



OPEN Reliability of the biceps curl test and proposed percentiles in schoolchildren living at moderate altitude in Peru

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The biceps curl test is easy to apply, does not require expensive equipment, and its short execution time makes it feasible in school settings with limited resources. To verify the reliability of the biceps curl test in children and adolescents and to provide reference values according to chronological age and sex. A total of 1103 schoolchildren aged 6 to 17 years (500 boys and 603 girls) were evaluated. Weight and height were evaluated and Body Mass Index (BMI) and Tri Ponderal Index (TPI) were calculated. The right and left hand biceps curl was evaluated in 30 s. Children aged 6 to 11 years used a 1 kg dumbbell and those aged 12 to 17 years used a 2 kg dumbbell. Percentiles were calculated using the LMS method. The values of the relative Technical Error of Measurement (TEM%) of the biceps curl test of both hands ranged from 0.48 to 2.89%. The intraclass correlation coefficient (ICC) evidenced high values of 0.93 to 0.99. The Bland-Altman plot showed wide limits of agreement (-1.28 to 1.29 rep). These findings demonstrate that the test is reliable and consistent for use in pediatric populations and is suitable for different stages of physical development in school children. The values showed stability and wide limits of agreement. In addition, the proposed percentiles are useful to evaluate and monitor the strength endurance performance of both arms.

Keywords Reliability, Pediatric strength, Altitude, Biceps curl, Children, Adolescents

The assessment of overall muscle strength is an important component of the physical examination that can reveal information about neurological deficits, muscle weakness, or lack of muscle endurance¹, from infancy to senescence². For example, in children and adolescents it is essential to monitor activities of daily living such as self-care, walking, running, jumping among other skills³. These actions not only promote proper social interaction, but also play an essential role in the prevention of diseases in adulthood.

It is a multidisciplinary practice that involves several professionals, including nurses, physicians, physical therapists, occupational therapists, chiropractors, and other experts such as physical education and sports teachers¹.

Muscular strength in general is determined by three basic concepts which are maximal strength, muscular power and strength endurance^{4,5}. The first refers to the amount of force exerted by a muscle or muscle group to produce a single maximal effort. While the second, refers to the ability to develop a maximal force in the shortest possible time (e.g., such as accelerating, jumping and throwing) and the third, strength endurance, is the ability of muscles to exert a force against a resistance over a period of time⁴.

Indeed, the assessment of strength endurance at the school level is crucial both for activities of daily living, as well as for the sporting arena. This assessment makes it possible to identify the level of muscular endurance of schoolchildren, which is essential to maintain performance and prevent muscle fatigue during sustained efforts.

In general, strength endurance measures are evaluated as part of a battery of physical fitness tests in schoolchildren related to health or sports performance⁶. Tests often used are hand grip strength, flexion and

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extension of arms on the floor (push-ups), suspension on a barbell, abdominal muscular endurance, among others^{7,8}.

To our knowledge, this biceps curl test, has not been applied in schoolchildren, nor included in any battery of physical fitness tests, although it has been widely used in young adult, middle-aged and elderly populations^{9–12}. Therefore, evidencing the reliability of the biceps curl test in school children and adolescents is a crucial process to ensure that the results obtained are accurate and reproducible.

The standard biceps curl test is a commonly used test to measure the strength and function of the biceps brachii and is widely used to control and monitor intervention programs in various populations⁹. This test is characterized by being field-based, rapid and serves to measure the strength endurance of the upper body (arms) and provides essential information about the physical condition and health level of a person^{6,13}.

In moderate altitude geographic regions of Peru, there is limited access to specialized instruments to measure muscular strength endurance in schoolchildren. This makes it difficult to reliably assess physical fitness in children and adolescents. Consequently, the standard biceps curl test could be a viable alternative to assess submaximal strength endurance, but as far as is known, its reliability in this specific population is unknown and there are no adequate reference values according to chronological age and sex. Thus, the biceps curl test is easy to apply, does not require expensive equipment, and its short execution time makes it feasible in school settings with limited resources.

On the other hand, altitude plays a relevant role in the physical growth of children and adolescents, whose heights are usually lower than international references and even those of their counterparts living at sea level^{14,15}. Therefore, schoolchildren living at moderate altitudes might present different physiological characteristics compared to those living at lower altitudes.

Therefore, the main objective of this study was to verify the reliability of the biceps curl test in children and adolescents from a moderate altitude region of Peru. In addition, a second objective was to provide reference values of the biceps curl test according to chronological age and sex.

Methodology

Type of study and sample

A descriptive (cross-sectional) study was carried out in schoolchildren living in a city of moderate altitude in Peru. The sample consisted of 1103 schoolchildren aged 6 to 17 years (500 males and 603 females). The sample selection was non-probabilistic (accidental).

The schoolchildren participated voluntarily in the study and were recruited from 4 state schools in the urban area of Arequipa (Peru). This city is located 2320 m above sea level and is situated south of Lima (capital of Peru)¹⁶. In Peru, the school system is divided into three levels: early education (3 to 5 years), primary education (6 to 11 years) and secondary education (12 to 17 years).

The study was approved by the ethics committee of the Universidad Católica Santa María de Arequipa (Peru) (UCSM-096–2022) and was conducted in accordance with the Declaration of Helsinki for Human Subjects. Informed consent was obtained from all participants and/or their legal guardians.

