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

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Abstract

Grip strength (GS) is used as an index of overall health in children. The objectives of our study were to assess GS, gender differences in GS in 9 -18 year old urban (U) and rural (R) Indian children, study association of GS with body composition (BC) and assess determinants. This was part of a multicentre, cross sectional, school-based study (n=1978, mean age 13.3 ± 2.2 years) from 3 U and R states. Anthropometry, BC, dietary intake, physical activity, sunlight exposure and GS (in Kg) measurements were performed. The mean GS increased with age but plateaued in girls after 12 years; was higher in boys (19.6 ± 9.2) than girls (14.3 ± 5.3) ($p < 0.05$). Mean GS was higher in U (21.05 ± 9.7) than in R boys (17.8 ± 8.2) ($p < 0.05$), comparable in U (14.9 ± 5.2) and R girls (13.8 ± 5.5). GS in girls remained lower than boys after adjusting for muscle mass (MM). Difference between boys and girls reduced after body size (BMI) correction, but remained low in girls plateauing after 15 years. MM and age were significant determinants of GS in all children. On addition of lifestyle factors, GS was explained to varied degrees, the least in U girls, followed by R girls and R boys and the most in U boys. *Conclusion*: In boys, nutrition though body size and composition was largely responsible for the differences in GS and in girls, additionally socio-cultural factors also possibly impact GS.

What Is Known

- Hand grip strength (GS) is an indicator of muscular strength and used commonly as an index of overall health in children.
- GS increases with age both in boys and girls but, remains lesser in girls than boys; these gender differences nullify after adjusting for muscle mass.

What is new:

- The GS was highest in urban boys and lowest in rural girls and plateaued in girls after 12 years; even after adjusting for muscle mass and BMI, the differences did not nullify.
- In boys, nutrition though body size and composition were largely responsible for the differences in GS and in girls, additionally socio-cultural factors also possibly impact GS.

Introduction

Hand grip strength (GS) is a significant indicator used to assess general health, muscular fitness, physical strength, overall nutritional status, as well as the degree of development and disability (neuromuscular diseases, progressive developmental diseases, falls and fractures) [1, 2]. It is evident from past research that GS is associated with metabolic health in adults as well as in children and low GS in childhood may have negative health implications in adulthood [3].

Published data on GS suggest that the increase in GS follows a similar pattern across the life span wherein it increases across childhood and peaks in early adult life after which it is maintained through midlife and declines thereafter [4]. GS is found to be affected by factors such as age, body composition, nutrition, gender, ethnicity, genetic makeup and cultural differences[1]. In addition to nutrition and gender, the grip strength is also affected by anthropometry and other lifestyle factors such as physical activity and sunlight exposure (as a proxy of vitamin D) [5, 6].

Further, GS is believed to be a good measure of total muscle strength and muscle strength in turn has been shown to have a positive relationship with muscle mass [7], [3]. Earlier studies from our centre and from other centres in India have found that body composition (BC) in Indian children is different from BC in Caucasian children and children of other ethnicities. Indian children have a higher body fat (and lower muscle mass) for a given body mass index (BMI) [8]. Thus, 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) [9, 10] may help in exploring this relationship in children who are well nourished versus those with compromised nutrition. Therefore, the objectives of our study were: 1) to assess GS and gender related differences in GS in 9 to 18 year old healthy Indian urban and rural children 2) to study the association of GS with body composition 3) to assess determinants (body composition, size and lifestyle factors) of GS in rural and urban Indian boys and girls.

Methods

Sample Selection: The data used for this study are a part of a large cross-sectional, observational, multi-centre study from urban and rural Indian school going children [11] from 6 Indian states (representing geographical locations). Data collection of the study was conducted from July 2016 to October 2017. Ethics committee 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 years before the study started. The detailed account of sample selection can be found in our earlier article [11].

From the 6 states, 3 states (from different geographical locations, urban and rural centres at each state), all children from 9 to 18 years of age (n=2072) were approached for additional assessments viz anthropometric, grip strength, body composition, dietary intake and physical activity assessment and written informed consent was obtained from 2024 children. However, 46 children were absent/not available on the days of measurements. Hence the data presented here is on 1978 children. The post-hoc power of the study for regression analysis to detect a small effect size and significance of < 0.5 was 0.89 with the achieved sample size in each group.

Anthropometric Measurements: Height and weight were measured in all children. Height was measured to the nearest millimetre using a portable stadiometer (Seca Portable stadiometer, 20-205 cm, Hamburg, Germany) by standard protocol and weight was measured using an electronic scale (Seca 876 Flat scale, Seca Gmbh & co. kg, Hamburg, Germany) to the nearest 100 g using standard protocols. The height for age (HAZ), weight for age (WAZ) and BMI for age (BAZ) Z-scores were computed from an Indian reference database [12].

Lifestyle Factors: Dietary intake, physical activity and sunlight exposure data were collected using validated questionnaires.

Dietary intake: Data on intake were collected by a 2 day (2 non-consecutive days, including 1 Sunday), 24-hour dietary recall, using multiple pass method by trained dietitians (acquainted with local foods) from each state. Standard cups and measures were used to collect the dietary data. Nutrient intakes were computed using a cooked food database software, C-Diet (version 3.2)[13].

