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Original Article

Normative reference values of grip strength, the prevalence of low grip strength, and factors affecting grip strength values in Indian adolescents

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Abstract
Problem statement: Grip strength is important in clinical and research settings to identify individuals who may be at risk for poor health outcomes and to monitor the effectiveness of interventions aimed at improving grip strength. ***Purpose:*** To develop age-and sex-specific hand grip strength reference standards and to explore the potential factors causing poor grip strength for Indian adolescents. ***Methods:*** A total of 1000 students (50% girls) aged 12 – 16 years were selected from the schools situated in different geographic divisions of North India using a probabilistic random cluster sampling. 'Peak Isometric grip strength' was measured following a standardized procedure using a standard adjustable-handle Jamar dynamometer. Percentile curves for age and sex were calculated. Pearson coefficient correlation was used to find out the existing relationship between quantitative variables. Bivariate logistic regression (odd ratio) was calculated to explore the potential factors affecting hand grip strength. Age and sex-related standardized effect sizes for identified factors causing poor grip strength were expressed in graphical form. ***Results:*** The study revealed that the hand grip strength performance improved with age along with the analyzed percentiles and Boys had higher values compared to Girls. Body mass and body stature were positively correlated to hand grip strength. underweight (BMI<18.5) and low economic status were recognized as potential factors responsible for poor grip strength in Indian adolescents. ***Conclusions:*** Norms for hand grip strength were provided for adolescents aged 12 -16 years. The obtained findings will enable physicians and therapists to take grip strength as an index of health status in normal children and adolescents for identifying the clinical application of the study.
Key Words: Grip Strength, Adolescents, Norms

Introduction

From early childhood, it is necessary to produce enough grip force to manage independently everyday tasks such as eating and playing. Grip strength is important as a measure of general health and is often estimated in screenings of normal motor function. It is also regarded as one of the most reliable clinical methods for the estimation of strength and is used extensively on adults (Mathiowetz et al., 1985; Nara, Kumar, Rathee, & Kumar, 2022; Thorngren & Werner, 1979). Hands are used in all activities of daily living, such as self-care, school, work, play, and leisure activities (Bohannon et al., 2006). Therefore, evaluation of hand function has become an essential part of physical/occupational therapy assessment for children with a range of disorders such as trauma, congenital, and neurological disorders. Normative data on hand grip strength are important to help identify the level of development and the degree of disability, to determine the efficacy of rehabilitation, and to assess the integrity of upper limb functions (American Society of Hand Therapists., 1981; Fess, 2002). For children, it has also become a routine as part of the clinical assessment of hand function since many children with various diseases or lesions have reduced grip strength. It is also used for treatment planning and evaluation.

Numerous studies have been published about hand grip strength for adults of different age groups and from diverse populations (Amaral et al., 2019; Bohannon, 2019; Halaweh, 2020; Hooyman et al., 2021; Mehmet et al., 2020; Zammit et al., 2019). However, few studies have been published on norms of hand grip strength in children and adolescents (Ager et al., 1984; Amaral et al., 2019; Daniels & Backman, 1993; Häger-Ross & Rösblad, 2002; Jeune et al., 2006; Molenaar et al., 2010; Omar et al., 2015; Sartorio et al., 2002). The most recent studies provided data from children in the USA (Kocher et al., 2019) and China (Zhang et al., 2021). The result from these studies revealed that the general level of grip strength has changed over generations and there may also be a cultural difference. In analogy, grip strength scores in a group of American children in 1964 were advanced by 1.5 – 2 years compared with data collected as early as 1899 (Montpetit et al., 1967). Moreover, Jenue and colleagues (Jeune et al., 2006) concluded that hand grip strength may differ across regions. This may be due to sociocultural differences such as nutritional status, leisure activities, technology development, and modernization. Therefore, establishing norms of hand grip strength for each geographical region is important for therapists.