The 4 selected schools or educational institutions (including primary and secondary level) were invited to participate, minimizing selection bias. To this end, informative meetings were scheduled in the schools to ensure that all parents understood the terms before giving their consent without exerting pressure or influence. It was also indicated that the data to be collected would be anonymous and confidential. This helped to avoid biases related to the perception of physical performance in the biceps curl test.

Schoolchildren who attended physical education classes in their schools once a week, those within the established age range (6 to 17 years old) were included. Schoolchildren who practiced any sport outside school hours and those who had some type of physical disability that prevented the evaluation of the anthropometric tests and the biceps curl were excluded.

Techniques and instruments

The anthropometric data and the muscle strength test were collected at the schools' facilities. The group of evaluators consisted of 02 physical education teachers with extensive experience in physical evaluations. Student data (date of birth, sex and year of study) were collected from the school administration.

A group data collection form was constructed, where data such as date of birth, date of evaluation, sex, anthropometric data (weight, height), and the right and left hand biceps curl test were recorded.

Anthropometric measurements were evaluated following the recommendations of Ross & Marfell-Jones¹⁷. Body weight and height were measured with as little clothing as possible (shorts, t-shirt and no shoes). Weight (kg) was assessed with a Seca brand digital scale with an accuracy of (100 g) and a scale of (0 to 150 kg). The scale is placed on a flat and stable surface. The participant is asked to stand still in the center of the scale until the weight is recorded.

Height (m) was assessed using a Seca brand aluminum stadiometer graduated in millimeters with a scale of (0 to 2.50 m). The head was positioned according to Frankfort's plane (an imaginary line passing from the lower edge of the eye orbit to the upper edge of the ear canal). Participants stood barefoot, with heels together and back straight against the stadiometer. The Tri-Ponderal Index TPI (kg/m^3) was calculated through the formula $[\text{TPI} = \text{Weight}(\text{kg})/\text{Height}(\text{m})^3]$. This indicator is suggested for moderate altitude populations¹⁸. Body Mass Index (kg/m^2) was also calculated with the formula: $[\text{BMI} = \text{Weight}(\text{kg})/\text{Height}(\text{m})^2]$.

The biceps curl test (30 s) was evaluated sitting on a chair. The participant holds a 1 kg dumbbell (children of both sexes from primary level 6 to 11 years old) and a 2 kg dumbbell from secondary level adolescents of both sexes from 12 to 17 years old. To evaluate this test, the protocol suggested by Rikli, Jones¹⁹ was followed. The exercise starts with the arm fully extended, flexing the elbow to bend the weight towards the shoulder and

then deliberately lowering it. This cycle involves bending the elbows to lift the dumbbell and returning to the starting position as many times as possible for 30 s. The test was performed with both the right and left arm. Each evaluator counted the number of repetitions individually, evaluated one by one, both for the test and for the retest. The objective of the test was to measure muscular endurance for repetitive movements in a limited time or submaximal muscular endurance¹⁹. It was performed twice to verify the relative technical measurement error (TEM%). It was considered 3 min of rest between the first and second measurement as described by Matos et al.²⁰.

Statistics

The normal distribution of the anthropometric data (weight and height) and of the biceps curl test was verified by the Kolmogorov-Smirnov test. To statistically analyze the data, the sample was divided into two groups: primary level (6 to 11 years) and secondary level (12 to 17 years). Descriptive statistics were calculated: mean, standard deviation and range. Differences between both sexes and both age groups were determined using the t-test for independent samples. The intraclass correlation coefficient (ICC) was also used to measure the concordance between test and retest for the biceps curl. Likewise, the Bland-Altman diagram²¹, which establishes the limits of concordance, was used to evaluate whether the concordance between test and retest is good or not. The LMS method²² was used to construct the percentiles. The LMS method is a non-structural mathematical model that makes it possible to adjust data and obtain normalized percentile standards.

The LMS method uses the Box-Cox transformation to fit the data distribution to a normal distribution by minimizing the effects of skewness. The LMS parameters are generated according to the maximum penalty method²³ and their respective smoothed curves, taking into account the degree of skewness (L), central tendency (M) and dispersion (S). Data processing was performed with the LMS Chartmaker Pro software (The Institute of Child Health, London, United Kingdom)²⁴. This program completes the smoothing process in four stages: data input, model fitting through the L, M and S curves, visualization of the percentile graphs and model control. For all cases, $p < 0.05$ was adopted and calculations were performed in Excel spreadsheets, SPSS 18.0 and MedCalc 11.1.

Results

The anthropometric variables characterizing the sample of schoolchildren living at moderate altitude in Peru are shown in Table 1. Males showed greater weight at 11, 15, 16 and 17 years of age in relation to females ($p > 0.5$). There were also differences in height and TPI at older ages. Males presented greater height and TPI than females from 13 to 17 years of age ($p < 0.05$). There were no significant differences at other ages.

Tables 2 and 3 show the reliability values of the biceps curl of both hands. It is observed that both in the right and left hand the values of the TEM% ranged from 0.48 to 2.89% in all ages and in both sexes. Meanwhile, the CCI (95% CI) showed high values, ranging from 0.93 to 0.99 in all ages and in both sexes. In general, in both test and retest measures there were no significant differences ($p > 0.05$), being these measures stable.

