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Normative Values for Muscular Fitness for Chinese Children and Adolescents Aged 7–18 Years

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Abstract: The primary aim of this study was to establish sex and age-specific muscular fitness (MF) norms for Chinese children and adolescents aged 7–18 years old. The secondary aim was to compare their MF values with those of children and adolescents in other countries and regions. The MF of 93,755 participants from China was evaluated by handgrip strength (upper limbs strength), sit-ups (trunk strength) and a standing broad jump (lower limbs strength), with a total of 90,424, 90,281 and 90,663 data values, respectively. The Lambda-Mu-Sigma (LMS) method was used to calculate smooth curves and table data. The MF of Chinese boys was higher than that of girls in all age groups. After the age of 11, the growth rate of boys accelerated while that of girls slowed down. Age-related changes were larger for boys than for girls. In the international comparison, all the MF indicators of Chinese children and adolescents were lower than those of their Japanese peers but were higher than those of their European peers, with the exception of handgrip strength. The results of this study can be used to evaluate, monitor and apply interventions that improve MF. They can also be used to compare trends across countries and regions.

Keywords: handgrip strength; sit-ups; standing broad jump; percentile curve; muscular fitness

1. Introduction

Muscular fitness (MF) is commonly used to represent muscular strength, endurance and power [1]. Different degrees of MF are needed to complete various exercise tasks; however, all physical movements require muscles to pull bones, which results in displacement [2]. A strong skeletal muscle system can ensure effective physical activity for children and adolescents and reduce their susceptibility to sports injuries [3]. In addition, high levels of MF can positively affect body composition, cardiopulmonary function and bone health and reduce the risk of chronic diseases and disabilities [4–7]. Given the importance of MF, the global physical activity guidelines clearly state that children and adolescents should perform high-intensity physical activities at least 3 days a week to increase muscle and bone strength [8]. Furthermore, appropriate resistance training activities are internationally recommended for children and adolescents [9]. Although MF has received widespread attention, it continues to decline among children and adolescents worldwide [10–14]. The decrease of physical activity and the increase of overweight and obesity may be important reasons for the continuous decline of MF, which has a significant impact on the sustainability of the health of children and adolescents [1].

Currently, MF tests in different countries and regions usually select specific indicators to evaluate the upper limbs, trunk and lower limbs. Handgrip strength is widely used to evaluate the strength of the upper limbs because of its convenience [15], high reliability [16] and validity [17], as well as its high correlation with muscle mass and bone density [18,19]. Sit-ups are an effective indicator of trunk strength. Physiological and biomechanical analyses of sit-ups among different populations have found that sit-ups have good validity and high reliability in all age groups, with no gender difference [20]. The vertical, square, standing broad and countermeasure jumps have all been used to evaluate the strength of the lower limbs in different physical fitness test systems worldwide. In contrast, the standing long jump is more relevant to upper and trunk strength and is characterized by its convenience, practicality, reliability and low cost [21,22].

The key to scientifically and accurately assessing MF lies in developing normative values. At present, many countries and regions have developed MF normative values for their children and adolescents [23–27]. For example, based on 2,779,165 children and adolescents aged 9–17 years old from 30 countries, Tomkinson et al. established sex and age-specific MF norms in Europe for health and fitness screening, profiling, monitoring and surveillance [26]. Since 1985, Catley et al. have analyzed the MF test results of Australian children and adolescents from 9 to 17 years old and have established sex and age-specific MF norms [27]. Previous studies have found that MF varies significantly among children and adolescents based on race, nutrition and social culture [28]. From the perspective of public health, the establishment of accurate MF normative values is of great significance for monitoring, evaluating and improving the physical health of children and adolescents in a region [29]. However, in China's current National Standards for Students' Physical Health, the MF test does not cover all students, and thus the establishment of a complete reference value is not possible. For example, there are no indicators to evaluate lower limb strength at ages 7–12 and no indicators to evaluate trunk strength at ages 7–8. Pull-ups are used to evaluate upper limb strength only in boys, and there is a disadvantage of low differentiation due to the difficulty of completion of this task [30]. In contrast, Japan's MF test has consistent indicators among all age groups and genders, and Japan has established complete MF reference values using yearly national monitoring data [31]. European countries, via the Eurofit test program, have also established a unified MF reference value [26].

To better evaluate and monitor MF and to enable the application of suitable interventions that improve MF among Chinese children and adolescents, the primary aim of the present study was to develop sex and age-specific MF norms for Chinese children and adolescents aged 7–18 years old; the secondary aim was to compare those values with the MF of children and adolescents in other countries and regions.

2. Materials and Methods

2.1. Participants

From 2015 to 2016, the research team conducted a large-scale, cross-sectional survey in six traditional administrative divisions of China (east, north, central south, northwest, southwest and northeast). Taking into account population weight, geographical location and gross national product per capita, the research team selected 27 cities from 31 provinces on the Chinese mainland, each with a primary and secondary school in both rural and urban areas. By using stratified cluster random sampling, test classes were selected from the designated schools. We recruited a total of 93,755 participants by class from schools in the six administrative divisions. Before the investigation, the students and parents were told that the purpose of the study was to understand the physical health of the students. Written informed consent was obtained from both the students and their parents, and the investigation was conducted as an anonymous survey. To avoid bias in testing methods, the research team conducted unified training for the physical education teachers. The same instrument types were used to perform the tests at each site. The data of the handgrip strength, sit-ups and standing broad jump amounted to 90,424, 90,281 and 90,663 samples, respectively, after extreme values were removed. An extreme value was defined as sex and age-specific MF Z score >3 or <−3 standard deviations (SD). This study was approved by the Human Experimental Ethics Committee of East China Normal University (No. HR2016/12055).

