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Relative age effect on muscle power in Brazilian youth: a population study

Efeito da idade relativa na potência muscular em jovens brasileiros: um estudo de população

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Abstract – This study aimed to examine the relative age effect on muscle power in a large sample of Brazilian children and adolescents. The sample consisted of 87,766 girls and boys aged 7-16 years, data collected in repeated cross-sectional surveillance carried out since 1999. The participants were grouped into four age subgroups within each chronological age based on birthdates. Upper and lower limbs muscle power were assessed using the 2-Kg medicine ball throw and horizontal jump tests, respectively. The normative distribution of physical fitness components was used for classification. The results showed a significant association between relative age and normative classification of muscle power. Among boys, there was a sequential increase in the frequency of individuals classified as "very good/excellent" as the relative age increased. A similar trend was observed among girls. The findings provided evidence of a relative age effect on muscle power in Brazilian children and adolescents. These findings have implications for the organization of structured physical activities and sports, as early-born individuals may have an advantage in performance. Further research is needed to explore the underlying mechanisms and potential interventions to mitigate the relative age effect and promote equal opportunities for all youth in physical activities and sports.

Key words: Muscle strength; Motor skills; Physical fitness testing; Adolescent sport; Children.

Resumo – *Este estudo teve como objetivo examinar o efeito da idade relativa na potência muscular em crianças e adolescentes brasileiros. A amostra foi composta por 87.766 meninas e meninos com idades entre 7 e 16 anos. Os participantes foram agrupados em quatro subgrupos etários dentro de cada idade cronológica tendo como base as datas de nascimento e da coleta dos dados. A potência muscular dos membros superiores e inferiores foi avaliada por meio dos testes de arremesso de medicine ball de 2 kg, e salto horizontal, respectivamente. A distribuição normativa (fraco; razoável; bom; muito bom; excelente) dos dois testes de potência foi utilizada para a classificação. Os resultados mostraram associação significativa entre os subgrupos etários e a classificação normativa da potência muscular. Entre os meninos, houve aumento na frequência de indivíduos classificados como "muito bom/excelente" à medida que a idade relativa aumentava. Uma tendência semelhante foi observada entre as meninas. Os achados forneceram evidências do efeito de idade relativa na potência muscular de crianças e adolescentes brasileiros. Esses resultados têm implicações práticas na organização de atividades físicas estruturadas e esportes em diferentes contextos, pois indivíduos nascidos mais cedo podem ter vantagem no desempenho em tarefas que exijam potência muscular. Mais pesquisas são necessárias para explorar os mecanismos subjacentes e intervenções que possam mitigar o efeito de idade relativa e promover oportunidades iguais para todas as crianças e adolescentes nas atividades físicas e esportes.*

Palavras-chave: *Força muscular; Destreza motora; Teste de aptidão física; Esportes para jovens; Criança.*

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INTRODUCTION

The participation of children and adolescents in physical activities, games and sports may occur in different settings and for different interests, reasons, and conditions, being influenced by multiple factors. Some of these factors are related to maturational processes. To mitigate the advantages or disadvantages associated with maturational processes, structured physical activities, games and sports practices for children and adolescents are commonly organized by chronological age groups. However, even within the same chronological age, those who were born in the first months of the age grouping system tend to perform better in motor and sports tasks than those who were born in the last months[1]. This phenomenon indicating differences between children and adolescents within the same age group is known as the relative age effect (RAE)[2].

The RAE has been widely studied in several competitive sports modalities of children and adolescents[1-5]. In general, the evidence from these studies shows that the proportion of youth athletes who were born earlier is greater than those who were born later within the same chronological age. One of the main reasons to explain this phenomenon is the early physical maturation (sexual or maturity off-set) of those early-born compared to those lately-born[2]. This feature is associated with advantages in physical size and fitness that are closely related to several sports' performance contributing to these children and adolescents being more often selected to compose competitive sports teams[2]. Besides, the disadvantages due the lower physical size and fitness of those lately-born seem to be associated with higher dropout of the sports competitive teams[2].