Figures 1 and 2 show the Bland-Altman plot applied for the test and re-tests of the biceps curl test in both sexes. The mean difference in the primary and secondary level boys for both hands were similar (for the right hand it was 1.02 ± 2.39 rep. and for the left hand it was 1.02 ± 2.39 rep). In primary level girls were also similar to boys, for example, for the right hand it was 1.02 ± 2.39 rep. and for the left hand it was 1.02 ± 2.39 rep.

Age (years)	Males										Females									
	n	Weight (kg)		Height (cm)		BMI (kg/m ²)		TPI (kg/m ³)		n	Weight (kg)		Height (cm)		BMI (kg/m ²)		TPI (kg/m ³)			
		\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD		\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD		
Primary education																				
6	36	24.2	5.0	118.2	6.5	17.2	2	14.6	1.6	35	23.4	3.6	119.5	4.8	16.4	2.1	13.7	1.8		
7	37	28.2	6.4	123.2	6.7	18.4	2.8	14.9	2.0	36	26.3	5.4	123.2	6.0	17.2	2.4	14	1.8		
8	38	29.6	5.6	128.5	5.2	17.8	2.3	13.9	1.6	39	30.1	7.3	127.5	6.9	18.3	3.0	14.4	2.1		
9	52	35.6	8.6	132.6	8.6	20.0	3.3	15.1	2.4	70	33.8	8.6	132.7	7.2	19.0	3.5	14.3	2.4		
10	72	39.4	9.0	137.3	7.0	20.8	4.1	15.2	3.2	64	40.9	10.7	140.1	8.6	20.7	4.3	14.8	3.2		
11	62	49.0*	12.8	148.6	9.1	21.9	3.8	14.7	2.2	47	43.8	8.1	147.4	6.9	20.1	3.1	13.6	2.2		
Secondary education																				
12	68	47.5	9.9	152.6	7.9	20.3	3.4	13.3	2.2	54	47.5	8.0	151.9	5.5	20.5	3.0	13.5	2.0		
13	47	53.3	10.9	160.4*	7.4	20.6	3.5	12.9*	2.1	40	52	8.6	153.1	5.6	22.1	2.8	14.4	1.8		
14	50	55.4	8.7	164.1*	6.9	20.5	2.5	12.5*	1.5	38	54.4	6.1	154.8	4.3	22.7	2.1	14.6	1.3		
15	47	61.0*	9.7	165.8*	5.1	22.2	3.3	13.4*	2.1	38	55.7	9.0	155.7	5.1	22.9	3.2	14.7	2.1		
16	55	59.4*	6.8	167.7*	6.1	21.1	2.1	12.6*	1.4	39	56.1	13.6	155.3	5.0	23.3	5.8	15	3.9		
17	30	63.7*	14.8	167.4*	4.6	22.7	5.1	13.6*	3.1	30	55.0	8.1	155.5	3.7	22.7	3.1	14.6	2.0		

Table 1. Anthropometric characteristics of the schoolchildren studied. X: mean, SD: standard deviation, BMI: body mass index, TPI: triponderal index, *: significant difference in relation to female ($p < 0.05$)

Biceps Curl _{Right} (1 kg)										
Age (years)	Males					Females				
	TEM	TEM (%)	Mean difference		ICC (95% CI)	TEM	TEM (%)	Mean difference		ICC (95% CI)
			\bar{x}	SD				\bar{x}	SD	
Primary education										
6	0.52	3.32	0.00	0.53	0.99 (0.98 to 0.99)	0.63	4.25	−0.13	0.74	0.96 (0.89 to 0.98)
7	0.48	2.59	−0.03	0.49	0.99 (0.99 to 0.99)	0.58	3.32	0.00	0.59	0.99 (0.98 to 0.99)
8	0.53	2.72	0.07	0.53	0.99 (0.98 to 0.99)	0.57	2.82	−0.06	0.57	0.99 (0.99 to 0.99)
9	0.48	2.04	0.00	0.49	0.99 (0.99 to 0.99)	0.6	2.6	0.04	0.6	0.99 (0.98 to 0.99)
10	0.58	2.31	0.03	0.58	0.99 (0.99 to 0.99)	0.56	2.3	0.03	0.56	0.99 (0.99 to 0.99)
11	0.59	2.27	−0.02	0.67	0.99 (0.99 to 0.99)	0.51	2.3	−0.04	0.51	0.99 (0.99 to 0.99)
Secondary education										
12	0.79	2.7	0.00	0.79	0.99 (0.99 to 0.99)	0.54	1.92	0.00	0.55	0.99 (0.99 to 0.99)
13	0.64	1.51	0.02	0.64	0.99 (0.99 to 0.99)	0.62	1.75	−0.15	0.61	0.99 (0.99 to 0.99)
14	0.6	1.32	0.00	0.61	0.99 (0.99 to 0.99)	0.63	1.66	−0.03	0.64	0.99 (0.99 to 0.99)
15	0.61	1.46	0.00	0.63	0.99 (0.99 to 0.99)	0.69	1.94	0.03	0.68	0.99 (0.98 to 0.99)
16	0.6	1.42	0.00	0.61	0.99 (0.99 to 0.99)	0.55	1.56	0.00	0.56	0.99 (0.99 to 0.99)
17	0.58	1.23	0.07	0.59	0.99 (0.99 to 0.99)	0.42	1.32	0.00	0.45	0.99 (0.99 to 0.99)

Table 2. Reliability values (test and retest) of the right arm biceps curl by age and sex. TEM: technical error of measurement; TEM%: relative technical error of measurement; \bar{x} = average; SD = standard deviation; ICC = intraclass correlation coefficient.