The literature on MF norms for children and adolescents from January 2010 to May 2020 was retrieved from the Web of Science for international comparison. The database search strategy was formulated around terms the "childhood OR children OR adolescence OR adolescents OR youth OR teen OR teenager" and "muscular fitness OR physical fitness OR handgrip strength OR grip strength OR sit-up OR standing broad jump OR standing long jump" and "norm OR reference OR normative value". A total of 32 related studies were retrieved from the literature search. The study of Tomkinson et al. is representative, and the test items are consistent with our study [26]; therefore, the data of their study were selected to represent the MF of European children and adolescents. The test items in this study are identical to those in Japan. The original data of MF for Japanese children and adolescents can be downloaded from the website of the Sports Department [31].

2.2. MF Testing

Handgrip strength was measured via an electronic hand dynamometer (Camry, Model: EH101, Camry Electronic, Co., Ltd., Zhongshan, Guangdong, China). The test was conducted with the participants in a standing position with their wrist in a neutral position and their elbow extended. The dominant hand was determined by asking whether the children and adolescents were left-handed or right-handed. The participants were then verbally encouraged to squeeze the handle as tightly as possible for 3–5 s. Three trials were allowed in the dominant hand, with a 60 s break between the trials, and the highest score was recorded as the peak handgrip strength (kg).

During the sit-up test, the participants were positioned flat on a mat with their arms crossed and their palms close to their shoulders, knee joints at 90° and their feet flat on the floor. To complete one sit-up repetition, the participants leaned forward until their elbows touched or passed their knees. We recorded the number of sit-ups completed within 30 s.

For the standing broad jump test, the participants wore light flat shoes and stood with their feet naturally apart behind the take-off line. The participants then jumped in situ, without running-up. We measured the distance from the take-off line to the nearest landing point. Three trials were allowed with a 60 s break between the trials, and the best score was recorded.

Before all the tests, the participants were led by a physical education teacher to do a 15 min warm-up exercise, which included jogging and stretching, to avoid injury.

2.3. Anthropometry

Body height was determined using a mechanical height gauge and measured, without shoes, to the nearest 0.1 cm. Bodyweight was measured in light clothing, without shoes, to the nearest 0.1 kg using an electronic scale. BMI was calculated from the subject's weight and height.

2.4. Statistical Analyses

The last birthday of each participant was used as the criterion for calculating age. The Lambda-Mu-Sigma (LMS) statistical method was used to provide percentile values of MF for Chinese children and adolescents. In brief, this method estimates the measurement centiles in terms of three age–sex-specific cubic spline curves: L curve (with Box–Cox power to remove skewness), M curve (median), and S curve (coefficient of variation) [32]. Smoothing parameters or equivalent degrees of freedom were used to express the extent of smoothing required. Data were imported into the LMS Chart Maker Pro Version 2.54 (Medical Research Council, London, UK) to construct the percentile curves. The effective degrees of freedom in the present study were 1 (L curve), 4 (M curve) and 3 (S curve) for boys, and 1 (L curve), 3 (M curve) and 3 (S curve) for girls.

For each MF test, differences in means between (a) age-matched Chinese boys and girls, (b) sex-matched Chinese children and adolescents of different ages and (c) sex and age-matched

Chinese and international children and adolescents were expressed as standardized effect sizes (11). For example, the standardized effect size of handgrip strength at age 7 equals the handgrip strength performance of 7-year-old boys minus the handgrip strength of 7-year-old girls, divided by the standard deviation of handgrip strength of 7-year-old girls. In age-matched Chinese boys and girls, we took the girls' mean MF performances of each age group as a reference and standardized the boys' MF. Positive effect sizes indicated that the mean MF performances for boys were higher than those for girls. In sex-matched Chinese children and adolescents of different ages, we standardized the MF performances of boys and girls aged 7–17 with reference to their 18-year-old mean MF performances. Negative effect sizes indicated that the mean MF performances for older children and adolescents were higher than those for younger children and adolescents. In sex and age-matched Chinese and international children and adolescents, we used the mean MF performances of boys and girls of each age group in China as a reference to standardize the MF performances of children and adolescents in Europe and Japan. Positive effect sizes indicated that the mean MF performances for international children and adolescents were higher than those for Chinese peers. Effect sizes of 0.2, 0.5 and 0.8 or −0.2, −0.5 and −0.8 were used as small, moderate and large thresholds, respectively [33].

3. Results

Tables 1–3 show the handgrip strength, sit-ups and standing broad jump normative values of Chinese 7–18-year-old children and adolescents from the fifth to the 95th percentile.

Table 1. Handgrip strength (kg) centiles by age and sex based on 90,424 performances of children and adolescents aged 7–18 years.