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To our knowledge, there is no report on the normative data of hand grip strength for Indian children and adolescents. Hand grip strength is one of the basic elements to be analyzed therapists compare typical and atypical children. Currently, the data on hand grip strength from Western countries has been used as a reference for the Indian population. However, these data are considered inappropriate because they do not take into account the differences in physical characteristics according to race/ethnicity and region. This is the same logic as using different norms for height and weight according to race/ ethnicity and region. Earlier research evident that Indian students have lower values of height and weight than their Western counterparts (Bridger Staatz et al., 2021; Choudhary et al., 2021; Khadilkar & Anuradha V, 2015; Nara, Kumar, Rathee, Kumar, et al., 2022; Pathmanathan & Prakash, 1994). Therefore, the Indian population may also vary in hand strength when compared to existing Western demographics. The current study aims to provide normative values of hand grip strength for 12 – 16-year-old students in India and to make comparison with existing western data.

Materials and Methods

Participants

The participants of this study were adolescents aged between 12 to 16 years, from the Haryana province located in the northern region of India, who returned the informed consent terms, signed by the guardians, and a completed questionnaire, within one to two weeks. The sample was probabilistic by clusters, within the random selection of 25 rural and urban public schools (10 private, 15 govt.) out of six administrative divisions of Haryana. The study protocol was approved by the Ethics Committee of Chaudhary Ranbir Singh University, Jind, Haryana.

A total group of 1800 subjects was initially selected and the exclusion criteria were: the presence of previous or present pathology in the upper limbs; or if they had visual, auditory, or vestibular defects, which could influence the measurements of strength. Inclusion criteria were age between 12 and 16 years and body height between 120 and 170 cm for girls and between 120 and 180 cm for boys. Maximum isometric grip strength was tested in successive participants fulfilling these criteria. The final sample of the participants, after the exclusions, totaled 1000 individuals (50% girls).

All the measurements were carried out following relevant guidelines and were conducted by trained staff. In each school, 1 – 2 professionals specialized in human sports science, and 4 – 5 trained and qualified physical education teachers were in charge of the measurements. To reduce measurement error, the measurement instruments were calibrated before use and the test was completed at a prior scheduled time of the day to reduce the data deviation caused by different test times.

Height was determined to the next succeeding 1 mm using a Harpenden stadiometer. Weight was measured to the nearest 0.1 kg using digital electronic scales with the students wearing very light clothes. Body Mass Index was calculated using weight in kg/height in meter^2.

Grip Strength Testing

Maximal isometric grip strength of the dominant and non-dominant hand was determined with a standard adjustable-handle Jamar dynamometer (Preston, Jackson, MI, U.S.A). The positioning of the individual during the collection was as per the recommendation by the American Society of Hand Therapists (ASHT), and by the International Federation of Societies for Surgery of the Hand (IFSSH) (Abdalla et al., 2005; Fess, 1986; Hunter et al., 2002). The positioning during the evaluation was seated in a chair without armrests, with the feet resting fully on the ground and the hip against the back of the chair. The arm remained parallel to the body, shoulder abducted, elbow extended at 90° and forearm in a natural position, wrist between 0° to 30° and 0° to 15° of ulnar deviation. Three consecutive measurements of the hands were performed for each palmar grip, alternating between the dominant and non-dominant sides, with a minimum interval of one minute between them to avoid muscle fatigue. The maximum value of two trials was noted for both the dominant and non-dominant hand.

Statistical Analysis

All statistical calculations were carried out using the IBM SPSS 26 (IBM, Armonk, NY, USA) statistical package and Originlab Pro 2023, 10.0.0.154 [(Learning Edition), registration ID: 0PC-B97-UFX].

Qualitative variables were presented as numbers and percentages, while quantitative variables were characterized using arithmetic mean and standard deviation. Percentile curves (5^{th} to 95^{th}) for each age group in respect of their grip strength was calculated using SPSS version 26, which summarizes the changing distribution of centile curves. Age and sex-specific values were calculated for the grip strength test. Besides, percentile values, mean, median, mode, minimum, and maximum values were also calculated and represented with percentile cut-points to acknowledge the distribution of the raw scores.

An Independent sample t-test was used to compare the two independent groups. Effect size (Cohen's d) was calculated to assess the degree of differences. Effect sizes of 0.2, 0.5, and 0.8 were used as thresholds for small, moderate, and large (Cohen, 1988). Karl Pearson correlation coefficient was performed to assess the significant relationship among the quantitative variables. Mukaka guidelines (Mukaka, 2012) were used to interpret correlation coefficients in medical research: greater than 0.9 (very high), 0.7 to 0.9 (high), 0.5 to 0.7 (moderate), 0.3 to 0.5 (low), and less than 0.3 (negligible). To explore which factors were potentially related to the low grip strength, the odd ratio (OR) and its 95% confidence interval was analyzed using binary logistics regression. The level of statistical significance was set at 0.05.

