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Trends in muscular fitness performance among 9-12-year-olds: implications for monitoring and test selection

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Abstract

Background and Study Aim	Long-term trends in muscular fitness show a gradual decline, which has become even more intense due to the Covid-19 pandemic. Declines in muscular fitness are associated with deteriorated health and well-being parameters. It is crucial to monitor this decline and appropriate tests need to be selected and interpreted correctly. The aim of this research was to apply muscle fitness tests and compare the development of performance between 9 and 12-year-olds and, at the same time, to compare performance differences between boys and girls.
Material and Methods	225 girls and 259 boys aged 9 to 12 years (11.1 ± 0.9) took part in the studies. Seven tests were selected to assess muscular fitness: bent-arm hang (BAH), push-ups, sit-ups, standing broad jump (SBJ), medicine ball throw (MBT), handgrip dynamometry (handgrip), and pulling back-leg dynamometry (back-leg).
Results	The results showed that the development curves of muscle tests are incomparable. A linear increase was recorded for the MBT test. The handgrip, back-leg, and MBT tests have similar development although they do not test the same type of force. A very different trend (stagnation, decline) was found for the BAH and push-up tests. Girls and boys showed a comparable trend in all tests, however, boys always had higher absolute performances.
Conclusions	Our data are intended to contribute to the expert discussion on the choice of muscular fitness tests. Based on these results, the selection of multiple tests may be recommended for optimal assessment of muscular fitness. In future research, it would be advisable to follow up by testing a larger cohort.

Keywords: physical fitness, strength, sex differences, dynamometry

Introduction

The secular trend in physical fitness shows that cardiorespiratory fitness and muscular fitness have undergone a gradual decline [1]. In previous decades, these reductions are up to tens of percent. At the same time, we observe a consistent increase in childhood obesity and reduced physical activity in children [2]. This situation has been exacerbated by pandemic restrictions due to the Covid-19 pandemic, leading to a worsening in body composition and muscular fitness levels in children and adolescents [3].

Recent studies have shown that the decline in physical activity in children and adolescents, along with an increase in screen time, is becoming a major concern [4, 5]. Muscular fitness plays a key role in children's physical development, as it forms the basis for physical activity, body image, and metabolic health [6, 7]. Muscular fitness decline has been associated with the development of obesity, poorer bone density, lower academic performance, and well-being deterioration. Markers of muscular fitness in childhood show an association with adiposity levels and cardio-metabolic parameters in adulthood [6, 8]. Emphasizing strength monitoring in childhood is henceforth a logical step. Measuring the level of muscular fitness gives us information about the state of society and consequently serves as feedback for the subjects. Ultimately, this information allows us to design appropriate and effective intervention programs.

Muscular fitness is commonly measured using standardised body weight tests or hand grip strength tests. Neither the number of tests nor their choice are uniform [9, 10, 11]. As a result, we need to know as much information as possible about muscular fitness tests and their association with maturation. The choice of tests and their evaluation is essential for general recommendations regarding exercise, fitness, and leisure time.

Monitoring the development of strength tests during childhood has been part of much research. There is an increase in strength performance prior to puberty, this trend is, however, not uniform for all types of tests. A steeper curve can be seen in the progression of the Standing broad jump test in children from 6 to 12 years, compared to push-ups or bent-arm hang (BAH) [12, 13, 14]. There is also a noticeable difference between the relative strength and absolute strength tests, which is evident in the push-ups, BAH, and handgrip strength tests

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respectively. Absolute strength shows a steeper trend [14, 15, 16, 17]. We also encounter a different pattern in the changes in dynamic strength in the standing broad jump and ball throw tests [12, 18].

Another characteristic feature of muscular fitness is different results between boys and girls, which they reach already during their prepubertal development. The difference in results is not just in terms of absolute values, but also of a different developmental curve. Changes in performance are closer to a linear progression in boys, while girls show a more moderate increase [12, 15, 19]. However, this trend cannot be established in absolute terms, as it varies depending on the test.

In general, commonly used tests for the assessment of dynamic, relative, and absolute strength may not show the same trend in the period before the onset of puberty. These findings are transferred to test interpretation and give us important information about changes in muscular fitness during the maturation process. The development of strength parameters is also related to the selection of age-specific tests. The authors are not aware of any study that has comprehensively monitored muscle fitness tests and analysed the development of changes. The aim of the study was to use seven muscular fitness tests and to compare the performance development of children aged 9 to 12 years old, with a simultaneous comparison of boys and girls.