Age (y)	N	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
Boys												
7	5018	5.99	6.86	7.97	8.79	9.51	10.20	10.90	11.67	12.59	13.90	15.00
8	3447	7.29	8.34	9.66	10.65	11.51	12.34	13.18	14.10	15.20	16.77	18.09
9	3836	8.65	9.88	11.43	12.59	13.60	14.57	15.56	16.64	17.93	19.77	21.32
10	4127	10.18	11.63	13.44	14.80	15.99	17.13	18.29	19.56	21.07	23.22	25.04
11	4106	12.03	13.73	15.88	17.48	18.89	20.23	21.60	23.09	24.87	27.41	29.56
12	3832	14.24	16.25	18.77	20.65	22.31	23.88	25.49	27.25	29.34	32.32	34.84
13	3785	16.75	19.05	21.96	24.12	26.02	27.83	29.68	31.70	34.10	37.53	40.42
14	3795	19.39	21.95	25.18	27.59	29.70	31.71	33.76	36.00	38.66	42.45	45.66
15	4125	22.04	24.80	28.27	30.85	33.10	35.25	37.44	39.82	42.66	46.70	50.11
16	4011	24.65	27.52	31.12	33.79	36.12	38.34	40.60	43.06	45.99	50.14	53.65
17	3361	27.21	30.13	33.77	36.47	38.83	41.07	43.35	45.83	48.77	52.95	56.48
18	2850	29.78	32.70	36.35	39.05	41.39	43.63	45.89	48.35	51.28	55.42	58.91
Girls												
7	4437	5.39	6.21	7.26	8.05	8.74	9.42	10.11	10.86	11.77	13.08	14.20
8	3201	6.77	7.75	9.00	9.95	10.78	11.58	12.40	13.30	14.38	15.93	17.26
9	3726	8.19	9.33	10.77	11.86	12.82	13.74	14.68	15.71	16.95	18.73	20.25
10	3670	9.64	10.92	12.54	13.76	14.83	15.87	16.92	18.08	19.46	21.45	23.14
11	3616	11.08	12.49	14.27	15.61	16.79	17.92	19.08	20.35	21.86	24.03	25.88
12	3513	12.48	14.00	15.93	17.37	18.64	19.85	21.10	22.46	24.09	26.41	28.39
13	3403	13.79	15.40	17.45	18.98	20.32	21.61	22.92	24.36	26.08	28.53	30.62
14	3546	14.98	16.67	18.81	20.41	21.82	23.16	24.53	26.03	27.82	30.38	32.56
15	3911	16.06	17.82	20.04	21.70	23.15	24.54	25.96	27.50	29.36	32.00	34.24
16	4052	17.06	18.87	21.15	22.86	24.35	25.78	27.23	28.82	30.72	33.43	35.73
17	3687	18.00	19.86	22.20	23.94	25.47	26.93	28.41	30.03	31.97	34.74	37.08
18	3369	18.93	20.83	23.22	24.99	26.55	28.03	29.55	31.20	33.17	35.98	38.36

Note: Ages shown represent age at last birthday (e.g., 7 = 7.0–7.9).

Table 2. Sit-ups (n/30 s) centiles by age and sex based on 90,281 performances of children and adolescents aged 7–18 years.

Age (y)	N	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
Boys												
7	5005	7.02	8.48	10.37	11.80	13.08	14.32	15.59	16.99	18.67	21.10	23.19
8	3433	8.07	9.66	11.71	13.26	14.64	15.97	17.34	18.85	20.67	23.28	25.51
9	3838	9.14	10.83	13.00	14.65	16.11	17.52	18.97	20.56	22.47	25.22	27.57
10	4115	10.18	11.95	14.22	15.94	17.45	18.91	20.41	22.06	24.04	26.88	29.31
11	4118	11.24	13.07	15.40	17.17	18.73	20.22	21.76	23.44	25.47	28.37	30.84
12	3845	12.31	14.19	16.59	18.39	19.99	21.51	23.08	24.79	26.85	29.80	32.30
13	3794	13.38	15.30	17.75	19.59	21.21	22.76	24.35	26.09	28.17	31.15	33.69
14	3777	14.35	16.31	18.79	20.65	22.28	23.85	25.45	27.20	29.30	32.30	34.85
15	4071	15.14	17.10	19.57	21.43	23.06	24.62	26.21	27.95	30.04	33.01	35.54
16	3992	15.71	17.64	20.08	21.90	23.50	25.03	26.59	28.30	30.34	33.25	35.72
17	3343	16.11	17.99	20.37	22.14	23.70	25.19	26.70	28.36	30.34	33.16	35.55
18	2828	16.43	18.26	20.57	22.29	23.79	25.23	26.69	28.29	30.20	32.92	35.22
Girls												
7	4427	7.21	8.72	10.66	12.14	13.44	14.70	15.99	17.41	19.12	21.58	23.67
8	3184	8.04	9.62	11.64	13.17	14.53	15.83	17.17	18.64	20.40	22.93	25.09
9	3711	8.90	10.53	12.61	14.19	15.58	16.92	18.29	19.79	21.60	24.18	26.39
10	3665	9.74	11.41	13.54	15.15	16.57	17.93	19.32	20.85	22.68	25.30	27.52
11	3612	10.53	12.23	14.39	16.02	17.45	18.83	20.23	21.77	23.62	26.25	28.50
12	3525	11.22	12.95	15.14	16.78	18.22	19.61	21.02	22.57	24.43	27.08	29.32
13	3421	11.80	13.55	15.76	17.42	18.87	20.27	21.69	23.25	25.12	27.78	30.04
14	3534	12.25	14.02	16.26	17.93	19.40	20.81	22.25	23.82	25.70	28.39	30.66
15	3901	12.60	14.38	16.64	18.34	19.82	21.24	22.69	24.28	26.18	28.88	31.18
16	4054	12.86	14.66	16.94	18.64	20.14	21.57	23.03	24.63	26.54	29.26	31.57
17	3716	13.06	14.87	17.16	18.87	20.38	21.82	23.29	24.89	26.81	29.54	31.86
18	3372	13.24	15.06	17.36	19.08	20.58	22.03	23.50	25.11	27.03	29.77	32.09

Note: Ages shown represent age at last birthday (e.g., 7 = 7.0–7.9).