Although the RAE seems to have greater effect in high-level youth sport competition than those of lower level[2,6], the advantages in physical size and fitness of children and adolescents who were born earlier compared to those who were born later within the same chronological age may manifest in others settings of structured physical activities, games and sports practices, as physical education classes, extra-curricular school sports, and non-competitive school sports. Due to disadvantages in physical size and fitness, lately born children and adolescents may have lower involvement, participation and positive experiences in the physical activities, games and sports practiced in the above mentioned settings than those early-born in the same chronological age. These features may contribute to those who were born late in the same chronological age reducing the interest and participation in sports, games, and general physical activities.

Concerning to physical fitness, some previous studies analysing the general population of children and adolescents[7-12] have confirmed the RAE. Results of these studies showed that those who were born earlier than those who were born later within the same chronological age year tend to be stronger, faster, and more resistant. These differences in physical fitness in favour of early born children and adolescents have been explained by the interaction among individuals, mainly those related to maturational processes, environmental and tasks related factors. For children (e.g., preschoolers and elementary schoolers) the maturational processes seem to be the main factor to explain the RAE in physical fitness. During adolescence the RAE in physical fitness is less pronounced than during childhood mainly in the middle and in the final of adolescence period. The RAE in physical fitness during adolescence seems to be less explained by maturational processes and more explained by the greater participation and experiences in activities that develop physical fitness of

those who were born earlier than those who were born later within the same chronological age.

Although some efforts have been conducted to better understanding the RAE on physical fitness of general population of children and adolescents[7-12], some features still need to be further explored. Only Nakata's study was performed covering an age band from children and adolescents (seven to 15 years old). Despite the total sample size of most of the studies were large, considering the necessity to stratify the samples by gender, chronological ages, and subgroups within the same chronological age to examine the possible RAE in physical fitness, for carrying out studies on this topic, a very large sample size is recommended. Previous studies performed the analyses using the mean differences of the fitness components among the subgroups of age and although, in general, the found results indicate RAE in physical fitness, for some subgroups of age within the same chronological age and for some fitness components these differences were of low magnitude[10,12]. Studies using other ways to analyze the RAE and examining specific physical fitness components of general children and adolescents could provide additional information and contribute to the better understanding of this topic.

Despite the contribution of all physical fitness components, muscle power is major for performance in most sports modalities[13]. In addition, this physical fitness component is directly related to performance in sprints and speed with change of direction[14] that are also important for a wide variety of physical activities, sports and games participation and performance. Thus, examining RAE in EMS of children and adolescents can contribute for a better organization of structured physical activities, sports, and games, both in competitive and non-competitive settings. The aim of this study is to examine the RAE on the lower and upper-limbs muscle power classification in a large sample of Brazilian children and adolescents.

METHOD

Study design

This study was performed using data from a repeated cross-sectional surveillance carried out since 1999 designed to evaluate physical fitness levels of Brazilian children and adolescents (6-17 years old) using a standardized data collection protocol including data from all 26 Brazilian federative states and Federal District. Ethical precepts were complied with.

Participants

The PROESP-Br since 1999 evaluated approximately 95.000 children and adolescents from 5.219 institutions. For this study, 570 evaluators-volunteers (physical education teachers, sports coaches and strength and conditioning professionals) participate in data collection. After registration, the volunteers received PROESP-Br guidelines[15] through an online multiplatform. Training for data collection was carried out through online video classes, one video for each test (about 3-5 minutes), in addition to complementary reading material. Video lessons are available full-time on the online multiplatform and a phone number is available (at the university) for specific questions. Originally, the

first studies were published between 2002 and 2005, but unfortunately, inter-evaluator reliability values were not reported at that time[16,17].

Using non-random sampling methods, participants in all five regions of Brazil, including the Amazon region and native peoples (indigenous), were recruited in at least five cities in each region, considering the wide geographic distribution of Brazil. Among recruitment sites, primary and secondary schools account for more than 70% (distributed over the years between 63-75%), the rest of the sites are made up of public and private sports clubs, sports schools, social projects, and local cross-sectional research projects (linked to PROESP-Br). In all stages of the research, participants were invited to participate in the study, and written informed consent was obtained from parents or legal guardians, aware that they could give up for any reason, without consequences.

