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Muscle endurance of Brazilian children and adolescents: a systematic review of the literature

Resistência muscular de crianças e adolescentes brasileiros: uma revisão sistemática da literatura

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Abstract – Muscle endurance (ME) is considered to be an important indicator of health-related fitness in childhood and adolescence. The present study aimed to identify and summarize the evidence on the prevalence of adequate ME in Brazilian children and adolescents (6 to 18 years old). A systematic search of studies published from 2009 to 2019 was performed in six databases (LILACS; SciELO; SportDiscus; Medline/PubMed; Web of Science; Scopus). We found 16,168 articles, 20 of which met the eligibility criteria and were included in this review for data extraction and assessment of their risk of bias. Among the 23,805 children and adolescents participating in the studies, 43.5% of the total (43.7% of boys and 41.0% of girls) had adequate abdominal ME. Different test batteries were reported, the main ones being PROESP/BR®, FITNESSGRAM®, and AAHPERD®. Most studies were carried out in the South (50.0%) and Southeast (20.0%) regions of Brazil. Regarding the distribution of studies by geographic region and human development index (HDI), there were no disparities in ME between studies conducted in regions with a lower HDI (43.1% for the Northeast and 32.2% for the North) and those with a higher HDI (46.8% for the South and 33.1% for the Southeast). We conclude that less than half of Brazilian children and adolescents of both genders have an abdominal ME adequate for health, with slightly lower values among females.

Key words: Adolescent; Child; Physical fitness.

Resumo – *A resistência muscular (RM) tem sido considerada um importante indicador da aptidão relacionada a saúde na infância e adolescência. O estudo teve como objetivo identificar e sumarizar as evidências sobre a prevalência de RM adequada em crianças e adolescentes (6 a 18 anos) no Brasil. Foi realizada uma busca sistemática em seis bases de dados (LILACS; Scielo; SportDiscus; Medline/Pubmed; Web of Science; Scopus), de estudos publicados no período de 2009 a 2019. Foram encontrados 16.168 artigos, sendo que 20 estudos preencheram os critérios de elegibilidade e foram incluídos na presente revisão para extração dos dados e avaliação quanto o seu risco de viés. Entre as 23.805 crianças e adolescentes participantes nos estudos, 43,5% do total (43,7% dos meninos e 41,0% das meninas) apresentaram RM abdominal adequada. Diferentes baterias de testes foram identificadas, sendo as principais PROESP/BR®, FITNESSGRAM® e AAHPERD®. A maioria dos estudos foram realizados de na região Sul (50,0%) e Sudeste (20,0%) do Brasil. Em relação as distribuições dos estudos pelas regiões geográficas e índices de desenvolvimento humano (IDH), não houveram disparidades na RM entre os estudos nas regiões com menores IDH (Nordeste 43,1% e Norte 32,2%) e as de maiores IDH (Sul 46,8% e Sudeste 33,1%). Conclui-se que menos da metade das crianças e adolescentes brasileiras de ambos os sexos possuem uma RM abdominal adequada para a saúde, com valores ligeiramente inferiores no sexo feminino.*

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

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INTRODUCTION

The interest in the study of physical fitness components related to the health of children and adolescents has been increasing over the last decades[1,2] due to the association of aerobic and muscular fitness (muscle strength and endurance) with health outcomes and cardiometabolic factors such as adiposity[3], and insulin resistance[4], motor skills[5], psychological outcomes, and academic performance[6,7].

Muscle endurance is defined as the ability to perform repeated contractions of one or more muscle groups under submaximal load, and has been considered an important indicator of health-related fitness since early childhood[8,9]. Studies have observed that a low prevalence of muscle endurance was associated with negative health outcomes even at a young age[2-7], with effects continuing into adulthood[2]. On the other hand, stronger children and adolescents with more muscle endurance can perform body movements more efficiently and effectively, a fact that may reduce susceptibility to future injuries, including in sports practices[10].