Table 3. Standing broad jump (cm) centiles by age and sex based on 90,663 performances of children and adolescents aged 7–18 years.

Age (y)	N	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
Boys												
7	5038	85.96	93.76	102.99	109.51	115.01	120.09	125.12	130.44	136.60	145.03	151.89
8	3445	95.17	103.39	113.12	120.01	125.82	131.19	136.50	142.13	148.64	157.55	164.82
9	3859	104.30	112.88	123.06	130.27	136.35	141.97	147.54	153.44	160.26	169.61	177.23
10	4137	113.33	122.26	132.85	140.35	146.69	152.54	158.34	164.49	171.61	181.36	189.32
11	4125	122.62	131.90	142.93	150.74	157.34	163.44	169.49	175.90	183.32	193.49	201.79
12	3852	132.52	142.20	153.70	161.86	168.74	175.12	181.43	188.13	195.89	206.52	215.20
13	3792	142.94	153.01	164.97	173.46	180.64	187.28	193.86	200.83	208.92	220.01	229.06
14	3802	153.21	163.57	175.89	184.64	192.04	198.88	205.67	212.87	221.21	232.66	242.00
15	4114	162.53	173.01	185.49	194.36	201.86	208.80	215.69	222.99	231.47	243.09	252.58
16	4030	170.39	180.83	193.26	202.11	209.58	216.51	223.39	230.68	239.14	250.75	260.24
17	3368	176.97	187.24	199.48	208.19	215.56	222.40	229.17	236.37	244.72	256.19	265.56
18	2845	182.87	192.91	204.89	213.42	220.64	227.34	233.98	241.04	249.23	260.48	269.68
Girls												
7	4472	86.21	93.31	101.96	108.25	113.65	118.72	123.81	129.27	135.70	144.65	152.09
8	3215	94.16	101.40	110.23	116.64	122.15	127.31	132.50	138.07	144.61	153.73	161.31
9	3738	102.05	109.38	118.32	124.80	130.37	135.59	140.84	146.46	153.08	162.29	169.94
10	3687	109.60	116.96	125.93	132.43	138.01	143.24	148.49	154.13	160.76	169.99	177.64
11	3618	116.55	123.88	132.80	139.27	144.82	150.02	155.24	160.85	167.43	176.60	184.21
12	3529	122.71	129.96	138.78	145.18	150.67	155.82	160.98	166.52	173.02	182.09	189.60
13	3415	127.94	135.09	143.80	150.10	155.51	160.58	165.67	171.13	177.54	186.46	193.86
14	3547	132.21	139.25	147.82	154.04	159.36	164.36	169.37	174.74	181.05	189.83	197.11
15	3920	135.56	142.50	150.95	157.06	162.31	167.22	172.15	177.44	183.65	192.29	199.46
16	4053	138.17	145.00	153.32	159.34	164.50	169.34	174.19	179.39	185.50	194.00	201.05
17	3706	140.28	147.01	155.19	161.12	166.20	170.96	175.73	180.85	186.86	195.23	202.16
18	3356	142.16	148.79	156.84	162.68	167.68	172.36	177.06	182.10	188.02	196.25	203.07

Note: Ages shown represent age at last birthday (e.g., 7 = 7.0–7.9).

Figure 1 shows the smooth curves for the 10th, 50th and 90th percentiles. Handgrip strength, sit-ups and standing broad jump measurements all increased with age.