For the present study, all children and adolescents between ages 7-16 years evaluated between January 1999 and December 2018 were selected. The sample was composed of 87.766 Brazilian boys (n=48.455) and girls (n=39.311). The exclusion criteria were: 1) have not complete information data in the database (name, age, sports practice, and anthropometric variables); and 2) repeated values in the same year (evaluated twice a year).

Birthdate distribution by quarters

The relative age was based on centesimal age and was the independent variable of the present study. It was calculated considering the date of birth and the date of participation in the battery of tests. After obtaining the centesimal age of each subject at the date in which the test battery was performed, they were grouped into four age subgroups within each chronological age as follows using as example the 7 years-old: 7.1 (7 years + up to 3 months), 7.2 (7 years and > 3 months up to 7 years and 6 months), 7.3 (7 years and > 6 months up to 7 years and 9 months) and 7.4 (7 years and > 9 months up to 7 years and 12 months – 1-day).

Assessment procedures

PROESP-Br guidelines[15] indicate that professors should initially advise participants to wear light clothing and appropriate footwear for sports practice whenever possible (without shoes for anthropometry). Next, the guidelines indicate that the teacher should perform a joint warm-up before each assessment section (there is a sequence of suggested activities). The guidelines suggest that teachers carry out the assessments in a maximum of 20 participants per section, and use four classes/sections (when possible) to carry out the assessments: day 1) body mass measurements (weight); stature (height); arm-span, waist circumference, and the sit and reach test (not included in this study); day 2) Abdominal strength test and Cardio-respiratory 6-min run test; day 3) horizontal jump and 20-m speed test; and day 4) medicine ball throw and agility test.

Guidelines recommend that teachers not perform assessments at very high or very low temperatures, but this was not controlled in this study. Another factor that could not be controlled was the type of test floor (but professors were encouraged to indicate the temperature). The guidelines are for the evaluation of the sports court of the school/club, but in Brazil, many schools do not have a court (in this case, tests were performed in a concrete space in the school) or have a concrete court.

Anthropometric measures

The PROESP-Br's guideline indicates that height can be verified with the aid of a tape measure (1.50 m) fixed to the wall (without wall baseboard) and extended from bottom to top, with the children held upright, with their feet and trunk against the wall. This measure was noted in centimeters to one decimal place. Body mass can be measured using an anthropometric scale (analog or digital), with accuracy to 500 grams and annotated in kilograms, using one decimal place.

Physical fitness – Muscle power

For upper limbs muscle power assessment, we used the 2-kg medicine ball throw test, this test proved to be valid for screening low bone density in Brazilian children[18]. For this test, a measuring tape was fixed to the ground perpendicular to the wall. The student sits with knees outstretched, legs joined and back fully supported by the wall. The student holds a medicine ball (2 kg) next to the chest with your elbows bent. At the signal of the evaluator, the student throws the ball as far as possible, keeping his back against the wall. The result is recorded in centimeters.

For lower limbs muscle power assessment, we use the horizontal jump test which is one of the most used tests for pediatric fitness and with good validity criterium in other populations[19]. The test was carried out with a measuring tape fixed to the ground, perpendicular to the starting line. The starting line was signaled using one of the lines that marked the sports courts. The zero point of the measuring tape was on the starting line. The student stands immediately behind the line, with feet parallel, slightly apart, knees semi-flexed and trunk slightly projected forward. At the signal, the student should jump as far as possible with both feet at the same time. The result was recorded in centimeters.

The classification of the upper and lower limbs muscle power performance was performed according to the proposal of the PROESP-Br. For skill-related physical fitness components the classification is based on the normative distribution of the Brazilian population by sex and chronological age, grouped into four categories: "poor" (percentile <40), "reasonable" (percentile 40-59), "good" (percentile 60-79), "very good/excellence" (Percentile ≥80)[15].

Statistical analysis

Descriptive statistics are presented as means and standard deviations, and as absolute and relative frequencies. The distribution of subjects within the four categories of normative classification for the ULP and LLP tests among age subgroups was presented by relative frequencies. These results were presented by chronological age and by sex. The Pearson Chi-Square test was used to compare the frequencies of subjects distributed within the four categories of normative classification for the ULP and LLP tests among age subgroups. These analyses were performed by sex and chronological age. For comparisons in which the Chi-Square test identified a statistical association ($p>0.05$), the age subgroup with a statistically higher number of cases than the other categories were identified when the standardized residual adjustment value was higher than two (2.0)[20].