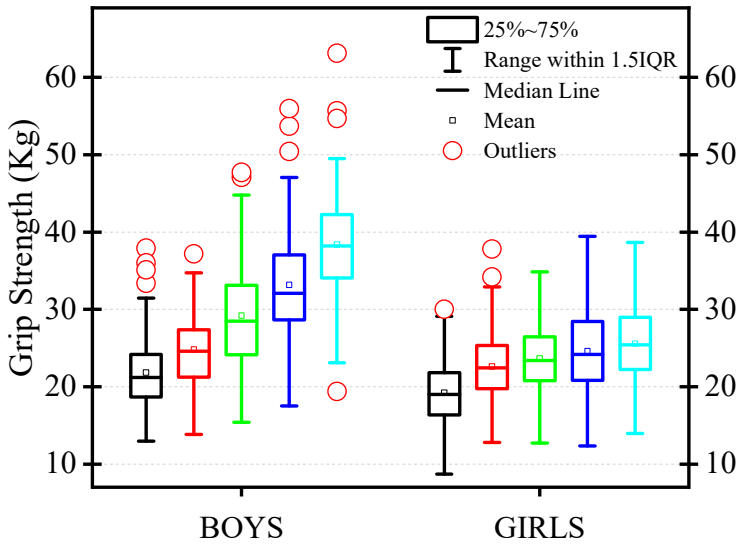

Fig. 1 Box plot showing maximum isometric grip strength of the dominant hand in each age group (12 – 16, left to right) for boys and girls.

Results

Table 1 showed the average of physical variables i.e., stature (standing height), body mass (weight), and body mass index. Table 2 showed the average and deviation grip strength of the dominant and non-dominant hands. In general, the dominant hand has a statistically significant difference ($p<0.05$) in comparison to the non-dominant hand for age and sex. Table 3 explored the sex and age-specific percentile values (5^{th}, 10^{th}, 25^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th}, 75^{th}, 80^{th}, 90^{th}, 95^{th} percentiles) for the grip strength test. Figure 1 depicts the data distribution information in terms of a box plot graph. Each box represents the 25^{th} – 75^{th} percentile and the horizontal line across the box is the median (50^{th} percentile).

Whisker lines extending above and below each box indicate the total range, with the exception of small dark rhombus shapes that represent outliers and a small square in the middle of the box representing the arithmetic mean. Figure 3 showed the percentile curves for 5^{th} to 95^{th} percentiles for grip strength measurement across different age and sex groups. The grip strength performance improved with age along with analyzed percentiles. For example, from 12 to 16 years old, the score of hand grip strength increased by 79.54% for boys and 35.29% for girls at P_{50} (Table 3). The largest rate (19.12%) of occurring was observed in 16 years age group for boys and 13 years age group for girls respectively. Boys had considerably better grip strength than girls across all age groups. The lowest rate of grip strength was noticed in 15 years age group for both sexes.

Table 1 Physical characteristics of participants, across age ranged and gender

	N size		Stature (cm)		Body Mass (kg)		BMI ($kg.m^{-2}$)	
Age	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
12	100	100	147.50	148.40	37.43	37.16	17.02	16.76
13	100	100	154.20	152.86	41.13	42.68	17.19	18.14
14	100	100	159.45	153.83	47.89	43.34	18.61	18.22
15	100	100	164.58	155.44	50.85	45.11	18.68	18.62
16	100	100	167.78	155.44	55.82	45.72	19.72	18.91
Total	500	500						

BMI = Body Mass Index, N = Number of Participants in Each Strata

Table 2 Mean hand grip strength for boys and girls

Age	Boys (Kilogram)		p-value	Girls (Kilogram)		p-value
	Dominant	**Nondominant**		**Dominant**	**Nondominant**	
12	21.91±4.79	20.61±4.83	P<0.05	19.09±3.81	17.68±4.20	P<0.05
13	24.80±5.21	23.46±4.92	P<0.05	22.69±4.45	21.22±4.21	P<0.05
14	29.18±7.00	27.69±7.08	P<0.05	23.67±4.70	21.66±4.51	P<0.05
15	33.17±7.18	31.84±6.74	P<0.05	24.53±5.22	23.04±4.65	P<0.05
16	38.38±7.07	36.23±6.66	P<0.05	25.57±5.07	23.00±4.69	P<0.05