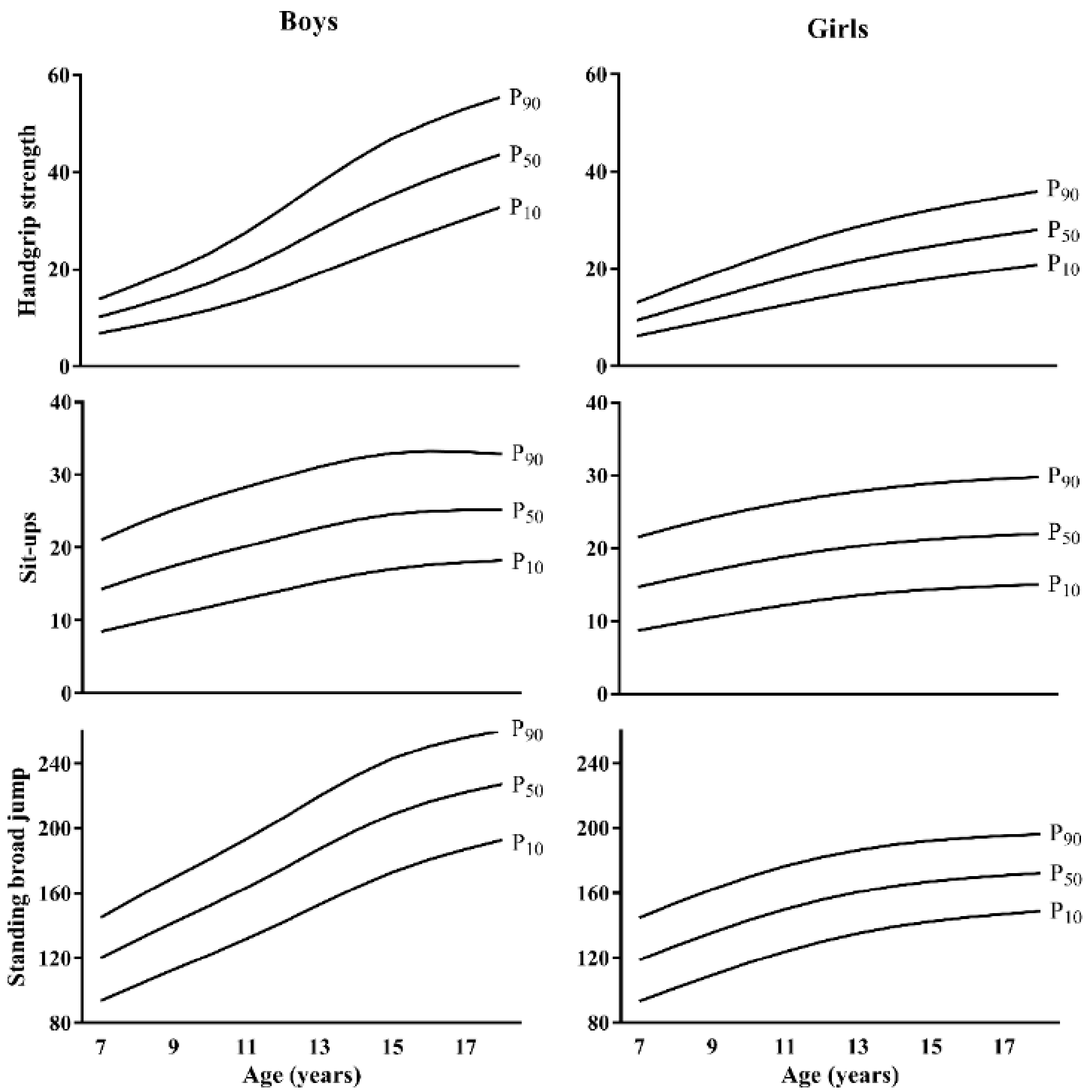

Figure 1. Smoothed centile curves (P_{10}, P_{50} and P_{90}) for handgrip strength (kg), sit-ups (*n*/30 s) and standing broad jump (cm) for Chinese children and adolescents.

Figure 2 shows the sex-related differences of MF. The handgrip strength, sit-ups and standing broad jumps of boys showed higher values than those of girls at all ages. There was little difference between boys and girls before 11 years old (effect size < 0.5); however, the difference progressed after age 11, especially in terms of handgrip strength and the standing broad jump.

Figure 3shows the age-related changes of MF. The age-related changes were larger for boys than for girls, which showed that the MF of boys increased more with age. For example, from the age of 7 to 18, the grip strength of boys increased by 425% and that of girls increased by 197%.

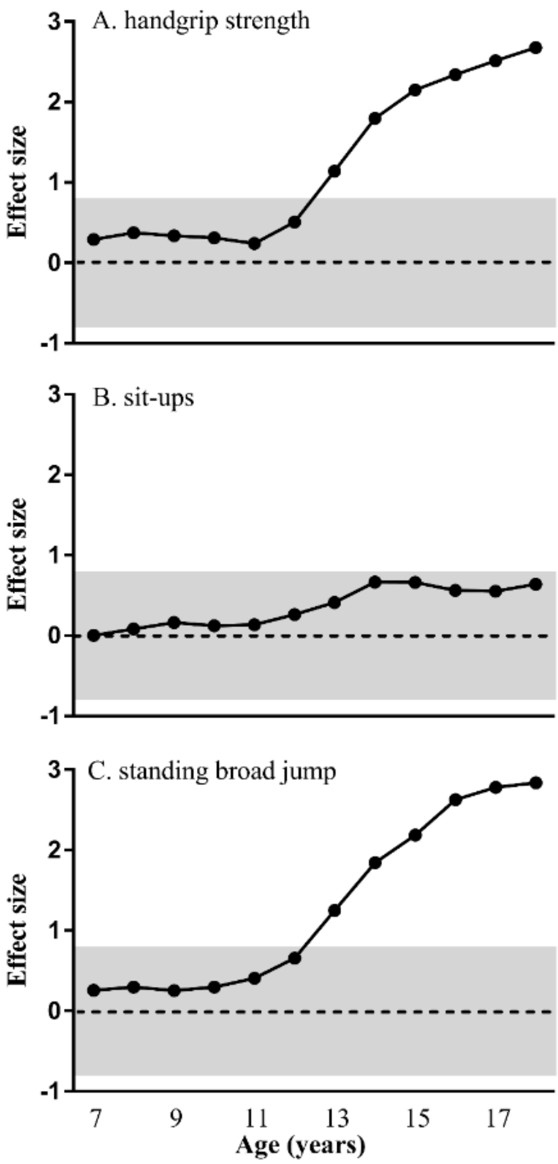

Figure 2. Sex-related differences in muscular fitness (MF) ((**A**) handgrip strength, (**B**) sit-ups, (**C**) standing broad jump) expressed as effect sizes. The limits of the grey zone represent the threshold for a large standardized difference (i.e., 0.8 or −0.8). Positive differences indicated that MF for boys were better than those for girls.