Physical activity and Sunlight Exposure: The QAPACE questionnaire adapted and validated for Indian school going children was used to capture physical activity data [14, 15]. The intra-class correlation coefficient for reliability of the questionnaire ranged from 0.94 to 0.99 for inactivity to vigorous activity. Time spent by the children in competitive sports activities such as badminton, football, tennis, baseball, volleyball were categorized as vigorous activity, while activities like running games, garden games, cycling, jogging, swimming were considered moderate activity. Light activity comprised of daily household work, reading, cooking etc. For inactivity, watching television, using laptops, mobile phones and other sedentary behaviour were included [16]. The activities were captured in minutes per week by trained nutritionists. Sunlight exposure was assessed by a validated questionnaire[17].

Grip Strength Assessment: Grip strength of the non-dominant hand was measured for all children with Jamar® Plus+ Digital Hand Dynamometer (Patterson Medical, Warrenville, IL, USA). The reliability of the dynamometer has been confirmed by previous studies (interclass correlation coefficients ranging from 0.95 to 0.99, r>0.96) [18–21]. Each child was made to sit on a chair (without armrest) in an upright position, shoulder adducted, with his/her feet flat on the ground. The child was given a 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 non-dominant hand and to keep the arm at 90º angle at elbow, forearm and wrist in neutral position and thumb facing upwards. The elbow was unsupported during the test [22]. 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 [23, 24].

Body Composition: Body composition analysis was performed by bioelectrical impedance analysis (BIA) method using TANITA BC 420 MA. The BIA was performed on each child after a minimum of 3 hours of fasting and voiding before the measurement and emptying their pockets. BIA measures body composition as fat percentage, fat mass, fat free mass, bone free lean tissue mass (muscle mass) and total body water by measuring bioelectrical impedance in the body in standing position. The reliability of BIA was assessed in a sample of 30 children and the intraclass correlation coefficient for the body fat percent, fat mass, fat free mass and muscle mass was found to be = 0.96, $p < 0.001$ [15, 25].

Statistical Analysis: Statistical analysis was carried out using the IBM SPSS Statistics for Windows (version 26.0, IBM Corp, Armonk, NY, USA). The study children were divided into 4 groups as urban boys and girls and rural boys and girls. Before statistical analyses were performed, all the study parameters were tested for normality. Results are presented as mean and SD for normal variables and median and inter-quartile range for non-normal variables. One-way ANOVA followed by pairwise comparisons using Tukey's multiple comparison method was used to test the significance of difference between the 4 groups in the anthropometric, body composition, grip strength and lifestyle parameters. Pearson's correlation coefficient was used to investigate the relationships between grip strength and body composition, diet (carbohydrate, protein, fat, zinc, and iron intake), sunlight exposure and physical activity; significance level was set at $p < 0.05$. Multiple linear regressions were fitted separately for the 4 groups to determine the predictors of grip strength (dependent variable). The regressions were performed in two blocks. 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 the second block.

Results

A total of 1986 children aged 9 to 18 years from various urban (n=1028, Girls: 476) and rural (n=950, Girls: 468) regions of India were studied. Mean age of the study participants was 13.3 ± 2.2 years. Table 1 summarizes the descriptive characteristics (mean ± SD) for the study population stratified by gender and urban/rural residence.

<u>Anthropometric Measurements:</u>

Boys and girls from both urban and rural regions showed significantly different growth as observed from their anthropometric measurements ($p<0.05$). Urban boys were taller and heavier than all their counterparts. Rural girls and rural boys were significantly shorter and lighter than their counterparts respectively ($p<0.05$) (table 1). The percentage of children having HAZ and BAZ less than -2 was higher in urban children as compared to rural children. ($p < 0.05$, table 1).

Lifestyle Factors:

<u>Dietary Intake:</u> The mean dietary intake of energy, protein, carbohydrate and fat was significantly higher in urban boys followed by urban girls, rural boys and girls ($p<0.05$ for all) (table 1). Moreover, the urban boys and girls consumed adequate energy (>80% of recommended dietary allowance (RDA)) (ICMR, 2010), but the rural boys and girl's energy consumption was inadequate (<75% of RDA). All children except for rural girls consumed adequate dietary proteins (>75% of RDA). Dietary fat intakes were adequate in all children. The mean dietary zinc and iron (growth promoting nutrients) consumption was also found to be the highest in urban boys and lowest in rural girls ($p<0.05$), but overall were inadequate in all children (iron < 65% RDA and zinc < 50 % of RDA).

<u>Physical Activity and Sunlight Exposure:</u> We observed that 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) hours/day) followed by the rural boys (0.8 (0.4-1.4) and 0.6 (0.3-1.1) hours/day) ($p<0.05$) respectively. In contrast, girls spent significantly less time in vigorous and moderate activity (urban girls: 0.5 (0.2-1.0) hours /day for both, rural girls: 0.3 (0.1-0.6) and 0.4 (0.2-0.8) hours/day)

($p<0.05$ for all) respectively. Girls were engaged in light activity for longer periods (urban girls: 1.4 (0.9-2.3) hours/day, rural girls: 1.8 (1.1-2.9) hours/day, urban and rural boys:1.3 (0.7-1.9) hours/day).