International guidelines, such as the Physical Activity Guidelines Advisory Committee, the World Health Organization and the Physical Activity Guide for the Brazilian Population, emphasize the participation of children and adolescents in physical activities that prioritize strengthening "muscle and bone" on at least three days a week[11-13]. However, a decline in muscle fitness levels has been observed in this population in various parts of the world[14-18]. In Brazil there is little information about the current scenario of prevalence of adequate muscle resistance in children and adolescents[1]. In 2018, the "Report Card Brazil: Health Indicators for Children and Adolescents" project, based on a systematic review of studies involving Brazilian children and adolescents, identified 17 studies showing that 40.2% of boys and 31.9% of girls had adequate abdominal muscle endurance, with most of these studies being concentrated in the southern region of Brazil[1]. Thus, there is a need to update the current scenario regarding muscle endurance in the country by expanding the number of bibliographic databases consulted and examining in depth the risk of bias assessment in the included studies.

Thus, the aim of this study was to identify and summarize the evidence on the prevalence of adequate muscle endurance among Brazilian children and adolescents (6 to 18 years old) in order to update the evidence previously published by the Report Card Brazil project.

METHODS

This systematic review is part of the Global Matrix 4.0 initiative of the Active Healthy Kids Global Alliance (https://www.activehealthykids.org/) based on the "Report Card Brazil: Health Indicators for Children and Adolescents (3rd edition)" project, which updates a previous systematic review[1] by expanding the number of bibliographic databases, the search strategy, and the temporal window of published articles. The systematic reviews of the health indicators covered by the "Report Card Brazil" protocol were registered in the OSF platform[19], which provides details about the project.

Eligibility criteria

The inclusion criteria were original studies involving Brazilian children and adolescents (6 to 19 years old) that measured muscle endurance in the trunk

region (abdominal) by flexion tests, as long as they reported the interpretation of adequacy of this physical fitness component and the prevalence of participants that met the muscle endurance criteria. Studies of any design (observational or intervention) published in Portuguese, English, or Spanish from January 2009 to December 2019 were considered when they reported baseline data.

Studies were excluded if: 1) issue was outside the scope of this review; 2) participants were younger (< 6 years) or older (> 19 years); 3) they involved participants of nationalities other than Brazilian; 4) children and adolescents had chronic conditions (HIV infection, congenital heart disease, cancer or chromosomal abnormalities), or were athletes. The Endnote X6® software (Philadelphia, USA) and the Rayyan® Platform (QCRI, QATAR) were used to exclude duplicate studies in different bibliographic databases. Studies such as narrative and systematic reviews, case reports, monographs, dissertations, and theses were also excluded.

Information sources

Six bibliographic databases were consulted: Latin American and Caribbean Literature in Health Sciences (LILACS) through the Bireme platform, Scientific Electronic Library Online (SciELO), SCOPUS, and Medical Literature Analysis and Retrieval System Online (MEDLINE) through PubMed and the Web of Science[19]. Additionally, the SportDiscus database was included among those consulted, assuming coverage of the topic related to physical fitness.

Search strategy

Procedures such as search, selection, inclusion and exclusion of original studies were carried out in pairs by two independent researchers (ECM and GM). All conflicts and disagreements were discussed in a consensus meeting and a third reviewer resolved them with a casting vote (LRAL). The search in the bibliographic databases used descriptors related to the outcome and the population of interest in separate blocks, presented in supplementary file Table 1. Boolean operators "AND" for addition and "OR" for substitution were used. The "NOT" operator was used to exclude studies involving adults and older adults in the Web of Science, Scopus and MEDLINE/PubMed databases. All searches were performed on October 28, 2020 using descriptors in Portuguese and English. Details of the search strategy for each database can be found in the supplementary file Table 2.

Study selection

The studies found in the aforementioned databases were downloaded and analyzed initially using EndNote X6® and then the Rayyan® platform to exclude duplicates. Titles and abstracts were read independently by two researchers to screen studies based on the eligibility criteria using the Rayyan® platform. The full text of the remaining studies was read considering the eligibility criteria (Figure 1). Eligible studies had their reference list checked to find potential studies that had not been identified by the initial search strategy. If these studies met the eligibility criteria, they were included in this review.