Figure 4 shows the differences in MF between Chinese children and adolescents and their international peers. Data on the MF of their European peers are from the study conducted by Tomkinson et al. The raw data are in percentile form. Owing to the large sample size, the 50th percentile can be used instead of the mean. The 50th percentile values of the handgrip strength of boys and girls aged 9–17 years in Europe were 15.3–45.0 kg and 13.6–28.4 kg, sit-ups were 17–25 times and 17–20 times and standing broad jumps were 133.8–205.8 cm and 123.9–156.4 cm, respectively. MF data for Japanese peers are from the official website of the Japanese government's Sports Department. The means of handgrip strength of Japanese boys and girls aged 7–18 years were 11.2–41.6 kg and 10.4–6.9 kg, sit-ups were 14.6–30.7 times and 13.9–23.3 times and standing broad jumps were 126.3–229.0 cm and 117.8–168.6 cm, respectively. The handgrip strength of Chinese children and adolescents was lower than that of their Japanese peers at all ages except 18 years, but the difference was small (effect size < 0.3). The handgrip strength of Chinese boys after the age of 13 years and girls after the age of 12 years was lower than that of their European peers, but the difference was slight (effect size < 0.3), except for the 14-year-old girls. Chinese children and adolescents scored lower than their Japanese peers after 8 years of age in sit-ups, and there was a great difference in boys after 13 years of age (effect size > 0.5). The numbers of sit-ups of Chinese children and adolescents were slightly higher than their European peers, but the difference was slight (effect size < 0.5). The standing broad jump distance of Chinese children and adolescents was lower than their Japanese peers, but the difference was slight (effect size < 0.5). The standing broad jump distance of Chinese children and adolescents was higher than that of their European peers, and there was a great difference after the age of 13 years (effect size > 0.5).

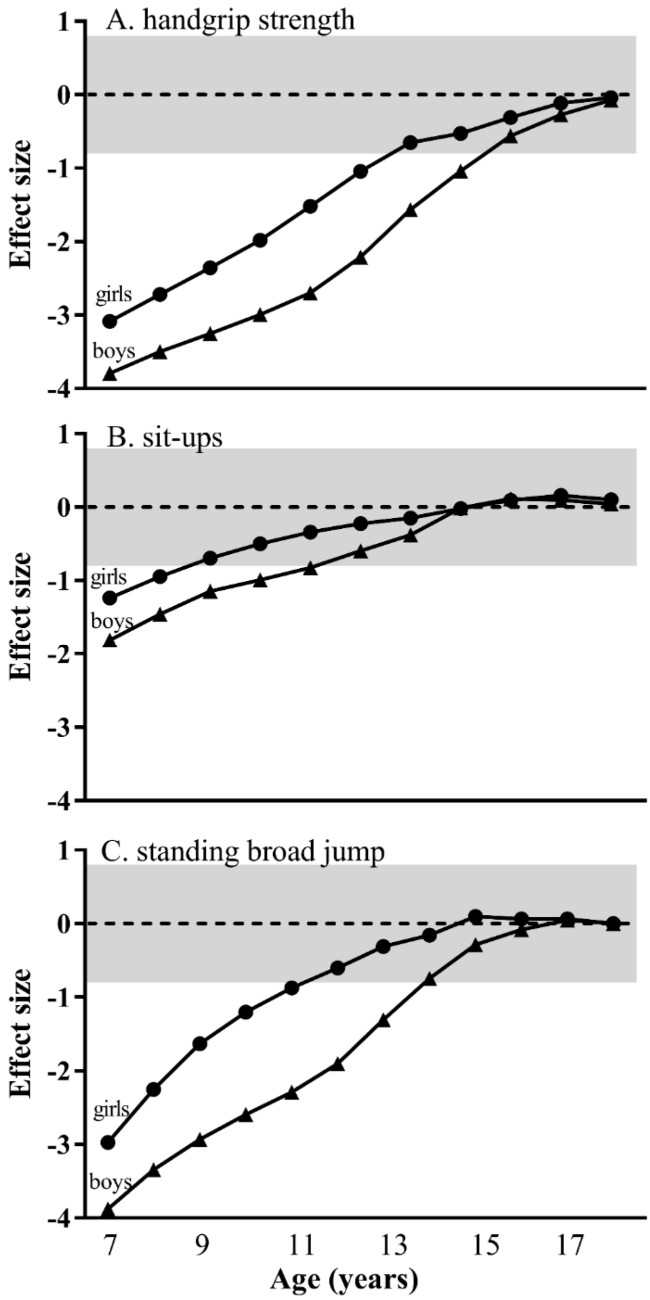

Figure 3. Age-related changes in MF ((**A**) handgrip strength, (**B**) sit-ups, (**C**) standing broad jump) expressed as effect sizes standardized to an effect size of age 18 years = 0. The limits of the grey zone represent the threshold for a large standardized difference (i.e., 0.8 or −0.8). Negative differences indicated that MF scores for older children and adolescents were better than those for younger children and adolescents.

