Differential Relationship of Grip Strength with Body Composition and Lifestyle Factors Between Indian Urban and Rural Boys and Girls

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Abstract

Objectives To assess grip strength and gender differences in grip strength in 9–18-y-old urban and rural Indian children, to study association of grip strength with body composition, and assess determinants of grip strength.

Methods This was part of a multicenter, cross-sectional, school-based study (n = 1978, mean age 13.3 ± 2.2 y) from three urban and rural states. Anthropometry, body composition, dietary intake, physical activity, sunlight exposure, and grip strength (in kg) were measured.

Results Mean grip strength increased with age but plateaued in girls after 12 y and was higher in boys (19.6 ± 9.2) than girls (14.3 ± 5.3) (p < 0.05). Mean grip strength was higher in urban (21.05 ± 9.7) than in rural boys (17.8 ± 8.2) (p < 0.05), and comparable in urban (14.9 ± 5.2) and rural girls (13.8 ± 5.5). Grip strength in girls remained lower than boys after adjusting for muscle mass. Difference between boys and girls reduced after body size [body mass index (BMI)] correction, but remained low in girls, plateauing after 15 y. Muscle mass and age were significant determinants of grip strength in all children. On addition of lifestyle factors to the model, grip strength was explained to varied degrees in the children.

Conclusion In boys, nutrition through body size and composition was largely responsible for the differences in grip strength, and in girls, additionally, sociocultural factors also possibly impacted grip strength.

Keywords Grip strength · Indian children · Urban children · Rural children · Body composition

Introduction

Hand grip strength (GS) is a significant indicator to assess general health, muscular fitness, physical strength, overall nutritional status, as well as the degree of development and disability [1, 2].

Age, gender, and anthropometric parameters contribute to the variation in GS and it may vary due to early growth, nutrition, and genetic factors [3]. Occurrence of greater GS in boys than in girls at all ages and especially during teenage years has been described since long time [4, 5]. Further, GS is also affected by lifestyle factors such as physical activity and sunlight exposure (as proxy of vitamin D) [4, 5].

GS is a good measure of total muscle strength and muscle strength, in turn, has been shown to have positive relationship with muscle mass [6]. Earlier studies from the authors' center and from other centers in India have found that Indian children have higher body fat (and lower muscle mass) for given body mass index (BMI) as compared to Caucasian children and children of other ethnicities [7]. Hence, it would be interesting to explore the relationship of GS with muscle mass in Indian children; this relationship of GS with body composition has not been investigated till date in Indian children and adolescents.

Since muscle mass and strength, both are affected by anthropometry, nutrition, and other lifestyle factors, studying children from rural areas who are known to have lower nutritional status [8, 9] may help in exploring this relationship in children who are well nourished versus in those with
compromised nutritional status. Therefore, the objectives of the present study were: 1) to assess GS and gender related differences in GS in 9- to 18-y-old healthy Indian urban and rural children; 2) to study association of GS with body composition; and 3) to assess determinants (body composition, size, and lifestyle factors) of GS in rural and urban Indian boys and girls.

Materials and Methods

Data used for this study are part of a large cross-sectional, observational, multicenter study from urban and rural Indian school going children conducted with an aim of creating sitting height percentiles in Indian children [10]. Based on the geographical zones, 6 states were randomly selected: Maharashtra and Gujarat (west zone), Chhattisgarh (central zone), Assam (northeast zone), Tamil Nadu (south zone), and Punjab (north zone). Data collection was conducted from July 2016 to October 2017. Ethics approval was obtained from the Institutional ethics committee. Written informed consent was obtained from health authorities, schools and parents, and assent was obtained from children older than 7 y before the study started. Children with any serious illness, suffering from chronic disorders or children with disorders likely to affect muscle function were excluded. Detailed account of sample selection can be found in the authors’ earlier article [11].

From the randomly selected schools from these states (one urban and one rural school in each state), all children aged 9 to 18 y (n = 2072) were approached for anthropometric, GS, body composition, dietary intake, and physical activity assessments, and written informed consent was obtained from 2024 children. Age was confirmed based on dates of birth obtained from school records. However, 46 children were absent/not available on days of measurements. Hence, data were obtained from 1978 children. Posthoc power of the study for regression analysis to detect small effect size and significance of < 0.05 was 0.89 with the achieved sample size in each of the four groups (urban boys and girls; rural boys and girls). Statistical analysis was carried out using IBM SPSS Statistics for Windows (version 26.0, IBM Corp, Armonk, NY, USA). Participants were divided into 4 groups as urban boys and girls and rural boys and girls. All study parameters were tested for normality. Results are presented as mean and SD for normal variables and median and interquartile range for non-normal variables. One-way ANOVA followed by pairwise comparisons using Tukey’s multiple comparison method was used to test significance of difference between the four groups. Pearson’s correlation coefficient was used to investigate relationships between GS and other independent variables; significance level was set at p < 0.05. Multiple linear regressions were fitted separately for the 4 groups to determine predictors of GS (dependent variable). Hierarchical multiple linear regression was performed. Independent variables were added one after another, block wise in the regression model. In the first block, muscle mass and fat mass were entered as predictors/independent variables and age, dietary intakes, physical activity, and sunlight exposure were entered in second block.