RESULTS

Table 1 describes the sample characterization according to sex, chronological age, and anthropometric variables. There are a smaller number of children and adolescents in the extremal chronological ages (7 and 16 ages). The frequency of subjects distributed within the four categories of normative classification for the upper and lower limbs muscle power according to the four age subgroups within each chronological age are presented in Figure 1 and Figure 2.

For boys, there is a sequential increase in the frequency of children and adolescents in the highest category of normative classification (very good/excellent) as the relative age increases (age subgroups) from seven up to 15 chronological years, when it stabilizes, both for upper and lower limbs muscle power (Figure 1A and Figure 2A). The frequency of boys classified as very good/excellent for both EMP tests were significantly higher ($p<0.05$) for the older age subgroups compared to younger age subgroups within 07 to 15 years of chronological ages. For girls, it occurs in the same way, but stabilizes earlier at 14 years of chronological age for upper limbs muscle power and at 13 years of chronological age for lower limbs muscle power (Figure 1B and Figure 2B). Comparing the older age subgroups to younger age subgroups, the frequency of classification as very good/excellent were significantly higher ($p<0.05$) for older than younger girls from 07 to 14 years of chronological age for upper limbs muscle power and from 07 to 13 years of chronological age for lower limbs muscle power (Figure 1B and Figure 2B). Furthermore, the difference between the frequencies of oldest and youngest girls within each chronological age in the highest category of normative classification for both EMP tests is lower than those observed for boys.

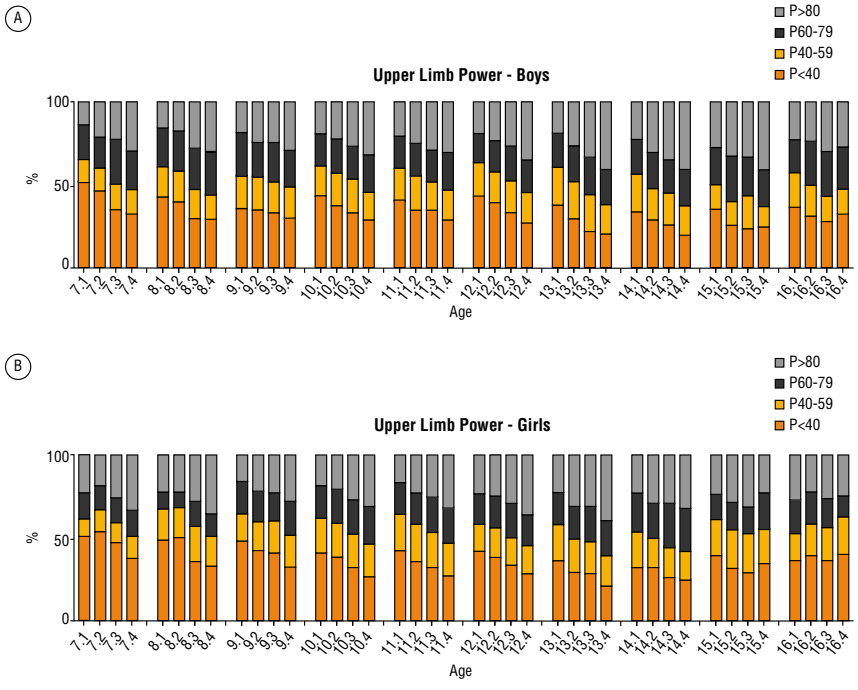

Figure 1. Effect of Relative Age in relation to normative classification of the Upper Limb Power in Boys (A) and Girls (B) aged from 7-16 years old.

Table 1. Sample characteristics about anthropometrics and physical fitness by sex and chronological age.