Biceps Curl left (1 kg)										
Age (years)	Males					Females				
	TEM	TEM (%)	Mean difference		ICC (95% CI)	TEM	TEM (%)	Mean difference		ICC (95% CI)
			\bar{x}	SD				\bar{x}	SD	
Primary education										
6	0.66	4.17	−0.03	0.67	0.98 (0.97 to 0.99)	0.58	3.63	0.2	0.56	0.99 (0.97 to 0.99)
7	0.63	3.29	0.07	0.64	0.99 (0.98 to 0.99)	0.67	3.7	0.00	0.68	0.99 (0.98 to 0.99)
8	0.53	2.51	0.00	0.53	0.99 (0.98 to 0.99)	0.62	3.02	0.00	0.63	0.99 (0.98 to 0.99)
9	0.59	2.55	0.00	0.59	0.99 (0.98 to 0.99)	0.6	2.61	0.01	0.6	0.99 (0.98 to 0.99)
10	0.64	2.55	0.00	0.65	0.99 (0.99 to 0.99)	0.51	2.07	−0.05	0.52	0.99 (0.99 to 0.99)
11	0.48	1.88	0.02	0.59	0.99 (0.99 to 0.99)	0.65	2.98	0.04	0.66	0.99 (0.99 to 0.99)
Secondary education										
12	0.90	2.89	−0.04	2.92	0.93 (0.90 to 0.96)	0.65	2.28	0.02	0.66	0.99 (0.99 to 0.99)
13	0.55	1.35	0.00	0.55	0.99 (0.99 to 0.99)	0.62	1.74	−0.03	0.63	0.99 (0.99 to 0.99)
14	0.74	1.64	0.00	0.76	0.99 (0.99 to 0.99)	0.71	1.86	0.03	0.72	0.99 (0.99 to 0.99)
15	0.6	1.44	0.02	0.61	0.99 (0.99 to 0.99)	0.68	2.01	0.00	0.7	0.99 (0.98 to 0.99)
16	0.67	1.63	−0.02	0.68	0.99 (0.99 to 0.99)	0.60	1.70	0.00	0.61	0.99 (0.98 to 0.99)
17	0.82	1.80	0.00	0.85	0.99 (0.98 to 0.99)	0.43	1.32	0.00	0.45	0.99 (0.99 to 0.99)

Table 3. Reliability values (test and retest) of the left arm biceps curl by age and sex. TEM: technical error of measurement; TEM%: relative technical error of measurement; \bar{x} = average; SD = standard deviation; ICC = intraclass correlation coefficient.

In children at the secondary level, the results were also similar in both hands and both sexes. In boys, the mean difference for right hand was 1.02 ± 2.39 rep and for left hand was 1.02 ± 2.39 rep). In girls, the mean differences for the right hand reflected 1.02 ± 2.39 rep and for left hand yielded 1.02 ± 2.39 rep).

In general, the limits of agreement for both sexes at the primary level (both hands) ranged from -1.10 to 1.19 rep, and similarly at the secondary level the values ranged from -1.28 to 1.29 repetitions. In all cases, the values were acceptable.

The comparisons of the biceps curl tests between both sexes (primary and secondary) are observed in Fig. 3. At the primary level, it is observed that the muscular strength endurance of both arms (right and left) are similar from 6 to 10 years of age in both sexes, there were no significant differences ($p > 0.05$), these values ranged from ~ -0.2 to 1.2 repetitions. However, at 11 years of age, males presented greater muscular strength endurance than their similar females of the same age (~ 3 to 3.2 repetitions) ($p < 0.05$).