Data collection process

Information about authorship, year of publication, study site, sample size, and percentage of participants by sex and age group was extracted from eligible studies (Table 1). In addition, information was extracted regarding the muscle endurance tests used, cutoff points, and the total prevalence of participants that met the muscle endurance criteria, stratified by sex and their classifications, if available (Table 2). All data extraction was performed in pairs by independent researchers (ECM and GM) and later validated by another independent researcher (LRAL).

Risk of bias assessment

The risk of bias was analyzed using the National Heart, Lung, and Blood Institute Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies[19]. This instrument contains 14 questions regarding the internal validity of the study, 10 of which refer to cross-sectional observational studies. The analysis process was conducted by one researcher (ECM) and validated by another independent researcher (MCPS), with conflicts being resolved by a third researcher (LRAL). A score of 0 (no) and 1 (yes) was assigned to each item evaluated and the arithmetic mean of the valid questions was obtained in order to calculate the final score of the instrument, excluding the questions that could not be answered by the information available in the study and/or not applicable to it. The final score was classified as low (score ≥ 0.70), moderate (≥ 0.50-0.69), and high (< 0.50) risk of bias.

Summary of results

When summarizing the results, the prevalence of children and adolescents who met the recommended health criteria regarding muscle endurance was primarily used, according to the cutoff points and to the classifications defined in the eligible studies themselves.

RESULTS

Based on the search strategy, 16,168 studies were identified in the databases. From these, 5,223 duplicate studies were automatically removed using Endnote® and another 3,043 duplicate studies were subsequently removed using Rayyan®. The remaining 7,902 studies were checked for eligibility criteria and 7,237 were excluded based on reading the title and 535 based on reading the abstract. Furthermore, the full text of 110 studies was read, resulting in 20 studies included in the present review. Figure 1 summarizes the analysis steps and shows the reasons for exclusion.

The characteristics of the 20 studies included in the review[20-39] are shown in Table 1. Ten studies (50.0%) were carried out in the South region[21,22,24,27,28,31,32,34,36,39], four in the state of Santa Catarina[22,27,28,31], and six in Rio Grande do Sul[21,24,32,34,36,39]. Four studies were carried out (20.0%)[20,25,26,35] in the Southeast region, two in the state of São Paulo[20,26], and two in Minas Gerais[25,35]. Three studies (15.0%) were conducted in the Northeast region[23,29,30] (Sergipe[23], Pernambuco[29] and Ceará[30]), two studies (10.0%) in the North region[33,37] (Amazonas[33] and Pará[37]), and only

one (5.0%) in the Midwest region (Mato Grosso[38]). Most studies investigated both genders[20-33,35,37-39] (n = 19) and comprised the age group from 6 to 18 years. All studies[20-39] had a cross-sectional design and, together, included a total of 23,805 Brazilian children and adolescents (Table 1).

Two different tests were used to assess abdominal muscle endurance in Brazilian children and adolescents. Traditional curl-up (n = 2)[25,27] and maximum curl-ups in 60 seconds (n = 18)[20-24,26,28-39] were used. There are different cutoff points in the literature for the assessment of muscle endurance based on curl-ups. The following physical fitness batteries were used: PROESP-BR (n = 14)[20-22,24,26,28-30,32-34,36,38,39], AAHRPED (n = 4)[23,31,35,37], and FITNESSGRAM (n = 2)[25,27]. Two studies reported data on the overall prevalence of adequate muscle endurance, but no data stratified by sex[34,36].

The overall prevalence of children and adolescents with adequate abdominal muscle endurance was estimated at 43.5% (with a wide range from 1.4%[35] to 75.5%[38]) in terms of health criteria defined by the physical fitness batteries themselves. The overall prevalence of muscle endurance adequate for health was 43.7% (range: 2.2%[35] to 91.3%[33]) for males and 41.0% (range: 0.0%[33] to 80.6%[30]) for females (Table 2).