Materials and Methods

Participants

A total of 6 public schools were selected at random. Children from grades 3 to 5 were involved in the study. The research sample comprised 225 girls and 259 boys who were from 9 to 12 years old (11.1 ± 0.9). All participants were of Caucasian ethnicity and met the following inclusion criteria: being between 9-12 years of age while the research was being conducted, having no objective medical conditions based on medical examination, and having parental/legal guardian consent. Only data from children who completed all tests were included in the statistical analysis, resulting in 37 children being excluded from the study.

Parents or legal guardians were informed about the research process, which took place in the second half of 2022 and was approved by the Committee for Research Ethics at the University of Hradec Králové (No. 12/2022). The study was conducted in accordance with the latest version of the Declaration of Helsinki.

Research Design

Testing

Anthropometry was measured without shoes and in light clothing. Weight was measured on an electronic scale (HN-289, Omron, Japan). The Body Mass Index (BMI) was further calculated by dividing the body weight by the height squared (kg/m^2).

Seven tests were selected to assess muscular fitness, which was designed to measure relative, absolute, and dynamic strength and to evaluate the level of upper and lower body strength. These tests were as follows: BAH, push-ups, sit-ups, standing broad jump, medicine ball throw, handgrip dynamometry (MAP 80K1S, KERN. Kern & Sohn GmbH, Germany), and pulling back-leg dynamometry (SH5007, Saehan Dynamometer. Saehan Corporation, India).

The testing process was conducted in two days and it had always preceded by technical drills. Participants had 2 to 3 attempts, with several minutes of sufficient rest in between. The best attempt always counted. The sequence of the tests was designed to avoid the influence of fatigue on the following testing process. Day 1 was devoted to the following movements: handgrip, SBJ, and push-ups, while day 2 was to back-leg, MBT, and BAH. At the beginning of testing, a dynamic warm-up exercise containing full-body movements was always performed.

Standing broad jump (SBJ)

The participant stands in a parallel position with both feet behind the marked line. A countermovement or arm swing could be used to jump. Participants had to land with both feet at the same time and block the jump without further advancement. A further attempt was allowed if the subject fell backward or touched the ground with another part of the body. The test was performed three times, counting the best jump. The distance was measured with tape from the starting line to the heel of the closest foot to the starting line.

Push-ups

A participant starts in the push-up position: hands and toes touching the floor, the body and legs are in a straight line, feet slightly apart, the arms at shoulder width apart and extended and at the right angle to the body. Keeping the back and knees straight, the subject lowers the body until there is a 90-degree angle at the elbows, with the upper arms parallel to the floor. The repetition is counted after the starting position is taken. The requirement was to perform the maximum number of repetitions. During the test, the subject was not allowed to change the position of his hands or toes.

Bent-arm hang (BAH)

A participant is assisted into position, the body lifted to a height so that the chin is above the level of the horizontal bar. The bar is grasped using an overhand grip, with the hands shoulder-width apart. The chin must not touch the bar. There was no requirement for the position of the lower limbs. The timing started when the subject is released. The test was stopped when the chin was below the level of the bar.

Sit-ups

A participant lies supine on the mat, keeping the hands on the shoulders and the knee flexed at an angle of 90°. A researcher holds the subject's ankles firmly for support. The subject must come up to a position where both elbows touch the knees. When returning to the starting position, both shoulder blades must touch the mat. The participant repeats this movement as many times as possible. The number of repetitions performed in 60 seconds was considered.

Medicine ball throw (MBT)

A subject stands with his feet in a parallel position with a medicine ball (3 kg, 30 cm diameter) at chest level, both hands on the medicine ball, elbows bent. The throw was performed using both hands without trunk rotation with a countermovement. The distance was measured from the point of ball impact to the point of throw. Each participant performed three throws, and the best result among attempts was considered.

Handgrip dynamometry (handgrip)

Grip strength was measured in a standing position with the shoulder adducted and flexed elbow. Measurements were taken twice, and the higher value was recorded.

Pulling back-leg dynamometry (back-leg)

A subject stands with both feet on the device and holds the handle with both hands. The handle has been adjusted so that it is approximately at the knee level and the chain passes between the legs. This motion simulates a partial deadlift. During the pull, the handle must not rest on the thighs. Measurements were taken twice, and a higher value was recorded.