Values are given as Mean ± SD

Table 3 Percentile Ranks for peak grip strength

Age	12		13		14		15		16	
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Mean	21.91	19.09	24.80	22.69	29.18	23.67	33.17	24.53	38.38	25.57
Median	21.27	18.84	24.58	22.45	28.48	23.49	32.06	24.08	38.19	25.49
Mode	19.60	16.33	24.58	21.77	21.68	21.32	31.93	23.59	33.29	20.41
Min	12.97	8.71	13.83	12.79	15.42	12.70	17.51	12.34	19.41	13.97
5	15.24	13.24	17.42	15.60	17.96	15.90	22.78	15.95	25.41	17.88
10	16.00	14.61	18.63	17.10	21.00	17.79	24.15	18.40	30.71	18.90
25	19.02	16.32	21.22	19.66	24.08	20.77	28.66	20.79	33.99	22.22
30	19.59	16.68	21.55	20.43	24.83	21.25	29.39	21.34	34.86	23.25
40	20.13	17.93	22.74	21.77	27.25	22.11	31.60	22.53	36.23	24.18
50	21.27	18.84	24.58	22.45	28.48	23.49	32.06	24.08	38.19	25.49
60	22.58	19.64	25.56	23.44	30.29	24.58	34.21	25.29	39.62	26.39
75	24.19	21.72	27.41	25.46	33.11	26.51	37.17	28.25	42.36	28.87
80	24.74	22.10	30.08	26.12	34.54	27.79	38.08	29.42	43.81	30.10
90	28.22	24.17	33.18	28.38	39.61	30.38	42.27	31.03	47.75	32.87
95	31.46	25.84	34.20	29.63	43.53	32.36	46.77	33.20	49.42	35.33
Max	37.92	30.03	37.19	37.83	47.72	34.84	55.97	39.46	63.14	38.65

Table 4 showed a quantitative relationship between the score of grip strength and measures of body composition i.e., statute, body mass, and body mass index across all ages and sex groups.14 years of age group showed a high degree of relationship with body stature and body mass. The correlation matrix including adjusted R^2 was depicted in Figure 2 respectively. Figure 4 illustrated normative reference values of different countries i.e., Ethiopia, Sweden, the United State of America, China, Iran, and India. The existing literate on particular ages was explored using different databases. A maximum rate of growth was noticed in the Swedish population for age and sex among selected studies.

The odd ratio (OR) for recognized factors was given in Table 5, although boys were generally stronger as indicated by a potential factor such as gender. Figure 5 showed the degree of difference in terms of effect size throughout the age and sex of the respondents. An independent sample t-test was performed between the groups of factors identified for poor grip strength and the calculated effect size was illustrated in Figure 5 as well.

Table 4 Correlation between dominant hand grip strength and body composition measures

Age	12	13	14	15	16
Boys					
Body Mass	.538**	.697**	.690**	.403**	.327**
Stature	.657**	.685**	.715**	.443**	.449**
BMI	.337**	.433**	.514**	.276**	.188
Girls					
Body Mass	.515**	.512**	.620**	.504**	.268**
Stature	.515**	.502**	.586**	.461**	.347**
p value	.000	.000	.000	.000	.000
BMI	.363**	.379**	.473**	.371**	.115
p value	.000	.000	.000	.000	.255

(* Significant at 0.05 level, ** Significant at 0.001 level)