Children and adolescents in the included studies lived in different Brazilian regions with a low[23,29,30,33,37] or high[20-22,24-28,31,32,34-36,39] human development index (HDI). In the North[33,37] there was an overall estimated prevalence of 32.2% (range: 1.5%[37] to 63%[33]), with an estimated prevalence of 46.8% (range: 2.3%[37] to 91.3%[33]) in males and of 0.4% in females (range: 0%35 to 0.8%[37]). In the Northeast region[23,29,30] there was an overall prevalence of 43.1% (range: 3.7%[23] to 67%[30]), with an estimated prevalence of 46.4% (range: 2.8%[23] to 75.1%[29]) in males and of 42.6% (range: 4.4%[23] to 80.6%[30]) in females. In the Southeast region[20,25,26,35] the overall estimated prevalence was 46.8% (range: 1.4%[35] to 58.7%[26]), with an estimated prevalence of 37.1% (range: 2.2%$_{36}$ to 64%$_{28}$) in males and of 29.1% (range: 0.8%[35] to 53.2%[26]) in females. In the South region[21,22,24,27,28,31,32,34,36,39] the overall prevalence was 46.8% (range: 16.9%[39] to 74.6%[32]), with an estimated prevalence of 41.7% (range: 7.4%[39] to 73.2%[32]) in males and of 52.1% (range: 26.2%[31] to 76%[32]) in females.

The prevalence of adequate abdominal muscle endurance differed according to the battery applied (i.e., PROESP-BR, AAHRPED, FITNESSGRAM). Studies that used the PROESP-BR battery[20-22,24,26,28-30,32-34,36,39] reported an overall prevalence of 53.4% (range: 16.9%[39] to 75.5%[38]), with a prevalence of 55% (range: 7.4%[39] to 91.3%[33]) in males and of 52.6% (range: 0%35 to 80.6%[30]) in females. However, studies that used the AAHRPED battery25[31,35,37], found an overall prevalence of 8% (range: 1.4%36 to 25.4%[31]), with a prevalence of 8% (range: 2.2%[35] to 24.7%[31]) in males and of 8% (range: 0.8%[33,37] to 26.2%[31]) in females. Lastly, studies that used FITNESSGRAM[25,27] reported an overall prevalence of 45.2% (range: 27.4%[25] to 63%[27]), with a prevalence of 47.6% (range: 33.2%[25] to 62.1%29) in males and of 38.1% (range: 21.8%[25] to 54.5%[27]) in females.

The studies showed a moderate (n = 13; 65%)[20-22,26-29,31,33,34,37-39] and low risk of bias (n = 7; 35%)[23-25,30,32,35,36]. Details of the studies regarding the risk of bias are presented in Table 3.