Statistical Analysis

The sample was divided into quartiles according to the date of children's birth (1st quartile: January-March 2nd quartile April-June, 3rd quartile: July-September, 4th quartile: October-December). According to the average values, trend graphs were created for muscle fitness tests and anthropometric variables. For the measured values, a test for normality of the data was performed (Shapiro-Wilks, Q-Q plot). The W value was compared at a significance level of p=0.05. Normality was tested for height and weight to confirm that this was a representative sample. Data analysis was performed using IBM SPSS software, version 20. A comparison of the development curves was performed using a qualitative method where there had to be an agreement between all authors.

Results

Table 1 shows the anthropometry measurements and the results of the muscular fitness tests. The table also includes the results of boys and girls. The data of height and weight showed a normal distribution. The percentage of obesity as a significant factor for the muscular fitness score was 12 %. Height and weight data showed a normal distribution (W= 0.012-0.078), while for muscle tests normality was confirmed only for SBJ (W=0.474).

Figure 1 shows developmental curves of muscle tests and anthropometry. The mean values and results of girls and boys are plotted.

Anthropometric variables show a gradual and comparable increase. For BMI, we observe fluctuations between quarters, but a rising trend is evident. Fluctuations (increases and decreases) between quartiles are also evident in other measurements, most notably in the bent-arm hang.

Most measurements show gradually increasing absolute values, although fluctuations between quartiles are noticeable. No clear upward trend can be established for bent-arm hang, stable comparable values are more likely set. A negative trend in performance was measured for the push-ups where there was a gradual decline in performance.

In general, not all tests show the same trend of gradual increase. The measurements show different trends in performance progression. For the handgrip, back-leg, and MBT movements, a plateau was recorded, with a larger increase from the third quartile of 2011. For the SBJ and sit-ups, there is a gradual continuous (linear) increase. For the bent-arm hang test, we rather observe values stagnation. For the fourth quartile of 2012, we observe deviations that are not in conformity with the trend of a gradual increase of values (height, handgrip, push-ups).

Girls generally performed lower than boys in all muscular fitness tests. Despite the variation across quartiles, both groups showed a comparable trend in their scores. Comparable parameters were observed for height and weight.