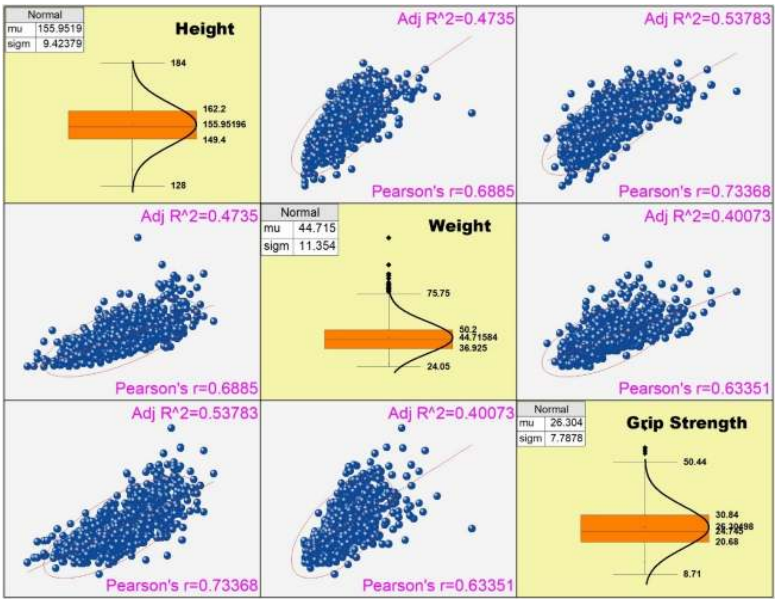

Fig. 2 Correlation matrix between grip strength and measure of body composition

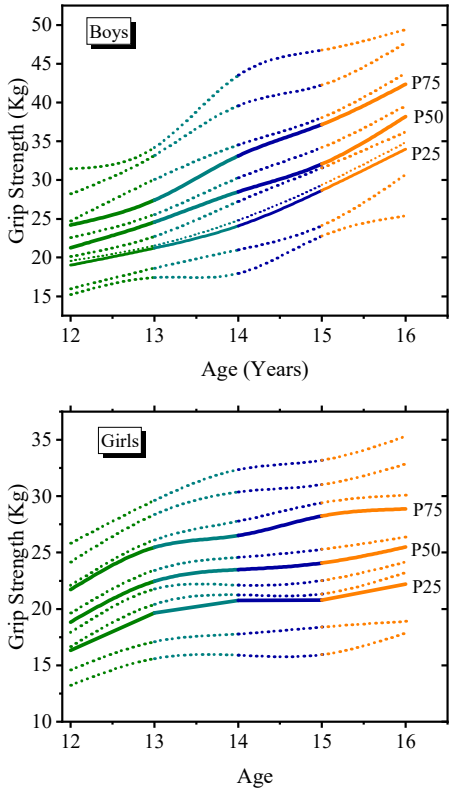

Fig. 3 Smooth centiles curves of grip strength test for Indian students aged 12 to 16 years (Bold curved showing P^{25}, $P^{50,}$ and P^{75} centiles)

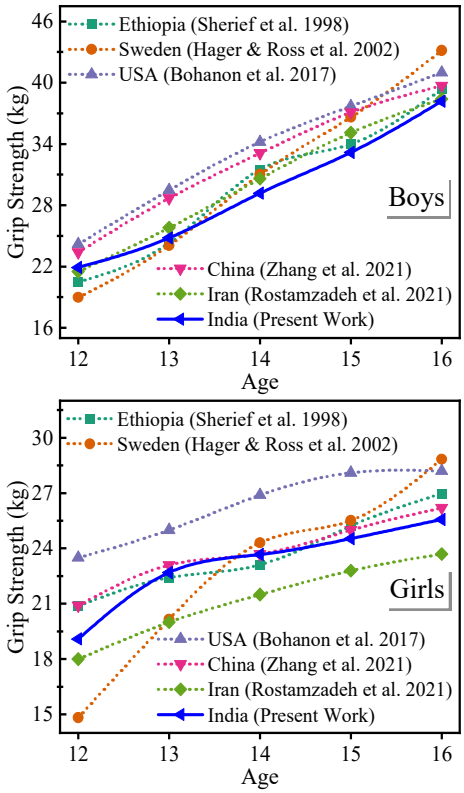

Fig. 4 Comparison of the studies of grip strength aged 12 to 16 years for boys and girls