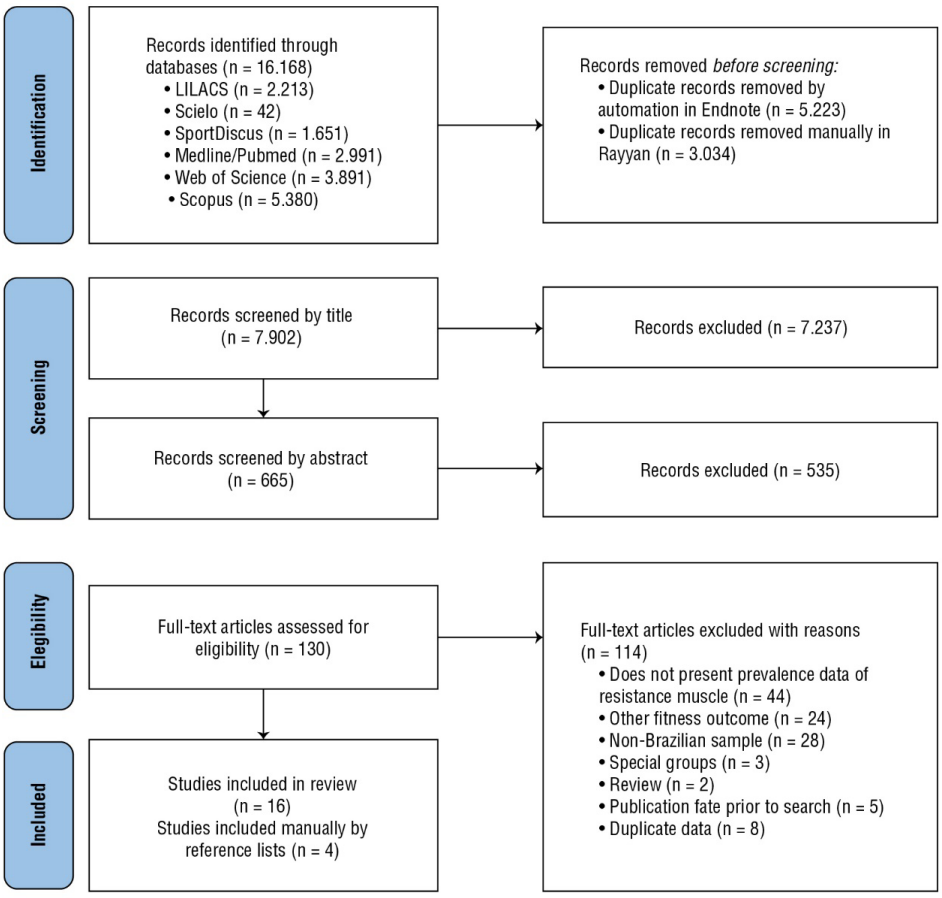

Figure 1. Flowchart of identification, selection, inclusion and exclusion of studies.

Table 1. Characteristics of the included studies (n=20) about muscular endurance with Brazilian children and adolescents, Brazil, 2020.

Author's, year	City – State (year of assessment)	n	% (female)	Age (years)
Andreasi et al.[20], 2010	Botucatu – SP (2007)	988	47.1	7 to 15 y
Burgos et al.[21], 2012	Santa Cruz do Sul – RS (2007)	1664	47.7	7 to 17 y
Capistrano et al.[22], 2016	Florianópolis – SC (2015)	98	50.0	7 to 10
Castro and Oliveira[23], 2016	Aracaju – SE (2015)	326	43.9	15 to 18
Saldanha et al.[24], 2019	Santa Cruz do Sul – RS (NR)	1251	54.7	7 to 17
Guedes et al.[25], 2012	Montes Claros – MG (2007)	2849	51.1	6 to 18
Luguetti et al.[26], 2010	São Paulo – SP (2003).	3145	49.4	7 to 16
Minatto et al.[27], 2016	São Bonifácio – SC (2010)	277	47.6	10 to 17
Montoro et al.[28], 2016	Florianópolis – SC (NR)	93	49.5	7 to 10
Nascimento et al.[29], 2019	Petrolina – PE (NR)	723	51.0	8 to 12
Nogueira and Pereira[30], 2014	Fortaleza – CE (NR)	344	31.4	11 to 16
Pelegrini et al.[31], 2011	Florianópolis – SC (2004-2005)	7507	45.2	7 to 10
Pereira et al.[32], 2016	Uruguaiana – RS (2011)	1455	50.9	10 to 17
Reis et al.[33], 2018	Manaus – AM (NR)	100	31.0	11 to 14
Sehn et al.[34], 2017	Santa Cruz do Sul – RS	1000	53.9	7 to 17
Silva et al.[35], 2013	Januária – MG (2009)	627	57.6	14 to 17
Tornquist et al.[36], 2013	Santa Cruz do Sul – RS (2007-2009)	626	46.8	7 to 17
Valente et al.[37], 2016	Tucuruí – PA (NR)	377	44.3	14 to 17
Werk et al.[38], 2009	Campo Grande – MT (2007)	290	56.1	7 to 10
Zimmermann and Matheus[39], 2017	Santa Maria – RS (NR)	65	43.1	7 to 17

Note. NR: not reported; n: sample size.

Table 2. Prevalence of adequate abdominal muscle endurance in Brazilian children and adolescents, Brazil, 2020.