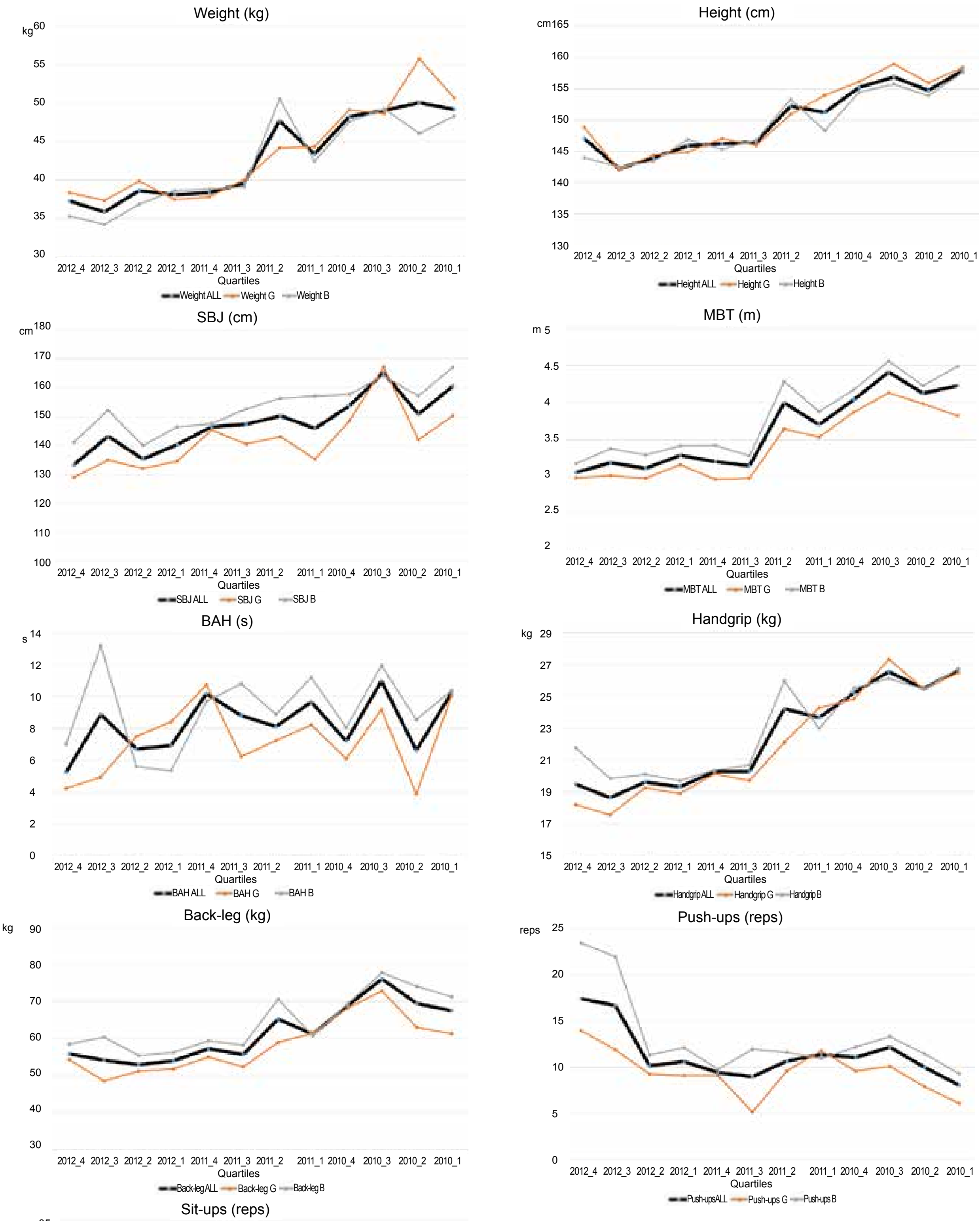
Discussion

The purpose of the research was to compare muscular fitness tests in prepubertal children, to look for trends in performance, and to compare girls and boys. The results show that an increase in muscle strength parameters is not comparable between the tests. We identified a linear increase only in the SBJ test, in other cases the curve has a different shape. The results of the back-leg, handgrip, and MBT have a comparable development, although they do not test the same type of strength. A very different trend in terms of stagnation or decrease was observed for the BAH and push-ups. Girls and boys showed

Table 1. Results of anthropometry and muscular fitness tests

Quartile	Weight (kg)	Height (cm)	BMI (kg/m²)	SBJ (cm)	MBT (m)	BAH (s)	Handgrip (kg)	Back-leg (kg)	Push-ups (reps)	Sit-ups (reps)
ALL										
2012_4	37.29	147.09	17.22	133.36	3.05	5.23	19.50	55.82	17.45	17.36
2012_3	35.88	142.30	17.61	143.22	3.19	8.88	18.65	54.13	16.74	20.70
2012_2	38.64	143.99	18.47	135.40	3.11	6.71	19.63	52.98	10.19	21.02
2012_1	38.08	145.90	17.85	140.43	3.29	6.90	19.31	53.96	10.62	22.89
2011_4	38.36	146.23	17.78	146.57	3.20	10.18	20.27	57.26	9.48	24.39
2011_3	39.57	146.49	18.40	147.33	3.15	8.79	20.28	55.65	9.02	19.75
2011_2	47.70	152.25	20.26	150.33	3.99	8.13	24.22	65.30	10.73	24.35
2011_1	43.40	151.22	18.85	145.93	3.70	9.66	23.66	61.17	11.41	23.44
2010_4	48.26	155.21	19.94	153.66	4.04	7.19	25.20	68.92	11.08	26.15
2010_3	49.07	156.88	19.76	165.21	4.41	10.98	26.55	76.07	12.23	28.81
2010_2	50.07	154.77	20.53	150.85	4.12	6.62	25.46	69.44	10.02	26.78
2010_1	49.21	157.92	19.62	160.53	4.23	10.25	26.64	67.44	8.11	28.72
Girls										
2012_4	38.41	148.86	17.33	129.00	2.99	4.22	18.21	54.29	14.00	19.71
2012_3	37.36	142.08	18.42	135.00	3.01	4.93	17.56	48.50	11.92	18.55
2012_2	39.89	144.42	18.91	132.08	2.98	7.50	19.27	51.20	9.32	24.62
2012_1	37.52	144.93	17.83	134.52	3.16	8.40	18.90	51.78	9.15	25.63
2011_4	37.83	147.10	17.29	145.41	2.97	10.74	20.15	55.00	9.14	25.45
2011_3	40.10	146.00	18.88	140.52	2.98	6.21	19.72	52.33	5.19	18.86
2011_2	44.21	150.94	19.12	143.00	3.64	7.23	22.11	58.89	9.61	24.89
2011_1	44.32	154.00	18.57	135.33	3.53	8.21	24.31	61.52	11.81	25.33
2010_4	49.09	156.17	19.98	148.50	3.87	6.09	24.82	68.15	9.65	27.81
2010_3	48.67	159.00	19.23	167.20	4.13	9.16	27.34	72.87	10.13	30.33
2010_2	55.71	155.97	22.57	142.00	3.98	3.88	25.48	62.94	7.94	25.88
2010_1	50.66	158.43	20.02	150.21	3.82	10.05	26.48	61.36	6.14	28.36
Boys										
2012_4	35.33	144.00	17.02	141.00	3.18	7.00	21.75	58.50	23.50	17.67
2012_3	34.28	142.55	16.72	152.18	3.38	13.20	19.84	60.27	22.00	24.36
2012_2	36.91	143.39	17.85	140.00	3.29	5.61	20.12	55.44	11.39	21.28
2012_1	38.67	146.90	17.87	146.58	3.42	5.35	19.73	56.23	12.15	22.81
2011_4	38.85	145.44	18.24	147.63	3.42	9.67	20.37	59.33	9.79	23.42
2011_3	39.15	146.87	18.02	152.63	3.28	10.79	20.70	58.22	12.00	20.44
2011_2	50.55	153.32	21.19	156.32	4.28	8.86	25.95	70.55	11.64	23.91
2011_1	42.44	148.30	19.15	157.05	3.87	11.18	22.99	60.80	11.00	21.45
2010_4	47.60	154.45	19.91	157.73	4.17	8.05	25.50	69.52	12.21	24.85
2010_3	49.29	155.75	20.05	164.14	4.56	11.95	26.12	77.79	13.36	28.00
2010_2	46.08	153.92	19.09	157.13	4.22	8.56	25.45	74.04	11.50	27.42
2010_1	48.29	157.59	19.36	167.09	4.49	10.38	26.74	71.32	9.36	28.95