QAPACE (quantification of physical activity in altitude in children and adolescents) questionnaire adapted and validated for Indian school-going children was used to capture physical activity data [14, 15]. Intraclass correlation coefficient for reliability of the questionnaire ranged from 0.94 to 0.99 for inactivity to moderate activity [15]. Time spent in various activities was captured in minutes per week by trained nutritionists. Sunlight exposure was assessed by validated questionnaire that evaluated aspects like timing and duration of sunlight exposure, mode of transport, use of sunscreen and type of clothes worn [16].

GS of the nondominant hand was measured for all children with Jamar® Plus + Digital Hand Dynamometer (Patterson Medical, Warrenville, IL, USA). Reliability of the dynamometer has been confirmed by previous studies (interclass correlation coefficients ranging from 0.95 to 0.99, r > 0.96) [17, 18]. Each child was made to sit on chair (without armrest) in an upright position, shoulder adducted, with his/her feet flat on ground. The child was given demonstration on how to use the dynamometer before administering the test. The dynamometer was adjusted as per the child’s hand. The child was asked to hold the dynamometer in his/her nondominant hand and to keep the arm at 90º angle at elbow, forearm and wrist in neutral position and thumb pointing upwards. The elbow was unsupported during the test [19]. Each child was verbally encouraged to press as hard as he/she could. Three trials were performed and an average was considered for further analysis [20, 21].

Body composition analysis was performed by bioelectrical impedance analysis (BIA) method using single frequency TANITA BC 420 MA.

Statistical analysis was carried out using IBM SPSS Statistics for Windows (version 26.0, IBM Corp, Armonk, NY, USA). Participants were divided into 4 groups as urban boys and girls and rural boys and girls. All study parameters were tested for normality. Results are presented as mean and SD for normal variables and median and interquartile range for non-normal variables. One-way ANOVA followed by pairwise comparisons using Tukey’s multiple comparison method was used to test significance of difference between the four groups. Pearson’s correlation coefficient was used to investigate relationships between GS and other independent variables; significance level was set at p < 0.05. Multiple linear regressions were fitted separately for the 4 groups to determine predictors of GS (dependent variable). Hierarchical multiple linear regression was performed. Independent variables were added one after another, block wise in the regression model. In the first block, muscle mass and fat mass were entered as predictors/independent variables and age, dietary intakes, physical activity, and sunlight exposure were entered in second block.
Results

Total of 1978 children aged 9 to 18 y from various urban (n = 1028, Girls: 476) and rural (n = 950, Girls: 468) regions of India were studied. Mean age of study participants was 13.3 ± 2.2 y. Table 1 summarizes the descriptive characteristics (mean ± SD) for the study population stratified by gender and urban/rural residence.

Rural girls and boys were significantly shorter and lighter than their respective counterparts (Table 1). Percentage of children with HAZ and BAZ less than −2 was higher in rural children as compared to urban (Table 1).

Mean dietary intake of macronutrients was significantly higher in urban boys followed by urban girls, rural boys and rural girls (Table 1). Moreover, mean energy intake was adequate in both urban boys and girls (> 80% of recommended dietary allowance (RDA)) [22], but mean energy consumption by rural children was inadequate (<75% of RDA). Mean protein intake was more than 75% of RDA in urban boys, urban girls and rural boys. However, it was found that mean protein intake of rural girls was less than 75% of RDA. Fat intakes were adequate in all children.

Urban boys spent significantly more time in vigorous and moderate activity [median (IQR)] [1.2 (0.6–2.0) and 0.7 (0.4–1.2) h/d, respectively] followed by rural boys [0.8 (0.4–1.4) and 0.6 (0.3–1.1) h/d, respectively]. In contrast, girls spent significantly less time in vigorous and moderate activity [urban girls: 0.5 (0.2–1.0) h/d for both, rural girls: 0.3 (0.1–0.6) and 0.4 (0.2–0.8) h/d, respectively]. Girls were engaged in light activity for longer periods than boys [urban girls: 1.4 (0.9–2.3) h/d, rural girls: 1.8 (1.1–2.9) h/d, urban and rural boys: 1.3 (0.7–1.9) h/d].

Also, it was seen that boys from both regions (rural boys: 49% and urban boys: 46%) had significantly higher sunlight exposure (> 30 min/d) than girls (rural girls: 37% and urban girls: 25%).