Author's	Assessment	Physical Fitness Battery	% who met the muscle endurance criteria		
			Total (n)	Male (n)	Female (n)
Andreasi et al.[20]	Maximum curl-ups in 60 s	PROESP-BR	45.0% (445)	49.0% (256)	40.5% (189)
Burgos et al.[21]	Maximum curl-ups in 60 s	PROESP-BR	56.8% (945)	62.3% (543)	71.2% (402)
Capistrano et al.[22]	Maximum curl-ups in 60 s	PROESP-BR	45.9% (40)	30.6% (15)	51.0% (25)
Castro and Oliveira[23]	Maximum curl-ups in 60 s	AAHPERD	3.7% (12)	2.8% (4)	4.4% (8)
Saldanha et al.[24]	Maximum curl-ups in 60 s	PROESP-BR	51.8% (648)	41.7% (236)	60.1% (412)
Guedes et al.[25]	Traditional curl-up	FITNESSGRAM	27.4% (780)	33.2% (462)	21.8% (318)
Luguetti et al.[26]	Maximum curl-ups in 60 s	PROESP-BR	58.7% (1846)	64.0% (1018)	53.2% (828)
Minatto et al.[27]	Traditional curl-up	FITNESSGRAM	63.0% (175)	62.1% (90)	54.5% (72)
Montoro et al.[28]	Maximum curl-ups in 60 s	PROESP-BR	38.7% (36)	31.9% (15)	45.6% (21)
Nascimento et al.[29]	Maximum curl-ups in 60 s	PROESP-BR	58.6% (424)	75.1% (266)	42.8% (158)
Nogueira and Pereira[30]	Maximum curl-ups in 60 s	PROESP-BR	67.0% (232)	61.4% (145)	80.6% (87)
Pelegrini et al.[31]	Maximum curl-ups in 60 s	AAPHERD	25.4% (1905)	24.7% (1017)	26.2% (888)
Pereira et al.[32]	Maximum curl-ups in 60 s	PROESP-BR	74.6% (1086)	73.2% (523)	76.0% (563)
Reis et al.[33]	Maximum curl-ups in 60 s	PROESP-BR	63.0% (63)	91.3% (63)	0.0% (0)
Sehn et al.[34]	Maximum curl-ups in 60 s	PROESP-BR	51.7% (517)	NR	NR
Silva et al.[35]	Maximum curl-ups in 60 s	AAHPERD	1.4% (9)	2.2% (6)	0.8% (3)
Tornquist et al.[36]	Traditional curl-up	PROESP-BR	43.0% (269)	NR	NR
Valente et al.[37]	Maximum curl-ups in 60 s	AAHPERD	1.5% (6)	2.3% (5)	0.8% (1)
Werk et al.[38]	Maximum curl-ups in 60 s	PROESP-BR	75.5% (219)	72.0% (93)	78.0% (126)
Zimmermann and Matheus[39]	Maximum curl-ups in 60 s	PROESP-BR	16.9% (11)	7.4% (2)	32.1% (9)

Note. NR: not reported; n: sample size; PROESP-BR: Projeto Esporte Brasil; AAPHERD: American Alliance for Health, Physical Education, Recreation and Dance.

Table 3. Risk of bias assessment in the studies included on the systematic review on muscle endurance in Brazilian children and adolescents, Brazil, 2020.

Author's	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Final Score*	Classification
Andreasi et al.[20]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	1	0.60	Moderate risk of bias
Burgos et al.[21]	1	1	CD	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Capistrano et al.[22]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Castro and Oliveira[23]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0.70	Low risk of bias
Saldanha et al.[24]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	1	0.80	Low risk of bias
Guedes et al.[25]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	1	0.80	Low risk of bias
Luguetti et al.[26]	1	1	CD	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Minatto et al.[27]	1	1	CD	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Montoro et al.[28]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Nascimento et al.[29]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Nogueira and Pereira[30]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0.70	Low risk of bias

Note. Q1. Was the research question or objective in this paper clearly stated?. Q2. Was the study population clearly specified and defined?. Q3. Was the participation rate of eligible persons at least 50%?. Q4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?. Q5. Was a sample size justification, power description, or variance and effect estimates provided?. Q6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?. Q7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?. Q8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?. Q9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?. Q10. Was the exposure(s) assessed more than once over time?. Q11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?. Q12. Were the outcome assessors blinded to the exposure status of participants?. Q13. Was loss to follow-up after baseline 20% or less?. Q14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?; CD, cannot determine; 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).