Boys (n=48455)										
Age (years)	7 (n=2283)	8 (n=3002)	9 (n=4148)	10 (n=7053)	11 (n=9289)	12 (n=9697)	13 (n=5781)	14 (n=3920)	15 (n=2060)	16 (n=1222)
	$\dot{X}$±SD	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**
Height	127.00±7.01	132.13±6.94	136.98±7.20	141.71±7.38	146.78±7.81	152.50±8.92	159.48±9.78	166.64±9.10	170.76±8.02	173.11±8.05
Weight	27.12±6.15	30.38±7.35	33.27±8.07	36.23±8.96	39.95±10.06	44.03±11.24	50.12±12.06	56.97±12.77	61.80±12.97	65.91±14.05
BMI	16.68±2.64	17.25±3.10	17.59±3.22	17.87±3.30	18.37±3.47	18.75±4.09	19.55±4.29	20.39±3.95	21.12±3.83	21.90±3.90
ULP	177.14±42.90	195.93±46.56	218.50±51.28	235.58±56.81	259.25±60.35	289.44±68.74	340.76±84.95	399.69±98.39	444.59±104.06	487.20±107.11
LLP	117.67±23.32	124.23±22.35	132.61±23.54	139.85±23.83	145.72±24.44	153.47±25.66	163.86±27.85	177.10±30.99	184.86±33.68	192.41±31.98
Girls (n=39311)										
Age (years)	7 (n=1979)	8 (n=2570)	9 (n=3383)	10 (n=5956)	11 (n=7999)	12 (n=7838)	13 (n=4383)	14 (n=2878)	15 (n=1421)	16 (n=904)
	$\dot{X}$±SD	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**	**$\dot{X}$±SD**
Height	125.29±6.67	130.79±7.00	136.81±7.31	142.80±7.86	148.98±7.92	154.30±7.36	158.24±7.14	160.48±6.88	160.88±7.33	161.52±7.07
Weight	26.19±5.77	29.30±6.70	32.83±7.82	36.46±8.89	40.99±9.66	45.70±9.90	50.39±10.17	53.92±10.10	55.69±10.73	56.81±11.13
BMI	16.58±2.70	16.98±2.92	17.40±3.13	17.73±3.27	18.33±3.35	19.08±3.34	20.05±3.41	20.89±3.40	21.49±3.93	21.71±3.66
ULP	158.26±35.84	176.90±42.83	197.13±45.90	215.97±50.12	239.91±53.75	262.20±57.21	291.13±62.55	306.12±69.52	316.43±74.93	328.65±65.04
LLP	104.96±22.32	113.11±21.86	120.97±22.65	128.03±23.57	132.50±23.71	136.49±24.66	140.03±26.17	139.56±28.14	137.49±30.99	137.51±31.85

Note. $\dot{X}$±SD: mean values and standard deviations; n: number of participants; BMI: body index mass; ULP: upper limb muscle power; LLP: lower limb muscle.

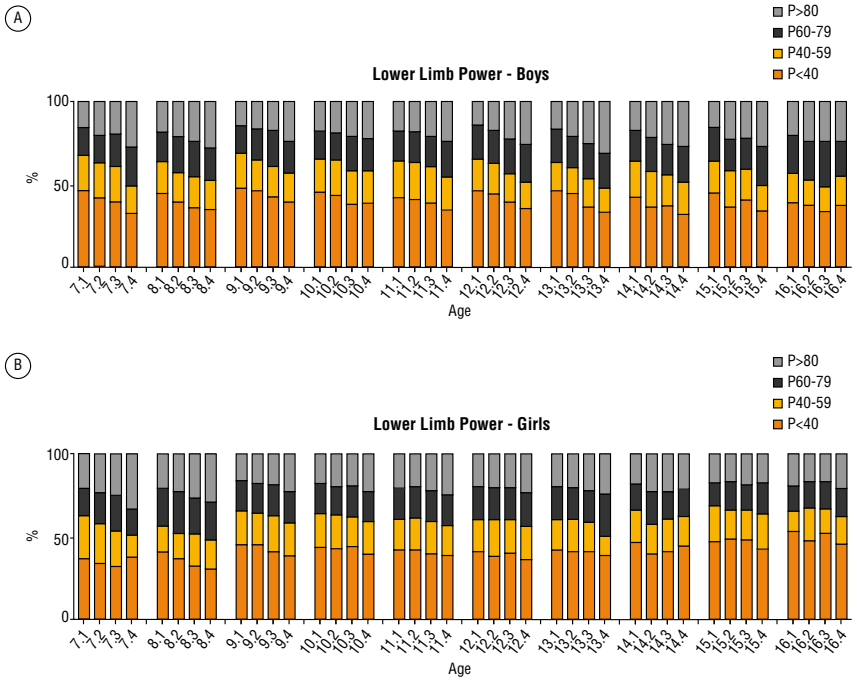

Figure 2. Effect of Relative Age in relation to Lower Limb Power in Boys (A) and Girls (B) aged from 7-16 years old.