Discussion

The present study included 1000 subjects aged between 12 – 16 years, from Haryana province located in the northern region of India. The obtained data were used to develop the sex-and-age-specific norms for the Indian population, which can be used as benchmark values for health and fitness screening and surveillance. It was observed that performance improved with age along with analyzed percentiles in the hand grip strength test. Boys had higher values as compared to girls in hand grip strength. Also, the sex differences increased with age. The dominant hand had a significant mean difference from the non-dominant hand in the grip strength test. 12 years age group contains a higher percentage of poor grip strength (64%) (Supplementary Data file, Table 2 & 3) for girls and (38%) for boys. While, 16 years age group reported the lowest percentage of poor grip strength among boys (1%), and girls (15%) respectively. A significant number of girls had poor grip strength as per existing reference values. Similar outcomes were reported in the study conducted in Taiwan, about sex and age-specific observations (Hallam & Weindling, 1998; Pan et al., 2020). Comparing the international studies with the results obtained in our study, it can be concluded that, the grip strength of Americans has the highest mean score followed by China throughout the age and sex-specific values. Except for the age of 12 years, the grip strength of Indian subjects was lowered among global studies for boys, while in the case of Indian girls, the mean score is higher than from Iran only. Indian youth underperformed in grip strength performance than their international counterparts. The obtained results from this study generally align with findings from previous research, such as for European (De Miguel-Etayo et al., 2014) and Australian (Catley & Tomkinson, 2013) populations. Hand grip strength was positively correlated with measures of body composition i.e., body mass, body stature, and body mass index but strongly correlated with body stature in boys and body mass in girls. Throughout the age groups of boys, the Pearson correlation coefficient for body stature ranged from .449 to .715 ($p < 0.01$). It is of interest to notice that girls' grip strength was positively related to body mass and a moderate to a strong degree of relationship ranged from .504 to .620 ($p < 0.01$) except for the age group sixteen. A gender difference was noticed in terms of body composition measures. The findings appear to be in line with the results of the study of Nara et al. (Maghfiroh et al., 2021; Nara, Kumar, Rathee, Kumar, et al., 2022) who reported a significant relationship between grip strength with measures of body composition and muscular strength. Bandyopadhyay Amit investigated the relationship between body composition and hand grip strength of male bricked workers in West Bengal and reported a significant relationship (Bandyopadhyay, 2008). Gerber, M et al. reported that hand grip strength was associated with lower body fat, higher muscle mass, and higher fat-free, both in boys and girls (Gerber et al., 2022). Ramírez-Vélez, R et al. developed a model where grip strength was a moderator of the relationship between anthropometric and body composition indicators in youth (Ramírez-Vélez et al., 2018).

Findings from previous research support our results indicating a positive correlation between body stature and grip strength (Backous et al., 1990; Pierson & O'connell, 1962; Ploegmakers et al., 2013).

Table 5 The odd ratio (OR) and its 95% confidence intervals (95% CI) for the factors potentially related to poor hand grip strength

Factor	OR (95% CI)	*p* Value
[1]Underweight (BMI<18.5)	3.920 (2.839 – 5.412)	.000
[2]Low Economic Status	1.922 (1.049 – 2.622)	.000
[3]Gender	2.551 (1.854 – 3.511)	.000
[4]Region	0.992 (0.726 – 1.355)	.959

[1]Underweight (BMI<18.5) [2]Economic Status (Low vs. high) [3]Gender (Girls vs. Boys) [4]Region (Rural vs. Urban)