SBJ - standing broad jump; MBT – medicinbal throw; BAH – bent-arm hang; Back-leg – Pulling back-leg dynamometry



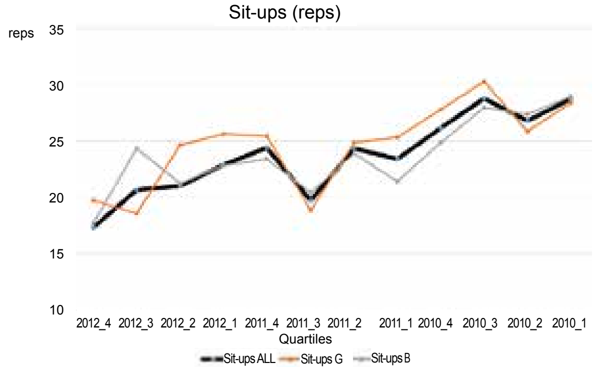


Figure 1. Trends in muscular fitness tests and anthropometry. SBJ – standing broad jump; MBT – medicinbal throw; BAH – bent-arm hang; Back-leg – Pulling back-leg dynamometry

a comparable developmental trend in all tests and boys always recorded higher absolute performances.

The results show a comparable linear increase in weight, height, BMI, and SBJ. In other cases, the curves show a different pattern. The findings of the trend for weight, BMI and SBJ are supported by other research [13, 20, 21] and this is hence a very well predicted parameter. The SBJ test, which assesses dynamic lower body strength, is thus different from other tests.

It was found that in terms of height and weight, the sample showed a normal distribution and is thus a normal population sample. Similarly, the cohort did not show a high number of obese children. For muscular tests, normality was confirmed only for the SBJ test (W=0.474). When displayed on a Q-Q plot for SBJ, a linear regular increase in performance with age can be observed. Only the back-leg test showed a linear-like pattern, but normality was not statistically confirmed (W=0.03). The results of the normality test support that a regular gradual increase in performance with age was not confirmed for most muscle tests.

A gradual linear increase in handgrip strength with a steeper ascent from the age of 11 is documented by Häger-Ross & Rösblad [19] and Butterfield et al. [15], but in Molenaar et al. [16] and Fredriksen et al. [22] the development is rather linear with no significant increase until the age 12. However, our measurements show that a steeper increase occurred in the second and in the first quartile of 2011, i.e. at years 10 of age. The dependence of the increase in absolute strength is mainly related to the degree of maturation, height and muscle mass, therefore, there are significant changes with the onset of puberty [17]. Accordingly, the handgrip developmental curve in prepubertal individuals has not been finally determined yet.