The lowest category of normative classification (P<40) is less frequent in older subjects within each chronological age. For boys the differences among older and younger age subgroups were statistically significant (p<0.05) from 07 to 14 chronological years for upper limbs muscle power and from 07 up to 15 chronological years for lower limbs muscle power. For girls, these differences (p<0.05) were observed in the upper limbs muscle power from 07 to 14 years of chronological age and from 07 to 12 years of chronological age in the lower limbs muscle power.

DISCUSSION

The main aim of this study was to examine the RAE on the normative classification of the upper and lower limbs muscle power performance in Brazilian children and adolescents. Our results showed that the frequency of subjects in the highest normative classification category (very good/excellence - P>80) is higher among the older ones within each chronological age. On the other hand, the frequency of children and adolescents classified in the lowest normative category (poor - P<40) is higher among the younger ones within each chronological age. Our findings are in line with results from previous studies that showed the RAE on physical fitness performance among children and adolescents[10-12].

Despite our results indicating that, in general, older children and adolescents within the same chronological age presented better performance and younger ones presented worse performance on the analyzed EMS tests, some differences between sexes were observed. For boys these results occurred in a consistent way from seven to 15 chronological years old in both, upper and lower limbs muscle power. For girls the RAE was found from seven to 14 chronological years old in upper limbs muscle power both, for a higher frequency of better performance among older subjects and higher frequency of worse performance

among younger ones within the same chronological age. However, for lower limbs muscle power the RAE occurred from seven to 13 chronological years for the higher frequency of older girls having better performance and only from seven to nine chronological years for the higher frequency of younger girls having worse performance. These differences between sexes may be related to biological maturation timing, that occur earlier in girls than in boys[21]. Consequently, girls reach post pubertal status earlier than boys too. It could help explain, at least in part, the RAE has been observed until 15 years old for boys, both in upper and lower limbs muscle power, and until 14 and 13 years old for girls in both physical capacities.

Previous studies have demonstrated the RAE on physical fitness in general[22] and in muscular power tests in specific[1]. Most of them were performed analysing the RAE on fitness in samples of young athletes of different sports modalities[1] needing more information about RAE on children and adolescents' population in general[10-12]. Nevertheless, the results of these studies are similar to those involving young athletes indicating the RAE on physical fitness with more consistent results for boys than girls, which occur until 12 - 14 years old. These results are in line with what was found in the present study. However, some characteristics of our study should be highlighted for its potential contribution to a better understanding of this issue and its practical application possibilities.

Different from previous studies that performed the RAE analyses using mean values of the physical fitness tests, in our study we investigated the difference in the relative frequency of subjects classified as very good/excellence (P>80) of four different age subgroups within the same chronological age according to a normative system of Brazilian children and adolescents' physical fitness classification. This methodological way to examine the RAE on physical fitness provides an additional way to interpret this phenomenon in this population. In the study of Drenowatz et al.[11], that used similar tests to assess upper and lower limb muscle power than those used in our study, found the mean difference between age-specific quartile 1 and quartile 4 in 10–11 years boys for upper limb (Ball Push) was of 16 cm (444 vs 460 cm) and for lower limb muscle power (Vertical Jump) was of 0.3 cm (21.8 vs 22.1 cm). Despite the statistical analyses indicating a significant trend across quartiles, suggesting the RAE for upper and lower limb muscle power in 10–11 years boys, the effect of these differences in terms of practical application are low. In this sense, our results provide an easy and practical way to interpret the RAE on physical fitness. Although grouping students according to birth quarter is suggested to minimize the impact of RAE[23], this alternative is difficult to be implemented in physical education classes because students are grouped according to some age grouping system (for example, April 01 to March 31, or January 01 to December 31).