Table 3. Continued...

Author's	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Final Score*	Classification
Pelegrini et al.[31]	1	1	CD	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Pereira et al.[32]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	1	0.80	Low risk of bias
Reis et al.[33]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Sehn et al.[34]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Silva et al.[35]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	1	0.80	Low risk of bias
Tornquist et al.[36]	1	1	1	1	1	0	NA	NA	1	NA	1	0	NA	0	0.70	Low risk of bias
Valente et al.[37]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	1	0.60	Moderate risk of bias
Werk et al.[38]	1	1	CD	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias
Zimmermann and Matheus[39]	1	1	0	1	0	0	NA	NA	1	NA	1	0	NA	0	0.50	Moderate risk of bias

Note. Q1. Was the research question or objective in this paper clearly stated?. Q2. Was the study population clearly specified and defined?. Q3. Was the participation rate of eligible persons at least 50%?. Q4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?. Q5. Was a sample size justification, power description, or variance and effect estimates provided?. Q6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?. Q7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?. Q8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?. Q9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?. Q10. Was the exposure(s) assessed more than once over time?. Q11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?. Q12. Were the outcome assessors blinded to the exposure status of participants?. Q13. Was loss to follow-up after baseline 20% or less?. Q14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?; CD, cannot determine; 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).

DISCUSSION

The present systematic review aimed to summarize the prevalence of adequate muscle endurance in Brazilian children and adolescents. The main results were: 1) abdominal muscle endurance was the main indicator used in the literature, mainly based on curl-up protocols; 2) only four out of ten Brazilian children and adolescents had adequate abdominal muscle endurance according to health criteria, with a slightly lower value in females; 3) most studies showed a moderate risk of bias regarding methodological issues; 4) the studies were carried out predominantly in the southern region of Brazil.

We found an overall prevalence of 43.5% of abdominal muscle endurance in relation to health criteria. The prevalence was 43.7% in males and 41% in females, results closely similar to those reported in a previous review[1], which found 40.2% of males and 31.9% of females with adequate abdominal muscle endurance levels. However, the values detected in our review differed substantially from those observed in other countries. For example, a North American review that used Fitnessgram®, carried out with 1,371,411 adolescents, reported higher values, with about 82.8% of adolescents meeting the criteria for abdominal muscle endurance, compared to the present study[40]. Another North American study[41] carried out with 14,128 adolescents, which also used the Fitnessgram® cutoff point, reported that 74.6% of males and 65.2% of females met the health criteria for abdominal muscular endurance. In Europe, a study carried out in Portugal with 22,048 adolescents reported that 83.8% of the boys and 81.3% of the girls met the health criteria for abdominal muscle resistance[42].

There are several reasons that may explain the difference between the Brazilian data summarized in this review and the North American and European studies. The inequality of income distribution[43], norms and cultural differences, and also barriers to physical activity experienced in Brazil can explain these differences. In addition, developed countries have better access to environments for physical activities in childhood[27], which may represent facilitators of fitness improvement. It is also possible to argue about the variations in the testing protocols and cutoffs, which renders the comparison between countries a great challenge[44].

Girls tend to have lower levels of muscle endurance than boys[20,26,27,43]. This may be related to sexual dimorphism, with males producing more growth hormone and testosterone during adolescence, which can increase body size and muscle mass and consequently promote functional differences[43]. Moreover, the cultural and norm context should be mentioned. In general, boys are exposed early to physical activities and sports, while there is a still barrier for girls to practice physical activity[45]. In the present review, no significant difference was observed between genders based on the available data.

Biological maturation is an important process that may be related to muscle endurance due to its variability during puberty, in particular by expressing different hormone levels[42,46]. Likewise, discrepancies between chronological and biological age, which increase variability for the same age group, can lead to a biased interpretation of physical fitness values because the analysis is performed as a function of chronological age. Also, limitations and operational issues for the assessment of biological maturation (i.e., sexual, skeletal, and somatic analysis) are known, in addition to the scarcity of specific cutoff points for biological age (stages of sexual maturation or bone age) that are necessary for an accurate interpretation of physical fitness.