Body weight tests are widely used owing to their easy administration and their connection to natural movement patterns. Rúa-Alonso et al. [3] and Tomkinson et al. [21] report a (moderate) linear trend in progression in the BAH test, which is different from our results. A clear positive trend cannot be identified from measurements by Castro-Piñero et al. [12] or Gulías-González et al. [23], where values fluctuate between years. The trend for the push-ups test, which can be described as slightly decreasing or stagnant between some quartiles, can also be observed in the research conducted by Castro-Piñero et al. [12]. Tomkison et al. [21] or Gulías-González et al. [23] report a very slight increase in performance for sit-ups – their data are comparable to ours. Thus, body weight tests generally do not show a consistent trend and we do not find full agreement even for every test across studies. It needs to be taken into account when setting standards and interpreting testing.

The percentiles are used to set standards [24], however, it is essential to determine which growing trend they have. For the SBJ test, it appears that a gradual linear increase can be expected for children between the ages of 9 to 12 - a similar gradual linear increase can be expected for the handgrip [22]. The situation is different for body weight tests given by the fact that research findings are not uniform. It is probably not possible to expect a linear increase in the performance of children of age from 9 to 12. The development between even larger groups is not identical and fluctuations, plateaus, or even declines in performance can be expected. A crucial factor in this context is, among others, the influence of weight or obesity, which significantly affects strength test results [25, 26].

Handgrip dynamometry is a reliable indicator of absolute strength [19]. The back-leg test is not yet as widespread, but given the same development trend, it could represent a suitable alternative. Interestingly, we also find a similar trend for MBT test, which is designed to assess dynamic strength. It is possible that this variation of the 3 kg medicine ball throw will be strongly dependent on absolute strength. A comparable trend in values increase was also found for weight. This trend indicates a significant relationship between weight and hand grip strength that has been repeatedly demonstrated [17].

Muscular fitness assessment includes absolute strength, dynamic strength, and relative strength (muscular endurance) testing. Very often, a limited number of tests are selected to assess the level of physical fitness or muscular strength [1, 9, 21]. Test selection is important for research and testing purposes in common practice. Our data suggest that repeated measurements with longer time intervals cannot predict developmental trends unambiguously and that there may be considerable variation between tests. All indications are that it is difficult to accurately determine the level of muscular fitness from one or two tests. This also makes it more difficult to interpret the results.

Girls and boys did not reach the same level of muscular fitness, nevertheless, their development of height and weight can be described as the same. Although greater differences appear after the onset of puberty, differences can be observed earlier. Differences between the absolute handgrip performances of girls and boys (6-12 years) were found by Fredriksen et al. [22] while confirming the same trend in the development of values. This trend was also supported by Butterfiel et al. [15], with significant differences between girls and boys only being evident after they reach the age of 12. However, Beunen & Thomis [27] report significant differences between girls and boys already at prepubertal age, in particular for SBJ and BAH tests. Even so, we believe that differences at this age will generally not be significant. A progressive increase in performance is also evident after the onset of puberty, although in this case, there is already a significant differentiation between girls and boys. Boys generally show a steep increase in performance in muscular tests [28]. The situation is different for girls, as stagnation can be expected in body weight tests (push-ups, BAH, SBJ) [12, 27]. The performance sex difference is due to hormonal, morphological, and body composition changes [29].

Weight or BMI significantly affects the results of muscular tests. We observe a negative effect in body weight tests, however, no such trend is shown for the handgrip strength test [26, 30]. If the research sample is not tested comprehensively, but only certain tests are used (e.g. push-ups, sit-ups, or handgrip), misleading conclusions may be drawn. Therefore, the percentage of obese individuals must be taken into account. In our study, 12 % of children were obese, which is a standard representation in the region [31].

We see the research limitation in the unequal number of children in each quartile, the biggest problem was the fourth quartile in 2012 with a low number of subjects. This may have led to a distortion of the beginning of the development curves.

Conclusions

It is essential to monitor the muscular fitness level of children, especially in view of the observed worldwide increase in weight and obesity. Test selection and interpretation play a central role in testing children of all ages. Research has shown that there are different developmental curves for muscular fitness tests and they thus cannot be expected to have identical progression. In most cases, progression has not been linear, and stagnation or decline have also been observed. Girls and boys showed the same trend in all cases, with boys achieving higher absolute performances. These research data are intended to contribute to the discussion on the choice of physical and muscular fitness tests. However, based on these results, the selection of multiple tests can be clearly recommended. As this is original research, it would be advisable to follow up with studies with a larger sample size or a larger age range.

Conflict of interest

The authors have no conflict of interest to declare.