Table 1

| Parameters                          | Boys |                                    |
|------------------------------------|------|-------------------------------------|
|                                    | Urban (n = 552) | Rural (n = 482) |
| Age (years)                        | 13.3 ± 2.2       | 13.6 ± 2.1         |
| Height (cm)                        | 155.0 ± 13*       | 150.6 ± 13.2*     |
| Weight (kg)                        | 46.8 ± 16.5*      | 39.1 ± 12.5*      |
| BMI (kg/m²)                        | 18.9 ± 4.4*       | 16.8 ± 3.2*       |
| HAZ (% Below −2)                   | 0.04 ± 1.0*b,c   | −0.73 ± 1.02*a,d  |
| BAZ (% Below −2)                   | −0.04 ± 1.16*c   | −0.74 ± 1.03*a,d  |
| Muscle mass (kg)                   | 35.3 ± 9.4*b,c   | 32.6 ± 8.5         |
| Muscle mass percentage             | 78 ± 11.6*b,c    | 84.6 ± 8.4*a,d    |
| Fat mass (kg)                      | 9.7 ± 5.4*b,c    | 11.0 ± 8.4*a,d    |
| Fat percentage                     | 17.8 ± 12.2*b,c  | 17.8 ± 8.3*a,d    |
| Grip strength (kg)                 | 21.1 ± 9.7*b,c   | 25.4 ± 9.4*a,d    |
| Grip strength/Muscle mass ratio    | 0.59 ± 0.2*b,c   | 0.54 ± 0.2*c,d    |
| Grip strength/BMI                  | 1.12 ± 0.4*b     | 1.07 ± 0.4*d       |
| Energy (kcal/d)                    | 2126 ± 591*b,c   | 1762 ± 606*a,d    |
| Protein (g/d)                      | 56 ± 18*b,c      | 43 ± 18*a,d       |
| Fat (g/d)                          | 72 ± 28*b,c      | 51 ± 26*a,d       |
| Carbohydrate (g/d)                 | 313 ± 87*b,c     | 281 ± 95*a,d      |

All values are mean ± SD

*Significantly different than urban boys

Significantly different than urban girls

Significantly different than rural boys

Significantly different than rural girls; *p < 0.05

BAZ BMI for age z score, BMI Body mass index, HAZ Height for age z score.
Rural boys had higher muscle mass percentage than urban boys. Likewise, rural girls had higher muscle mass percentage than urban girls. Conversely, rural boys and rural girls had lower fat percentage than urban boys and urban girls, respectively (p < 0.05) (Table 1).

Mean GS was significantly higher in boys (19.6 ± 9.2 kg) as compared to girls (14.3 ± 5.3 kg) and increased gradually with age in both genders. Mean GS was significantly higher in urban than in rural boys, while in urban and rural girls it was comparable; GS in girls was significantly lesser than boys in both urban and rural regions (Table 1).

Association of GS with age, body composition, diet, physical activity, and sunlight exposure were evaluated (Table 2). GS showed positive correlation with age in all participants (p < 0.05). On plotting GS against age (for both genders and urban/rural residence), an increase in GS in both urban and rural boys was observed; differences in GS between urban and rural boys increased with age (from around 11 to 16 y) and started reducing 16 y onwards (Fig. 1). Unlike in boys, GS plateaued in girls after 12 y of age with slight increase till 15 y. GS in urban girls was higher than that in rural girls till 15 y after which both the curves merged (Fig. 1). Differences in urban and rural girls were less pronounced than in boys.

GS was also positively correlated with muscle mass (MM). The association was strongest in urban boys, then in rural boys followed by urban girls and rural girls (p < 0.05).

To further examine the effect of body size on GS, GS was adjusted for BMI (GS/BMI). GS to BMI ratio increased with age in boys but plateaued in girls at the age of 14 y. Difference in GS between genders in urban and rural children decreased after correcting for body size pointing towards the effect of body size on GS (Fig. 2).

Significant positive correlation of GS with dietary intakes of protein and sunlight exposure was also observed in majority of the present study population; however, the associations were weak with smaller correlation coefficients. An association of light activity was noted only in rural girls (Table 2).

Separate gender and residence wise multiple linear regression models were examined to determine the predictors of GS (Table 3). Overall, the variance of GS was explained the highest in urban boys, then in rural boys, rural girls and

| Parameters                      | Urban boys | Rural boys | Urban girls | Rural girls |
|---------------------------------|------------|------------|-------------|-------------|
| Age (years)                     | 0.786      | 0.775      | 0.589       | 0.544       |
| Muscle mass (kg)                | 0.823      | 0.734      | 0.526       | 0.423       |
| Proteins (g/d)                  | 0.232      | 0.128      | NS          | 0.103       |
| Sunlight exposure (min/d)       | 0.216      | 0.126      | 0.185       | NS          |
| Light activity (min/wk)         | NS         | NS         | NS          | 0.244       |

All correlations were significant (p < 0.05)
it was explained the least in urban girls. It was noted that muscle mass was a strong predictor of GS in both boys and girls from both regions \((p < 0.001)\). Fat mass was significant negative predictor of GS in rural boys and girls \((p < 0.05)\).