The present study investigated the potential factors that cause poor grip strength (Table 5). Being underweight, having low-economic status, and the sex of the participants was identified as potential factors causing poor grip strength. The overall odd ratio (OR) for weight category vs. grip strength is 3.920 (95% CI, 2.839 – 5.412), indicating that the students who have a normal weight are 3.93 times probably have a normal grip strength than underweight students. The detailed crosstabulation (Supplementary file, Table 4) revealed the category-wise odd ratio. In the underweight category, the ratio of normal grip strength/poor grip strength (65.3%/34.7%) was 1.88:1 respectively. But, in the normal weight category, the ratio of normal grip strength/poor grip strength (88.1%/11.9%) was 7.40:1 as well. Another significant factor causing poor grip strength was the low economic status with OR 1.922 (95% CI, 1.049 – 2.622). The individual having higher economic status is 1.922 approximately 2 times the chances of being normal grip strength in comparison to low economic status. The third factor was identified as the gender of the participants with OR of 2.551 (95% CI, 1.854 – 3.511). As the study already established the fact that boys had higher grip strength than girls throughout the age groups. The present findings were supported by the study held in Taiwan's Chinese population (Wu et al., 2009) and reported age and gender as potential factors responsible for poor grip strength. Kun-Hsi Liao investigated significant differences in grip strength among low, medium, and high BMI groups (Liao, 2016). Alex M. Wolfe et al. examined the association between socioeconomic status and musculoskeletal and cardiorespiratory fitness in children and youth aged 3 to 15 years.). The odds of low/poor musculoskeletal fitness were 1.7 and 1.6 times higher in the low and moderate socio-economic status groups (respectively) compared to the children from high socio-economic status families. The moderate socio-economic status group had odds of poor cardiorespiratory fitness 1.6 times higher than the high socio-economic status group as well. Children and adolescents from high socio-economic status families tend to have higher mean fitness and were less likely to have low/poor fitness (Wolfe et al., 2020). The effect size between the potential factors causing poor grip strength was calculated to justify the outcomes of given odd ratios concerning the age and sex of the participants. The degree of differences was classified into three categories 0.2 small, 0.2 – 0.5 moderate, and 0.5 to 0.8 large. Boys had a higher effect size between different weight and economic status groups (Figure 5 – a, & b). Interestingly no significant difference was observed between rural and urban boys in their grip strength. While girls showed small to large effect sizes in respect of rural and urban regions (Figure 5 – c).

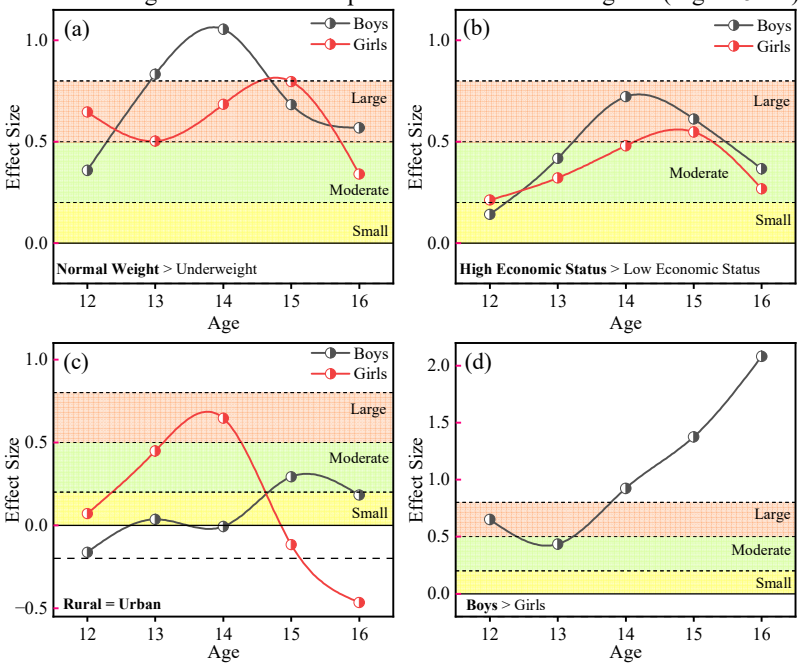

Fig. 5 Age-Related difference in hand grip strength test [**(A)** Showing difference between underweight vs. **normal weight*, (B)** Low economic vs. **high economic status***, **(C)** Rural vs. urban participants, and **(D)** between **boys*** and girls.] expressed as standardized effect sizes. The limits of the degree of differences were

also mentioned in the graph (i.e., small = ±0.2, Moderate = ±0.2 to ±0.5, large = ±0.5 to ±0.8). Positive Effects sizes indicate the degree of mean differences between strata *(*Positive Effect Size*).

Conclusion

The present study produced nationally representative normative-referenced percentile values for grip strength tests. Measures of body composition are strongly associated with hand grip strength All these norms suggested sex-based differences in hand grip strength and older students performed better than their younger counterparts. Being underweight and having low economic status were identified as potential factors causing poor grip strength. Thus, there is a need for a distinguished approach in the physical education class in terms of adjustment of physical activity based on sex, age, and body composition and executing further strategies for the prevalence of low grip strength among adolescents. The findings will be further useful for physicians and therapists to compare the score of patients with healthy individuals according to their age and sex.

Conflict of Interest: The authors declare no conflict of interest.

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