitness of children and adolescents in relation to the abdominal muscular endurance component, two batteries (PROESP/BR[19] and AAHPERD[26]) used cut-points based on normative values, that is, curves in percentiles of the population, and one (FITNESSGRAM[30]) used reference values that indicate the future risk of children and adolescents to develop cardiovascular diseases. Gulias-Gonzales et al.[39] developed percentile values of Spanish children aged 6-12 years and reported that it is more interesting to establish categories associated with the risk of developing cardiovascular diseases as proposed by FITNESSGRAM[30] than percentile curves that often fail

to report the real risk of the low physical fitness found.

Regarding the aim of studies, no study included in this review had as main aim to measure the abdominal muscular endurance component in children and adolescents. In most studies, this component was evaluated only for comparison with other variables that could influence health-related physical fitness and/or in conjunction with the other components that compose the physical fitness construct. The lack of specific studies focusing on the muscular endurance component is an issue that deserves to be highlighted. Although it is important to investigate the general physical fitness of children and adolescents, the information of the individual components is also relevant, as it will allow specific improvement actions.

In Brazil, *stricto sensu* Graduate programs in Physical Education that constitute Area 21 of the Coordination of Improvement of Higher Education Personnel (CAPES) present high concentration in the southern and southeastern regions of the country[40]. This condition, coupled with the fact that large part of the scientific studies carried out in Brazil are linked to higher education institutions that have graduate programs, may justify the finding of the present review that most articles included were carried out in the southern and southeastern regions of Brazil.

With respect to the risk of bias, 14 of the 17 articles included in this review were classified as having low risk of bias[11,13-16,20-22,24,25,27,28,31,33] and other three studies[12,23,29] as moderate risk of bias. None of the studies included met questions 6 and 12 of the methodological quality instrument, which referred to the evaluation of the exposure before the measurement of the result and if the evaluator of results was blind. One reason that may have contributed to the non-meeting of question six of the instrument was the cross-sectional design of studies, which does not allow the evaluation of variables at different moments. Regarding question 12, which deals with the blindness of evaluators, none of the studies included in this review reported this condition in methodological aspects, which suggests that more attention should be paid to this aspect in the writing of manuscripts.

Regarding question 14 of the risk of bias instrument, which assesses whether variables with confusion potential were measured or adjusted, only three studies have met this condition[13,22,33]. This finding may indicate that the authors did not consider possible variables that could confuse the association with the outcome of interest. Failure to meet this methodological item may lead to a false association between independent variables and muscular endurance, thus compromising the veracity of the results obtained.

The present study presents some limitations such as the investigation of only cross-sectional studies, the number of databases investigated (only four), the inclusion of only articles in English and Portuguese, the selection of only studies that evaluated muscular endurance by curl-up test and/or push-up test, which resulted in studies predominantly with the curl-up test. The following are strengths of the present review: (1) the provision of data regarding the physical fitness level in relation to the abdominal muscular endurance component of Brazilian children and adolescents. This

information may support future studies aimed at evaluating this physical fitness component in children and adolescents, as well as stimulating the development of strategies aimed at increasing this physical fitness component in the scientific and school environments and public health policies; (2) to highlight the state of the art in relation to cut-points used to evaluate abdominal muscular endurance in Brazil, suggesting that cut-points based on health criteria should be used and created to evaluate this health-related physical fitness component.

CONCLUSION

With data obtained from this systematic review, it could be concluded that less than half of children and adolescents in Brazil meet health criteria for abdominal muscular endurance. Some suggestions for this area and for future studies are: 1) the proposal of more studies that aim to evaluate abdominal muscular endurance as primary outcome; 2) the investigation of factors related to abdominal muscular endurance considering the adjustment of statistical analyses and potential confusion variables; 3) the use and proposal of cut-points for abdominal muscular endurance based on health criteria is urgent for a more accurate classification of the prevalence of Brazilian children and young who meet health criteria.

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Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

DASS is the principal investigator and conceived the idea of the manuscript. GBQD and LRAL draft of the first version of the paper and made the extractions of the data. All authors read and approved the final manuscript.

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