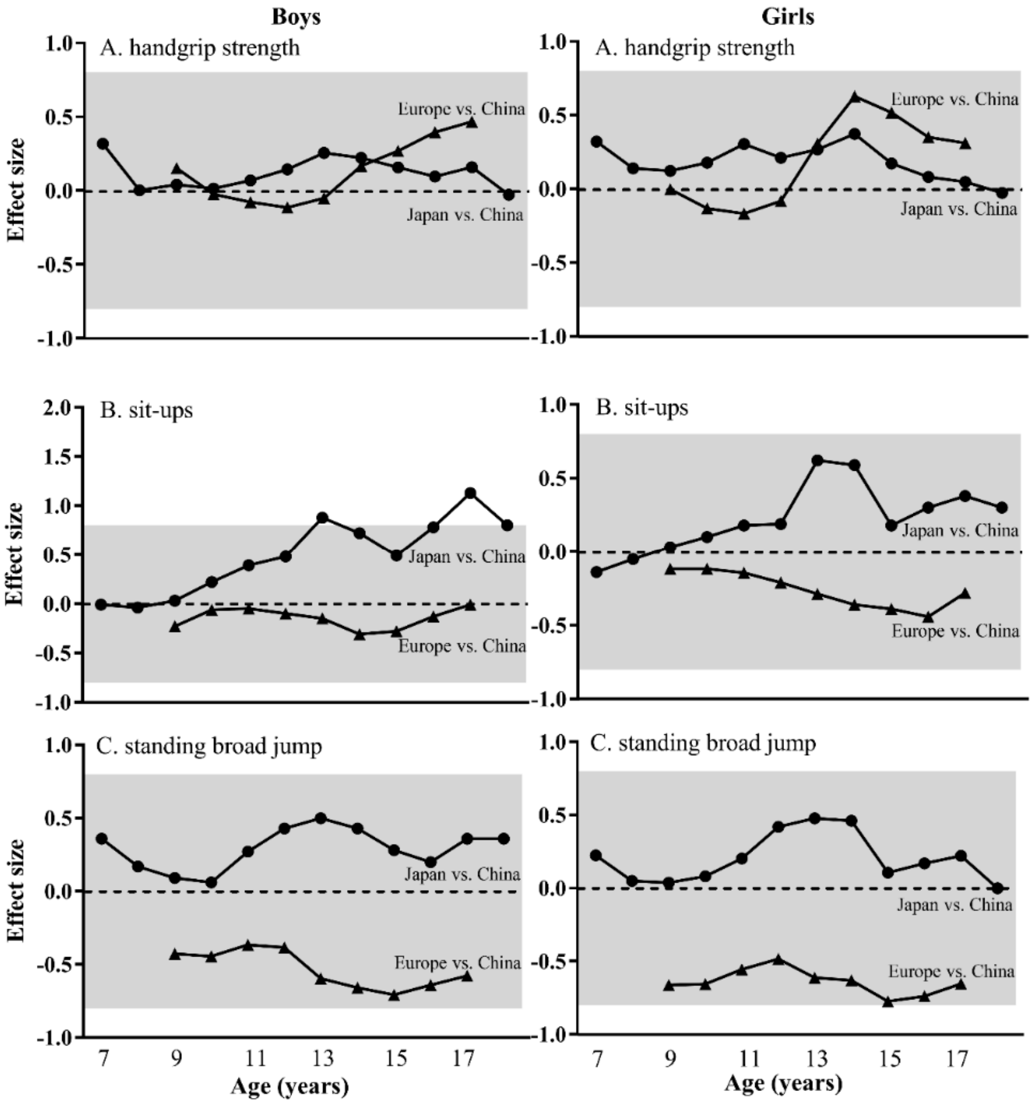

Figure 4. Sex and age-specific effect sizes for MF ((**A**) handgrip strength, (**B**) sit-ups, (**C**) standing broad jump) for Chinese boys and girls relative to their international peers. The limits of the grey zone represent the threshold for a large standardized difference (i.e., 0.8 or −0.8). Positive differences indicated that MF scores for international children and adolescents were better than those for Chinese peers. In the comparative data, n = 203,295 handgrip strength performances, n = 481,032 sit-ups performances, n = 464,900 standing broad jump performances in Europe; n = 30,051 handgrip strength performances, n = 29,817 sit-up performances, n = 29,858 standing broad jump performances in Japan.

4. Discussion

Many countries and regions in the world have developed MF normative values for children and adolescents. However, because there is no unified MF test index, China has not yet developed MF normative values for children and adolescents. Therefore, population weighing, the geographical location and the gross domestic product per capita of various regions of China were comprehensively considered in this study, and representative samples were selected to provide MF normative values for Chinese children and adolescents aged 7–18 years for the first time. In addition, this study found that the MF of Chinese boys was greater than that of Chinese girls at all ages, and that age-related changes were larger for boys than for girls. Finally, all MF indicators of Chinese children and adolescents were lower than those of their Japanese peers, but their sit-up and standing broad jump results were better than those of their European peers.