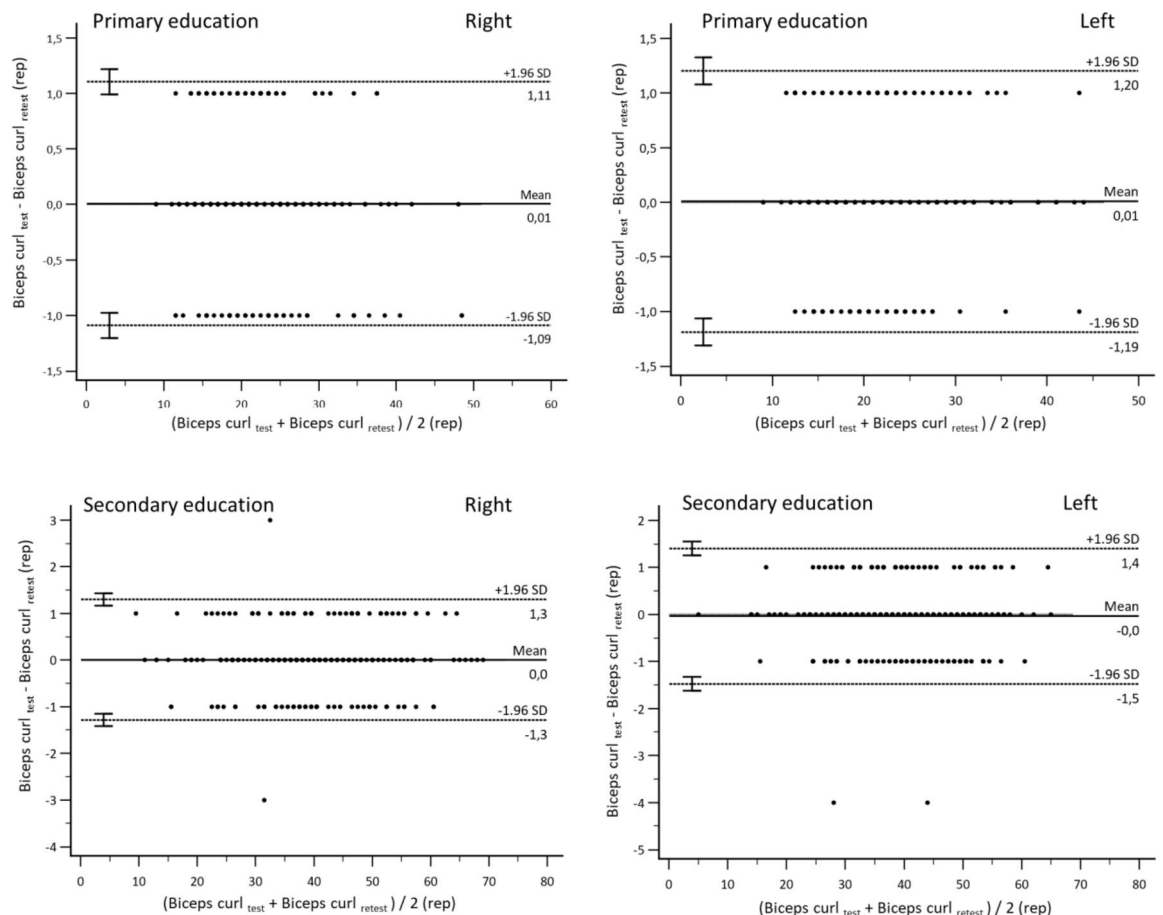


Fig. 1. Bland-Altman graph evaluating concordance between the test and retest of the biceps curl test of primary and secondary school children.

In secondary school children, there were no differences at 12 years of age in both hands (right and left) ($p > 0.05$). From the age of 13 to 17 years, males present higher values in muscular strength endurance of both arms in relation to females ($p < 0.05$). These values range from ~4.9 to 14.8 repetitions.

Table 4 shows the percentiles developed to evaluate the biceps curl of primary and secondary school children by age and sex (P5, P15, P25, P50, P75, P85 and P95). In both sexes it is observed that the 50th percentile increases as age advances up to 14 years of age, then at 15 to 17 years of age the values stabilize in both sexes.

Discussion

The results of the study have evidenced that the strength endurance test (biceps curl) of both hands is reliable to be applied to primary and secondary school children living in a moderate altitude region of Peru.

These findings are consistent with other studies that have sought similar reliability objectives using the biceps curl test in adolescents²⁵, young adults²⁶ and adults with some diseases²⁷ and without diseases²⁸.

The weights used in the dumbbells in these studies were 2.27 to 3.63 kg as opposed to those used in the present study, which were 1 kg for children at the primary level (6 to 11 years) and 2 kg for adolescents at the secondary level (12 to 17 years).

In general, children of both sexes during the growth stage rapidly increase muscle strength, with boys having advantages over girls during adolescence²⁹. Therefore, the weights of the dumbbells at the primary level of 1 kg were increased to 2 kg for the secondary level. For muscle strength is proportional to the cross-sectional area of skeletal muscle, meaning that the growth curves of strength parallel the growth curves of body weight and skeletal muscle mass³⁰.

In fact, when comparing muscle strength (biceps curl) during childhood (primary education), there were no significant differences between both sexes. However, during adolescence (secondary education), adolescents of both sexes continued to increase strength endurance linearly until around 14 years of age, and then reached relative stability at older ages.

The decision to adjust the weight of the dumbbells (1 kg for primary school children and 2 kg for high school adolescents) is based on this theoretical understanding of muscle development. For the knowledge of age- and gender-associated changes in strength during childhood and adolescence is relatively limited compared to other physiological parameters³¹, thus, age-associated strength development can be attributed to changes in growth and maturation, whose gender differences appear around age 14^{31,32}.