Age was a strong predictor of GS in both boys and girls from both regions \((p < 0.001)\). Sunlight exposure was also found to be a predictor of GS in urban boys \((p < 0.01)\), and girls \((p = 0.01)\). Association of GS with protein intake was found to be significant only in rural girls where it was a positive predictor \((p = 0.001)\). Furthermore, association of GS with physical activity was also found to be nonsignificant for majority of the present study population except for rural girls in whom it was a positive predictor \((p < 0.05)\).

**Discussion**

The present study on urban (U) and rural (R) 9–18-y children from 6 states of India revealed that U boys had the highest GS and R girls the lowest; GS was higher in boys at all ages than in girls. GS increased with age in both genders; urban boys had higher GS than rural boys at all ages. The difference in GS between U and R girls was less than in boys and the two curves for girls’ GS merged at around 16 y. Muscle mass, body size, and lifestyle factors (dietary protein, physical activity, and sunlight exposure) were variably associated with GS in the four groups. Following age, MM was the chief determinant of GS in urban children and rural boys; contribution of lifestyle factors to GS was higher in girls, more so in rural girls.

Higher GS in U in comparison with R boys was probably due to better nutrition, higher moderate physical activity, and increased sunlight exposure. Reports suggest that U children enter puberty earlier than their rural counterparts [23], and this may also have contributed to these differences; later puberty in R boys may explain the reduction in differences in GS in U and R boys after 16 y. Surprisingly, the differences in U and R girls’ GS were less than in boys and at 15 y; mean GS was same in both sets of girls. Once again, later puberty in rural girls may have resulted in rural girls catching up by 15 y.

Unlike in boys, combination of nutritional and lifestyle factors did not result in higher GS in U girls post 15 y, implying that there were other reasons for this lack of U/R differences in girls. It is speculated that sociocultural influences including, but not limited to, reduced physical activity after achieving menarche (moderate-to-vigorous physical activity mean pre- vs. postmenarche: U Girls: 1.4 vs. 1.1 h/d, R Girls: 1.0 vs. 0.9 h/d) may possibly explain the reduced GS/MM and GS/BMI ratio in girls in comparison with boys and also, the lack of differences in U and R girls.

Results of the present study indicate that body composition and lifestyle factors may affect GS differently in urban and rural children. Some studies have reported correlations of age, anthropometric parameters, and body composition with GS in children [6, 24–29].

As far as the authors know, theirs is the first Indian multicentric study to assess GS in children from urban and rural areas. There are limited data describing regional difference in GS within a country [30]. The present study
has important public health implications; while nutrition seems to be driving the differences in GS in U and R boys, in addition, sociocultural factors may play a vital role in girls. Thus, strategies to improve GS in rural boys and girls need to be different. One of the limitations of this study is that, as this was school-based, sexual maturity staging could not be performed. Date of menarche was recorded which was earlier in urban girls than in rural girls (11.5 y vs. 12.3 y); however, no other puberty-related data were available. Further, physical activity and sunlight exposure data were collected using questionnaires, which are not objective methods of assessment of these parameters. Also, the present study was cross-sectional; describing increase in GS with age would be more appropriate using longitudinal data.

### Conclusion

This multicentric study on Indian children revealed that urban boys had higher grip strength than rural boys; likewise, urban girls had better grip strength than rural girls. Apart from age, nutrition working through body size and composition was largely responsible for the differences in GS in boys, while, in addition to nutrition, sociocultural factors also possibly impacted GS in girls. Strategies to improve nutrition and address sociocultural factors, especially in rural girls, are critical towards optimizing muscular fitness.

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### Authors’ Contributions

SK: Data collection and analyses, manuscript drafting; VE: Conceptualization and design, data collection, manuscript drafting; PP: Manuscript drafting; SV: Data collection, manuscript drafting; VK: Manuscript drafting; KG: Data analysis, manuscript drafting; AK: Conceptualization and design, data collection & analysis, interpretation of results, manuscript drafting. AK will act as the guarantor for this paper.

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### Declarations

**Ethics Approval** This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Institutional Ethics Committee.

**Consent to Participate** Written informed consent was obtained from the parents of subjects and written informed assent was obtained from the subjects.
Consent to Publish  The parents signed informed consent regarding publishing the data of their children.

Conflict of Interest  None.

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