References

1. Masanovic B, Gardasevic J, Marques A, Peralta M, Demetriou Y, Sturm DJ, et al. Trends in Physical Fitness Among School-Aged Children and Adolescents: A Systematic Review. *Front Pediatr* 2020;8:627529. https://doi.org/10.3389/fped.2020.627529
2. Garrido-Miguel M, Cavero-Redondo I, Álvarez-Bueno C, Rodríguez-Artalejo F, Moreno LA, Ruiz JR, et al. Prevalence and Trends of Overweight and Obesity in European Children From 1999 to 2016: A Systematic Review and Meta-analysis. *JAMA Pediatr* 2019:e192430. https://doi.org/10.1001/jamapediatrics.2019.2430
3. Rúa-Alonso M, Rial-Vázquez J, Nine I, Lete-Lasa JR, Clavel I, Giráldez-García MA, et al. Comparison of Physical Fitness Profiles Obtained before and during COVID-19 Pandemic in Two Independent Large Samples of Children and Adolescents: DAFIS Project. *Int J Environ Res Public Health* 2022;19:3963. https://doi.org/10.3390/ijerph19073963
4. Fang K, Mu M, Liu K, He Y. Screen time and childhood overweight/obesity: A systematic review and meta-analysis. Child: Care, Health and Development 2019;45:744–53. https://doi.org/10.1111/cch.12701
5. ten Velde G, Lubrecht J, Arayess L, van Loo C, Hesselink M, Reijnders D, et al. Physical activity behaviour and screen time in Dutch children during the COVID-19 pandemic: Pre-, during- and post-school closures. *Pediatric Obesity* 2021;16:e12779. https://doi.org/10.1111/ijpo.12779
6. García-Hermoso A, Ramírez-Campillo R, Izquierdo M. Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. *Sports Med* 2019;49:1079–94. https://doi.org/10.1007/s40279-019-01098-6
7. Sánchez-Miguel PA, Leo FM, Amado Alonso D, Hortigüela-Alcalá D, Tapia-Serrano MA, De La Cruz-Sánchez E. Children’s Physical Self-Concept and Body Image According to Weight Status and Physical Fitness. *Sustainability* 2020;12:782. https://doi.org/10.3390/su12030782
8. Barbosa CCL, da Costa JC, Romanzini CLP, Batista MB, Blasquez-Shigaki G, Fernandes RA, et al. Interrelationship between muscle fitness in childhood and bone mineral density in adulthood: mediation analysis of muscle fitness in adulthood. *BMC Public Health* 2023;23:648. https://doi.org/10.1186/s12889-023-15545-7
9. Artero EG, Ruiz JR, Ortega FB, España-Romero V, Vicente-Rodríguez G, Molnar D, et al. Muscular and cardiorespiratory fitness are independently associated with metabolic risk in adolescents: the HELENA study. *Pediatr Diabetes* 2011;12:704–12. https://doi.org/10.1111/j.1399-5448.2011.00769.x
10. de Miguel-Etayo P, Gracia-Marco L, Ortega FB, Intemann T, Foraita R, Lissner L, et al. Physical fitness reference standards in European children: the IDEFICS study. *Int J Obes* (Lond) 2014;38 Suppl 2:S57-66. https://doi.org/10.1038/ijo.2014.136
11. Magnussen CG, Schmidt MD, Dwyer T, Venn A. Muscular fitness and clustered cardiovascular disease risk in Australian youth. *Eur J Appl Physiol* 2012;112:3167–71. https://doi.org/10.1007/s00421-011-2286-4
12. Castro-Piñero J, González-Montesinos JL, Mora