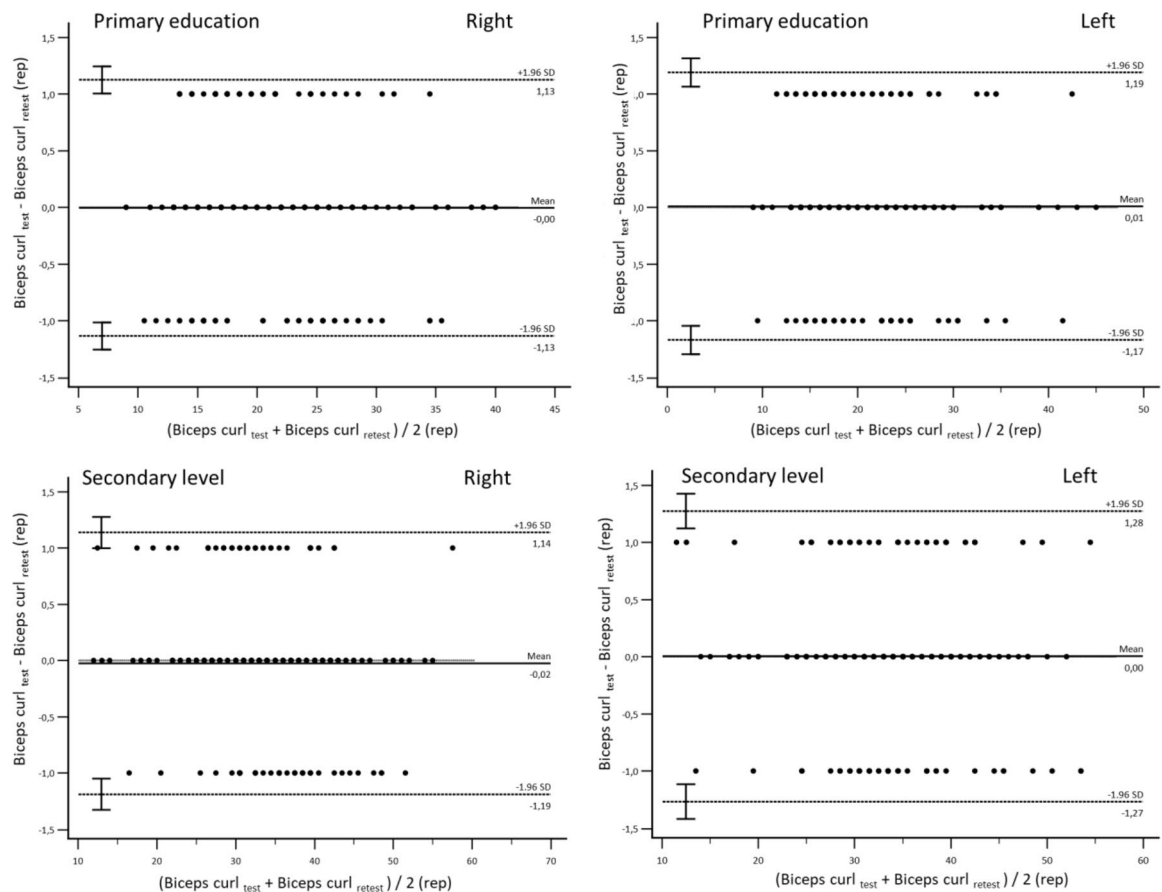


Fig. 2. Bland-Altman plot evaluating concordance between the test and retest of the biceps curl test of primary and secondary school girls.

These findings are in agreement with the literature, where they indicate that optimal development of muscle mass and muscle strength are reached during adolescence^{33,34} and peak in early adulthood, then decline with age from approximately the fifth decade onwards^{35,36}. Therefore, assessing muscular endurance during school age is relevant, as it can help prevent several common disorders, such as osteoporosis and sarcopenia, later in life^{34,37,38}.

The reliability demonstrated in some studies described above, reinforces the usefulness of the biceps curl test as an effective tool for muscle strength assessment in pediatric populations, which may be beneficial for measuring lower body musculoskeletal strength and power in school children³⁹. In addition, it can be included in physical education, training and rehabilitation programs in various populations^{25,40}.

The strength endurance test (biceps curl) is reliable for assessing primary and secondary school children in a moderate altitude region of Peru. This suggests that the test can be used effectively in these contexts and can be included in a battery of physical tests in growing and developing populations.

The percentiles developed in this study show reference values to evaluate muscular endurance by means of the biceps curl test for children and adolescents in a region of moderate altitude in Peru.

These results suggest the use of percentiles as a fundamental tool to assess muscular endurance in children and adolescents by age and sex. This proposal will allow accurate and reliable assessments to monitor muscular development, adapt to physical education programs, youth sports training programs and to monitor physical health from infancy to adolescence.

Several studies have prioritized the assessment of muscular endurance through push-up, barbell suspension, isometric strength tests^{41–43}. The results obtained through these tests show that they are important for determining physical fitness and muscle development in children and adolescents.

Muscular endurance, regardless of the type of test to be evaluated, reflects the capacity of a muscle group to exert submaximal force for prolonged periods and can be evaluated with standardized tests and can even serve to relate to other indicators⁵.

In essence, the assessment of general fitness requires sex- and age-specific reference values against which individual and population fitness status can be compared⁴². This tool allows for meaningful interpretation of development in children and adolescents and provides comprehensive feedback to teachers, adolescents and children, parents, and public policy makers⁴⁴.