In this sense, our results provide an easy and practical way to interpret the RAE on physical fitness. For extracurricular sports, as well as for competitive youth sports, the alternative of grouping subjects by quarter of birth is perhaps even more difficult, as in many cases the teams are organized into groups of two years of chronological age, such as under 09, under 11, under 13, under 15 and under 17. Therefore, it is essential that teachers and coaches understand the RAE and seek to provide learning and training environments that consider it, providing opportunities for younger subjects within the same chronological age to develop and improve their skills and competences. These aspects may contribute to minimizing the advantages of those who are older within the

same chronological age group and improve the participation, development and retention in sports and physical activities in general of those in disadvantage in relation to the RAE[24]. Additionally, the insights from this study can be valuable in the talent identification process, particularly in identifying key fitness parameters associated with superior performance. This knowledge can help coaches and talent scouts in evaluating potential candidates and identifying athletes with high performance potential. Finally, as physical fitness in general and EMS in specific play a key role for the performance in several sports[13], our results suggest that for talent identification and for competitions and sports tournaments themselves, the strategies of organization could be carried out, at least, by semester of birth.

CONCLUSION

Our findings collectively evidenced the RAE in muscle power assessed from normative values of Brazilian children and adolescents' physical fitness classification. The frequency of subjects in the highest normative classification category (very good/excellence - P>80) was higher among the older ones within each chronological age and the frequency of children and adolescents classified in the lowest normative category (poor - P<40) was higher among the younger ones within each chronological age. The magnitude of the RAE was greater for boys than for girls and also covered a larger age range for boys than for girls.

This evidence may be considered in different settings involving children and adolescents, as in School Physical Education, in school sports, in the organization of games and sports competitions, and for talent identification, mainly for those modalities that for upper limb muscle power are important for the performance. In School setting, as in physical education classes as in extracurricular sports, teachers must be aware that RAE influences fitness performance and it can play a key role in other motor, cognitive and social abilities that must be developed in children and adolescents.

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COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee –Universidade Federal do Rio Grande do Sul and the protocol (no. 2008010) was written 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

Conceived and designed experiments: GGB, JBM, ACAG, GDF, ESP; Analyzed the data: GGB, GDF, ESP; Wrote the paper: GGB, JBM, ACAG, FSF, AFS, GDF, ESP.

References

1. Cobley S, Baker J, Wattie N, McKenna J. Annual age-grouping and athlete development: a meta-analytical review of relative age effects in sport. Sports Med. 2009;39(3):235-56. http://doi.org/10.2165/00007256-200939030-00005. PMid:19290678.
2. Barnsley RH, Thompson AH, Barnsley PE. Hockey success and birthdate: the relative age effect. Canadian Association for Health. Phys Educ Recreat J. 1985;51:23-8.
3. Musch J, Grondin S. Unequal competition as an impediment to personal development: a review of the relative age effect in sport. Dev Rev. 2001;21(2):147-67. http://doi.org/10.1006/drev.2000.0516.
4. Helsen WF, Van Winckel J, Williams AM. The relative age effect in youth soccer across Europe. J Sports Sci. 2005;23(6):629-36. http://doi.org/10.1080/02640410400021310. PMid:16195011.
5. Smith KL, Weir PL, Till K, Romann M, Cobley S. Relative age effects across and within female sport contexts: a systematic review and meta-analysis. Sports Med. 2018;48(6):1451-78. http://doi.org/10.1007/s40279-018-0890-8. PMid:29536262.
6. Delorme N, Boiché J, Raspaud M. The relative age effect in elite sport: the French case. Res Q Exerc Sport. 2009;80(2):336-44. http://doi.org/10.1080/02701367.2009.10599568. PMid:19650399.
7. Roberts SJ, Boddy LM, Fairclough SJ, Stratton G. The influence of relative age effects on the cardiorespiratory fitness levels of children age 9 to 10 and 11 to 12 years of age. Pediatr Exerc Sci. 2012;24(1):72-83. http://doi.org/10.1123/pes.24.1.72. PMid:22433266.
8. Sandercock GR, Taylor MJ, Voss C, Ogunleye AA, Cohen DD, Parry DA. Quantification of the relative age effect in three indices of physical performance. J Strength Cond Res. 2013;27(12):3293-9. http://doi.org/10.1519/JSC.0b013e318291b28d. PMid:23539082.
9. Veldhuizen S, Cairney J, Hay J, Faught B. Relative age effects in fitness testing in a general school sample: how relative are they? J Sports Sci. 2015;33(2):109-15. http://doi.org/10.1080/02640414.2014.934708. PMid:24998606.
10. Nakata H, Akido M, Naruse K, Fujiwara M. Relative age effect in physical fitness among elementary and junior high school students. Percept Mot Skills. 2017;124(5):900-11. http://doi.org/10.1177/0031512517722284. PMid:28756733.
11. Drenowatz C, Ferrari G, Greier K, Hinterkörner F. Relative age effect in physical fitness during the elementary school years. Pediatr Rep. 2021;13(2):322-33. http://doi.org/10.3390/pediatric13020040. PMid:34201263.