Physical activity directly contributes to physical fitness regardless of gender. Habitual physical activity may be related to adequate abdominal muscle endurance as a result of chronic organic adaptations that cause improvement and maintenance of muscle fitness. Since children and adolescents continue this active behavior into adult life[20,47], individuals who do not perform physical activities at sufficient levels, especially those meeting the demands of strength, have higher odds of not reaching adequate levels of muscle endurance[48]. High levels of moderate to vigorous physical activity in childhood and adolescence, and consequently a higher level of physical fitness, are related to more favorable health, reducing the present and future risk of obesity and cardiovascular diseases and promoting greater skeletal and mental health[44,49]. In contrast, low muscle fitness is related to early death and to future chronic diseases, and is thus an important health indicator in children and adolescents that urgently needs to be improved in this population[44].

Our analysis of muscle endurance data for Brazilian children and adolescents from different Brazilian regions shows that ten studies took place in the South region[21,22,24,27,28,31,32,34,36,39], more than double the number of studies conducted in each of the other Brazilian regions. In this regard, it is noteworthy that many studies were the result of graduate programs based on investments in scientific and technological development over the years. Although social, cultural and environmental discrepancies may affect physical fitness[31], in our review, we did not observe disparities between studies conducted in Brazilian regions with a lower HDI (Northeast and North: 43.1% and 32.2%, respectively)[23,29,30,33,37] and

studies conducted in regions with a higher HDI (South and Southeast: 46.8% and 33.1%, respectively)[20-22,24-28,31,32,35,39].

However, an influence of the physical fitness battery of tests on the overall prevalence of abdominal muscle endurance was observed, especially with the use of AAPHERD[23,31,35,37], which showed a lower prevalence of adequate values, mainly diverging from PROESP-BR[20-22,24,26,28-30,32-34,36,38,39]. A possible explanation for this difference may be the fact that the cutoff points of AAPHERD[25,33,36,37] were established for North American children and adolescents who, as mentioned above, differ from Brazilian children in several aspects.

Assessment of risk of bias revealed that none of the included studies considered questions related to the assessment of exposure before the measurement of the result or had a blind outcome evaluator. In this regard, a cross-sectional design has inherent limitations in causation due to temporal issues. Evaluator blinding is widely used in clinical trials and this methodological approach for reducing observer bias can also be applied to observational studies[50]. Assessment of risk of bias revealed that only six studies considered confounding variables in the data analysis[20,24,25,32,35,37]. Failure to comply with this methodological issue may lead to spurious correlations and compromise the conclusions.

This systematic review has limitations: 1) only cross-sectional studies were investigated, although this was not an exclusion criterion from the protocol; 2) the studies used different curl-up protocols and consequently different cutoffs for interpretation, which could create discrepancies in the overall prevalence; 3) few studies used muscle endurance in other regions of the body such as the upper limbs, which were not considered in this review.

This systematic review updates the study by Davoli et al.[1] and emphasizes that less than half of Brazilian children and adolescents meet the appropriate criteria for abdominal muscle endurance. Furthermore, abdominal muscle endurance was tested by curl-ups, which was still the main indicator in studies carried out predominantly in the southern region of Brazil. No disparities were found in abdominal muscle endurance between Brazilian regions, but most studies showed a moderate risk of bias. This review may contribute to the development of interventions and public policies aimed at improving muscle fitness in Brazilian children and adolescents.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

This research is in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Participated in the analysis, interpretation and writing of the work: MCPSJ. Participated in the collection of information, analysis, interpretation, literature survey and critical review:

ECM and GM. Participated in the conception and development, methodological design, supervision, data collection, analysis and interpretation, writing and critical review: LRAL.

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SUPPLEMENTARY MATERIAL

Supplementary material accompanies this paper.
Supplementary File Table 1: Free access in https://osf.io/5w98x/
Supplementary File Table 2: Free access in https://osf.io/5w98x/