Some recent studies consider that the assessment of physical fitness and especially muscular strength endurance should be considered as a marker of health^{45–47}. This requires a distribution of percentiles, which are often typically classified into five categories: $\leq p10$ as very poor, $p10$ to $\leq p25$ poor, $p25$ to $\leq p75$ medium, $p75$

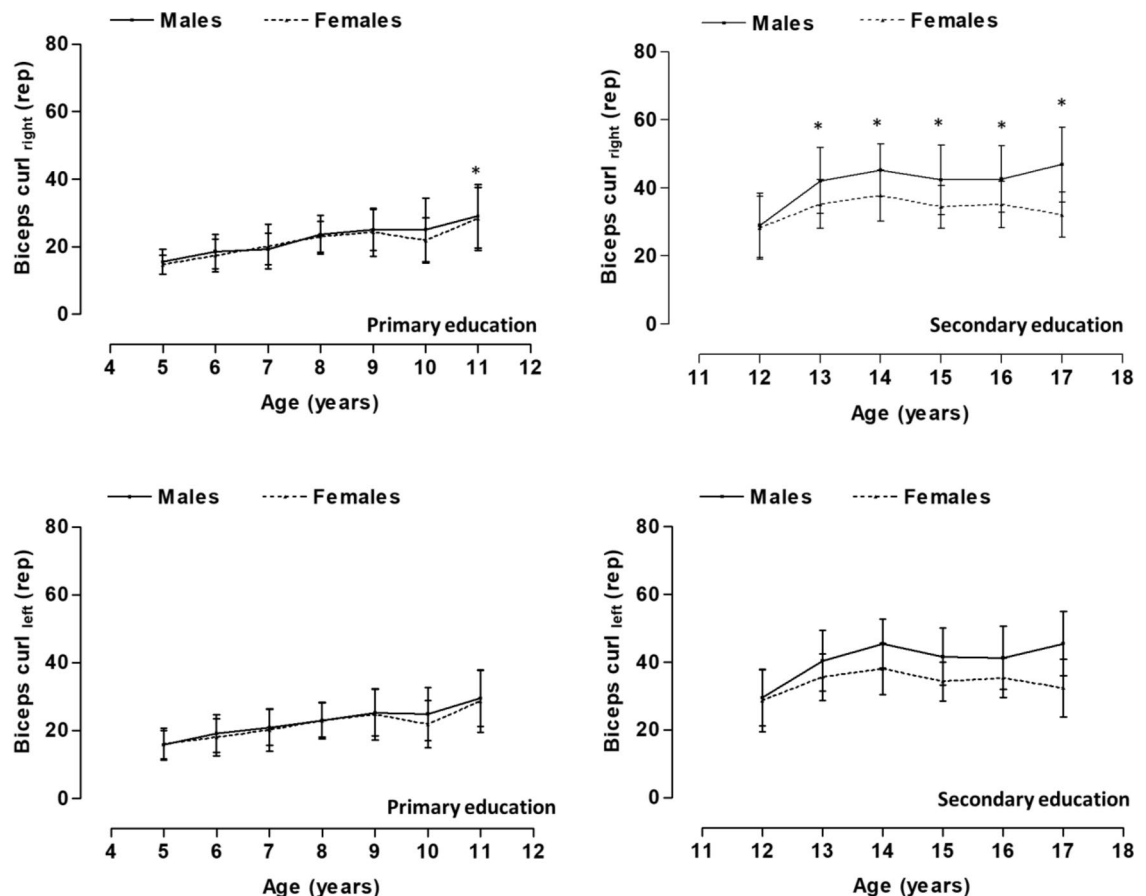


Fig. 3. Comparison of mean biceps curl values between both sexes by age and level of school education (primary and secondary).

to $\leq p90$ good and $\geq p90$ very good^{45,48}. Other studies indicate categorizing fitness into three categories: $\leq p15$ can be interpreted as a low level or a warning sign, between $p15$ to $p85$ as adequate and $\geq p85$ as a high level of fitness⁴⁹.

Percentiles are a statistical tool to identify children and adolescents with submaximal muscular endurance below the average for their age and sex. For example, it can motivate to categorize and/or identify schoolchildren who are below the 15th percentile. This could suggest specific interventions during physical education classes and at the same time promote physical development and self-confidence among schoolchildren.

This study provides useful tools, by describing percentiles and three categories ($\leq p15$ poor, between $p15$ to $\leq p85$ as adequate and $\geq p85$ high muscular endurance), to assess strength endurance in children and adolescents. These cut-off points allow accurate interpretation of test results and help identify those who might benefit from specific interventions to improve their muscular endurance.

This pattern is also consistent with somatic and functional growth theories, which postulate that peak muscle strength correlates with the time of greatest gain in lean mass during puberty³⁰.

Linking these results to broader theories reinforces the validity of the study design and highlights its contribution to the understanding of physical development in schoolchildren, providing a solid basis for the implementation of this test in the educational and clinical settings.

The study has some limitations that should be acknowledged. For example, the sample selection was non-probabilistic, so the results obtained in this study cannot be generalized to other populations. Also, it was not possible to evaluate an upper limb muscle strength test as a criterion method. In addition, future studies should use other field tests to achieve concurrent validity in pediatric populations.

It is also necessary to highlight the strengths of this study. First, it is one of the first studies to use the biceps curl to assess strength endurance in children and adolescents living in a moderate altitude region of Peru. Secondly, the test proved to be reliable and the test-retest values evidenced stability and wide limits of agreement. Third, the percentiles developed provide useful tools to evaluate and monitor strength endurance performance of both arms according to age and sex, thus contributing to a better understanding and follow-up of muscle development in primary and secondary school children. This tool can also be used to design specific training programs to improve physical performance, prevent muscle fatigue and reduce the risk of injury, thus contributing to their comprehensive development and long-term well-being.