12. Folgado H, Bravo J, Quintas A, Raimundo A, Gonçalves B. Relative age effect in physical fitness of South Portugal students between 10 and 18 years old. Int J Environ Res Public Health. 2021;18(11):6092. http://doi.org/10.3390/ijerph18116092. PMid:34198739.

13. Kraemer WJ, Newton RU. Training for improved vertical jump. Sports Sci Ex. 1994;7:1-12.

14. Mello JB, Pinheiro EDS, Ferreira GD, Bergmann GG. Relationship between Sprint, lower limb power, and change of direction speed in adolescents. Motriz. 2021;27:e1021012920. http://doi.org/10.1590/s1980-65742021012920.

15. Gaya AR, Gaya ACA, Pedretti A, Mello JB. Projeto Esporte Brasil, PROESP-Br: manual de medidas, testes e avaliações. 5ª ed. Porto Alegre: Universidade Federal do Rio Grande do Sul; 2021. 39 p.

16. Gaya ACA, Guedes C, Torres L, Cardoso M, Poletto A, Silva M, et al. Aptidão física relacionada à saúde : um estudo piloto sobre o perfil de escolares de 7 a 17 anos na Região Sul do Brasil. Rev Perfil. 2002;6(6):50-60.

17. Bergmann GG, Araújo MLBD, Garlipp DC, Lorenzi TC, Gaya ACA. Annual alteration in the growth and health-related physical fitness of the school children. Rev Bras Cineantropom Desempenho Hum. 2005;7:55-61.

18. Mello JB, Pedretti A, Bergmann GG, Gaya AR, Ubago-Guisado E, Gaya ACA. Sprint and upper limbs power field tests for the screening of low bone mineral density in children. Front Physiol. 2022;13:1066462. http://doi.org/10.3389/fphys.2022.1066462. PMid:36569752.

19. Castro-Piñero J, Ortega FB, Artero EG, Girela-Rejón MJ, Mora J, Sjöström M, et al. Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. J Strength Cond Res. 2010;24(7):1810-7. http://doi.org/10.1519/JSC.0b013e3181ddb03d. PMid:20555277.

20. Agresti A. Categorical data analysis. 2nd ed. Hoboken: Wiley; 2002. http://doi.org/10.1002/0471249688.

21. Malina RM. Top 10 research questions related to growth and maturation of relevance to physical activity, performance, and fitness. Res Q Exerc Sport. 2014;85(2):157-73. http://doi.org/10.1080/02701367.2014.897592. PMid:25098012.

22. Castagna C, Abt G, D'ottavio S, Weston M. Age-related effects on fitness performance in elite-level soccer referees. J Strength Cond Res. 2005;19(4):785-90. PMid:16287368.

23. Smith KL, Bélanger M, Chittle L, Dixon JC, Horton S, Weir PL. Does relative age influence organized sport and unorganized physical activity participation in a cohort of adolescents? Sports. 2022;10(7):97. http://doi.org/10.3390/sports10070097. PMid:35878108.

24. Baxter-Jones AD, Barbour-Tuck EN, Dale D, Sherar LB, Knight CJ, Cumming SP, et al. The role of growth and maturation during adolescence on team-selection and short-term sports participation. Ann Hum Biol. 2020;47(4):316-23. http://doi.org/10.1080/03014460.2019.1707870. PMid:31960720.