Based on the MF data of 93,755 children and adolescents, this study developed the most representative sex and age-specific MF normative values for 7–18-year-old children and adolescents in China, which can be used for the evaluation, monitoring and intervention of MF. Furthermore, this study has important practical significance for improving the MF of children and adolescents in China. Although the data in this study were not directly related to health outcomes, individuals with a low MF could be screened out by comparisons with their peers, which could reflect individuals' health statuses to a certain extent. Following the recommendations of the existing literature, this study used a standard five-quantile-based framework to classify MF levels in children and adolescents [34]. Children and adolescents below the 20th percentile were classified as "very low/poor", in the 20–40th centiles as "low/poor", in the 40–60th centiles as "moderate", in the 60–80th centiles as "high/good", and those above the 80th centile as "very high/good" [34]. One study showed that individuals below the 20th percentile had a higher health risk, and this is often used as a threshold to define healthy and unhealthy [35]; however, a Swedish cohort study showed significantly higher rates of all-cause mortality, cardiovascular disease mortality, and suicide mortality in populations with an MF below the 10th percentile [4]. This suggests that further research is needed to determine the minimum threshold for health-related MF to reduce the risk of multiple diseases and avoid developmental problems through early intervention.

This study found that there were large differences based on sex and age in the MF scores of Chinese children and adolescents. The specific performance is as follows: (1) the MF score of the boys was higher than that of the girls in all age groups; (2) the difference in MF scores of boys and girls gradually increased after the age of 11 years, with the MF of boys increasing rapidly while that of the girls slowed down; (3) the increase of MF in boys from 7 to 18 years old is greater than that in girls. Similar differences in sex and age have been found in many previous studies, which may be due to two factors. First, this may be related to sex differences in height and weight observed between sexes, which are important predictors of MF [36]. In the growth process of children and adolescents, height and weight increase with age, and the growth peaks at about 12 years of age [37]. In this period, the slope of the height and weight growth curve of the boys was larger than that of the girls, and the body shape showed a significant difference based on sex [37]. Second, the difference may be related to the physiological maturity of adolescence. After puberty, the influence of physiological maturity on the MF of adolescents differs between sexes. According to a study, the increase in physical fitness, such as strength, of adolescent girls is mainly due to an increase in height and weight, while boys' physical fitness changes qualitatively due to other factors (such as the level of androgen, especially testosterone) [38].

This study found that compared with European peers, Chinese children and adolescents have less upper limb strength and greater trunk and lower limb strength, while compared to their Japanese peers, Chinese children and adolescents have less upper limb, trunk and lower limb strength. The difference in MF scores between Chinese and European children and adolescents is mainly related to the difference in body type. A previous study found that the average height and weight of children and adolescents in Europe was higher than those in China [39]. Although a higher height and weight have a positive impact on handgrip strength, which measures absolute strength, they negatively impact tests wherein subjects must overcome their weight, such as sit-ups and standing broad jumps [40]. This is also an important reason why the curves seem to maintain similar shapes when compared between sit-ups and standing broad jumps, as in both exercises, the individuals need to overcome their own weight. In addition, MF is not only related to body shape but is also regulated by genetic factors [40]. Leong et al. conducted a prospective epidemiological study on the predictive value of handgrip strength in 17 countries. The results showed that Africans had the lowest handgrip strength, with Arabs slightly higher, that Chinese were similar to Latinos and that Europeans had the highest handgrip strength [41]. For differences in handgrip strength between races, a previous twin study showed that genetics accounts for about a third to a half of the variation [42–44].

The difference in MF between Chinese and Japanese children and adolescents may be related to physical activity [40]. First, both Chinese and Japanese ethnicities belong to the Mongolian race in East Asia, and they have a similar genetic background with little difference in genetic factors [45]; second, this study adopts the same MF test method as that of Japan to avoid methodological bias; third, there is little difference in the height and weight between Chinese and Japanese children and adolescents, and in some age groups, these variables are higher in China than in Japan. The main difference between Chinese and Japanese children and adolescents is physical activity. According to the results of the Global Matrix 3.0 on physical activity for children and youth, the physical activity evaluation indexes of Chinese children and adolescents are lower than those of Japan, especially in terms of organized sport and physical activity and active transportation [46]. It is suggested that Chinese government departments should provide strong policy support, pay attention to school-based physical activity intervention and promote organized sport and physical activity [47]. At the same time, government departments should also create a good physical activity environment to increase active transportation [48,49].

A strength of the present study is the large scope and variation in the study population, which covered six administrative regions of China, which also greatly increases the generalizability of the findings. However, some methodological limitations must be taken into consideration. First, this study is a cross-sectional study and is therefore unable to judge the long-term trend of MF development in Chinese children and adolescents. Second, there are differences among children and adolescents in different areas of China in terms of their lifestyle, ethnicity and dietary habits, which may affect MF and lead to biased results. Third, the Eurofit handgrip strength test is different from that used in this study, which may affect the research results.

5. Conclusions

This study is the first to provide sex and age-specific normative values for Chinese children and adolescents aged 7–18 years that can be used for the evaluation, monitoring, and intervention of MF. By comparing an individual's MF with the normative value for their age and sex, a relative level of MF can be determined. For individuals with MF indicators below the 20th percentile, timely intervention may be required; for individuals above the 80th percentile, elite sporting or athletic development programs can recruit them for participation. Secondly, the data of this study can be used for cross-country and regional comparisons, which is helpful to promote the MF of Chinese children and adolescents. Finally, given the importance of MF to the health of children and adolescents, we suggest that the education and health departments of the Chinese government should adopt unified indicators to monitor the MF of children and adolescents aged 7–18 as soon as possible to reverse the continuous decline of MF in Chinese children and adolescents.

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