There are several future directions that deserve to be explored, as the findings of this study can serve as a basis for research to analyze whether the characteristics of muscular endurance in the biceps curl vary according

Age (y)	Biceps Curl right										Biceps Curl left									
	L	M	S	P5	P15	P25	P50	P75	P85	P95	L	M	S	P5	P15	P25	P50	P75	P85	P95
Males - Primary education (1 kg)																				
6	−0.15	15.15	0.25	10	12	13	15	18	20	23	−0.64	15.17	0.25	11	12	13	15	18	20	25
7	−0.05	17.5	0.25	12	14	15	18	21	23	27	−0.43	17.82	0.26	12	14	15	18	21	24	28
8	0.05	19.73	0.26	13	15	17	20	24	26	30	−0.22	20.14	0.26	13	16	17	20	24	27	32
9	0.17	21.97	0.27	14	17	18	22	26	29	34	0.01	22.15	0.26	14	17	19	22	27	29	34
10	0.31	24.06	0.28	15	18	20	24	29	32	37	0.24	24.07	0.27	15	18	20	24	29	32	37
11	0.47	26.79	0.28	16	20	22	27	32	35	41	0.46	26.72	0.27	16	20	22	27	32	35	40
Males - Secondary education (2 kg)																				
12	0.59	31.24	0.28	18	23	26	31	37	41	47	0.65	31.19	0.26	19	23	26	31	37	40	46
13	0.64	36.6	0.27	22	27	30	37	44	48	54	0.81	36.56	0.25	22	27	31	37	43	46	52
14	0.64	40.62	0.26	25	30	34	41	48	52	59	0.97	40.54	0.24	25	31	34	41	47	51	56
15	0.61	42.75	0.25	27	32	36	43	50	54	62	1.13	42.45	0.22	27	33	36	43	49	52	58
16	0.57	44.05	0.23	29	34	37	44	51	55	62	1.3	43.53	0.2	28	34	37	44	49	53	58
17	0.54	45.34	0.22	30	36	39	45	52	56	63	1.48	44.73	0.19	30	36	39	45	50	53	58
Females - Primary education (1 kg)																				
6	0.06	14.43	0.25	9	11	12	14	17	19	22	−0.21	15.28	0.29	10	11	13	15	19	21	25
7	0.12	17.02	0.26	11	13	14	17	20	22	26	−0.04	17.43	0.29	11	13	14	17	21	24	28
8	0.18	19.53	0.27	12	15	16	20	23	26	30	0.11	19.62	0.29	12	14	16	20	24	27	31
9	0.25	21.66	0.28	13	16	18	22	26	29	33	0.24	21.64	0.29	13	16	18	22	26	29	34
10	0.33	23.19	0.28	14	17	19	23	28	31	36	0.33	23.27	0.29	14	17	19	23	28	31	36
11	0.41	25.05	0.28	15	18	21	25	30	33	38	0.42	25.23	0.29	15	18	21	25	30	33	39
Females - Secondary education (2 kg)																				
12	0.46	28.32	0.27	17	21	23	28	34	37	42	0.51	28.62	0.27	17	21	24	29	34	37	43
13	0.48	31.95	0.25	20	24	27	32	38	41	47	0.58	32.31	0.25	20	24	27	32	38	41	47
14	0.49	34.36	0.24	22	27	29	34	40	43	49	0.67	34.67	0.23	22	27	29	35	40	43	49
15	0.51	35.05	0.21	24	28	30	35	40	43	49	0.78	35.27	0.21	24	28	30	35	40	43	48
16	0.55	34.7	0.2	24	28	30	35	39	42	47	0.92	35.05	0.19	24	28	31	35	40	42	46
17	0.6	33.84	0.18	25	28	30	34	38	40	44	1.08	34.49	0.18	24	28	30	35	39	41	44

Table 4. Biceps curl values (right and left described in percentiles according to age and sex. P: percentil.

to geographic altitude. In this sense, future studies could evaluate populations in low and high altitude regions, with the main objective of comparing these parameters and determining possible physiological adaptations associated with different geographical conditions.

Conclusion

This study demonstrated that the biceps curl test is a reliable tool to evaluate muscular endurance in children and adolescents living in a moderate altitude region of Peru. The values obtained in the retest showed stability, as well as wide limits of agreement. Furthermore, the proposed percentiles are useful for evaluating and monitoring endurance performance of both arms, considering age and sex. The results support the use of this test as an effective tool for the evaluation and monitoring of submaximal muscular endurance in pediatric populations.

Data Availability

Te dataset used and analyzed during the current study are available from the corresponding author on reasonable request.

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Te dataset used and analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Authors' contributions M.C.B., R.G.C., and R.V.E. contributed to the design of the research study. M.C.B, R.G.C., J.S.T., and L.T.P. collected data. M.C.B., R.G.C., L.C.C., M.A., and P.O., contributed to the discussion, wrote the manuscript and reviewed/edited the manuscript. M.C.B. and R.G.C edited and reviewed the manuscript. All authors revised and agreed on the views expressed in the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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