J, Keating XD, Girela-Rejón MJ, Sjöström M, et al. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009;23:2295–310. https://doi.org/10.1519/JSC.0b013e3181b8d5c1
13. Hardy LL, Merom D, Thomas M, Peralta L. 30-year changes in Australian children's standing broad jump: 1985-2015. J Sci Med Sport 2018;21:1057–61. https://doi.org/10.1016/j.jsams.2018.04.005
14. Nassif H, Sedeaud A, Abidh E, Schipman J, Tafflet M, Deschamps T, et al. Monitoring fitness levels and detecting implications for health in a French population: An observational study. *BMJ Open* 2012;2. https://doi.org/10.1136/bmjopen-2012-001022
15. Butterfield SA, Lehnhard RA, Loovis EM, Coladarci T, Saucier D. Grip strength performances by 5- to 19-year-olds. *Percept Mot Skills* 2009;109:362–70. https://doi.org/10.2466/PMS.109.2.362-370
16. Molenaar HM (Ties), Zuidam JM, Selles RW, Stam HJ, Hovius SER. Age-Specific Reliability of Two Grip-Strength Dynamometers When Used by Children. *JBJS* 2008;90:1053. https://doi.org/10.2106/JBJS.G.00469
17. Wind AE, Takken T, Helders PJM, Engelbert RHH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Pediatr* 2010;169:281–7. https://doi.org/10.1007/s00431-009-1010-4
18. Golle K, Muehlbauer T, Wick D, Granacher U. Physical Fitness Percentiles of German Children Aged 9–12 Years: Findings from a Longitudinal Study. *PLoS One* 2015;10:e0142393. https://doi.org/10.1371/journal.pone.0142393
19. Häger-Ross C, Rösblad B. Norms for grip strength in children aged 4-16 years. *Acta Paediatr* 2002;91:617–25. https://doi.org/10.1080/080352502760068990
20. Thomas E, Petrigna L, Tabacchi G, Teixeira E, Pajaujiene S, Sturm DJ, et al. Percentile values of the standing broad jump in children and adolescents aged 6-18 years old. *Eur J Transl Myol* 2020;30:9050. https://doi.org/10.4081/ejtm.2019.9050
21. Tomkinson GR, Carver KD, Atkinson F, Daniell ND, Lewis LK, Fitzgerald JS, et al. European normative values for physical fitness in children and adolescents aged 9-17 years: results from 2 779 165 Eurofit performances representing 30 countries. *Br J Sports Med* 2018;52:1445–14563. https://doi.org/10.1136/bjsports-2017-098253
22. Fredriksen PM, Mamen A, Hjelle OP, Lindberg M. Handgrip strength in 6-12-year-old children: The Health Oriented Pedagogical Project (HOPP). *Scand J Public Health* 2018;46:54–60. https://doi.org/10.1177/1403494818769851
23. Gulías-González R, Sánchez-López M, Olivas-Bravo Á, Solera-Martínez M, Martínez-Vizcaíno V. Physical fitness in Spanish schoolchildren aged 6-12 years: reference values of the battery EUROFIT and associated cardiovascular risk. *J Sch Health* 2014;84:625–35. https://doi.org/10.1111/josh.12192
24. Vanhelst J, Ternynck C, Ovigneur H, Deschamps T. Normative health-related fitness values for French children: The Diagnoform Programme. *Scand J Med Sci Sports* 2020;30:690–9. https://doi.org/10.1111/sms.13607
25. Lloyd LK, Bishop PA, Walker JL, Sharp KR, Richardson MT. The Influence of Body Size and Composition on FITNESSGRAM(r) Test Performance and the Adjustment of FITNESSGRAM(r) Test Scores for Skinfold Thickness in Youth. *Meas Phys Educ and Exer Sc* 2003;7:205–26. https://doi.org/10.1207/S15327841MPEE0704_1
26. Thivel D, Ring-Dimitriou S, Weghuber D, Frelut M-L, O'Malley G. Muscle Strength and Fitness in Pediatric Obesity: a Systematic Review from the European Childhood Obesity Group. *Obes Facts* 2016;9:52–63. https://doi.org/10.1159/000443687
27. Beunen G, Thomis M. Muscular Strength Development in Children and Adolescents. *Ped Exer Sc* 2000;12:174–97. https://doi.org/10.1123/pes.12.2.174
28. Viru A, Loko J, Volver A, Laaneots L, Karelson K, Viru M. Age periods of accelerated improvement of muscle strength, power, speed and endurance in the age interval 6-18 years. *Biology of Sport* 1998;15:211–27.
29. Bandyopadhyay A, Goswami B, Singha Roy A, Dalui R. Impact of Pubertal Growth on Physical Fitness. *Amer J of Sports Sc Med* 2014;2:34–9. https://doi.org/10.12691/ajssm-2-5A-8
30. Ajisafe T. Association between 90o push-up and cardiorespiratory fitness: cross-sectional evidence of push-up as a tractable tool for physical fitness surveillance in youth. *BMC Pediatrics* 2019;19:458. https://doi.org/10.1186/s12887-019-1840-9
31. Spinelli A, Buoncristiano M, Kovacs VA, Yngve A, Spiroski I, Obreja G, et al. Prevalence of Severe Obesity among Primary School Children in 21 European Countries. *Obes Facts* 2019;12:244–58. https://doi.org/10.1159/000500436

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