Furthermore, boys from both regions (49 and 46%, $p > 0.1$) showed a significantly higher sunlight exposure (>30 min/day) than girls from both regions (rural girls: 37% and urban girls: 25% with > 30 min/day) ($p<0.05$) (table 1).

Body Composition:

On assessment of body composition, significantly ($p<0.05$) higher muscle mass percentage and the lowest fat percentage were noted in rural boys and lowest muscle mass percentage and highest fat percentage were noted in urban girls (table 1).

Grip Strength:

Mean grip strength (GS) was significantly higher in boys (19.6 ± 9.2 kg) as compared to girls (14.3 ± 5.3 kg) ($p<0.05$) and increased gradually with age in both genders. Mean GS was significantly higher in urban (21.1 ± 9.7 kg) than in rural boys (17.8 ± 8.2 kg) ($p<0.05$) while, in urban (14.9 ± 5.2 kg) and rural girls (13.8 ± 5.5 kg) it was comparable; GS in girls was significantly lesser than in both urban and rural boys ($p<0.05$) (table 1).

On plotting GS against age (for both genders and urban/rural residence), we observed an increase in GS in both urban and rural boys; the differences in GS between urban and rural boys increased with age (from around 11 to 16 years) and started reducing from 16 years (figure 1). Unlike in boys, the GS plateaued in girls after 12 years of age with slight increase till 15 years. The GS in urban girls was higher than that in rural girls till 15 years after which both the curves merged (figure 1). The differences in urban and rural girls were less pronounced than in boys.

Body Composition, Lifestyle Factors and GS Association:

We evaluated the association of GS with body composition, age, diet, physical activity and sunlight exposure (table 2). GS showed a positive correlation with age (Boys – urban: r=0.786, rural: r=0.775; Girls – urban: r=0.589, rural: r=0.544, $p<0.05$ for all). It was observed that GS was also positively correlated with muscle mass (MM). The association was strongest in urban boys (r=0.82), then in rural boys (r=0.73) followed by urban girls (r=0.52) and rural girls (r=0.42), ($p<0.05$ for all). Given the corelation of GS with MM and to correct for MM, GS/MM ratio was computed. The results revealed that in boys, GS for MM ratio increased with age while in girls, after 15 years of age, the GS for muscle mass plateaued (figure 2) and remained lower than in boys. To further examine the effect of body size on the grip strength, GS was adjusted for BMI (GS/BMI). The GS to BMI ratio increased with age in boys but plateaued in girls at the age of 14 years. The difference in grip strength between genders in urban and rural children decreased after correcting for body size pointing towards the effect of body size on GS (figure 3).

A significant positive correlation of GS with dietary intakes of proteins and sunlight exposure was also observed in a majority of our study population. An association of light activity was noted only in rural girls (table 2). Furthermore, to investigate the independent influence of sunlight exposure on GS, we plotted the time of sunlight exposure against GS to MM ratio. Results revealed that GS to MM ratio was high for children having sunlight exposure greater than 30 minutes than below 30 minutes ($p<0.05$). (figure 4) indicating a role of sunlight exposure in muscle strength.

Separate gender and residence wise multiple linear regression models were examined to determine the predictors of GS (table 3). A regression analysis was performed and variables were added in 2 blocks (Block 1: muscle Mass, fat Mass; Block 2: age and other lifestyle factors). Overall, the variance of grip strength was explained the highest in the urban boys (r^2 = 74.3) then in rural boys (r^2 = 67), rural girls (r^2 = 48.7) and least was explained in urban girls (r^2 = 46.2). It was noted that muscle mass was a strong predictor of GS in both boys and girls from both regions (urban: boys: b=0.655, girls: b = 0.341, rural: boys: b = 0.492, girls: b = 0.483, $p<0.001$ for all). Fat mass was a significant negative predictor of GS in rural boys and girls (boys: b = -0.164, $p = 0.006$, girls: b = -0.188, $p = 0.001$).

In the second block age, diet, physical activity and sunlight exposure were assessed as predictors of grip strength. We observed that age was a strong predictor of GS in both boys and girls from both regions (urban: boys: b=1.195, $p<0.001$, girls: b=0.831, $p<0.001$; rural: boys: b=1.483, $p<0.001$, girls: b=0.784, $p<0.001$). Sunlight exposure was also a predictor in urban boys (b=0.023, $p<0.01$), and girls (b=0.026, $p=0.01$). The association of GS with protein intake was found to be non-significant for a majority of our study population except for rural girls where it was a positive predictor (b=0.141, $p=0.001$). Zinc intake was a predictor of GS for urban boys and girls (urban: boys: b=0.453, $p=0.020$, girls: b=0.710, $p=0.003$). Furthermore, the association of GS with physical activity was also found to be non-significant for a majority of our study population except for rural girls in whom it was a positive predictor (light activity: b=0.001, $p=0.008$, vigorous activity: b=0.002, $p=0.039$).

Discussion

Our study on urban (U) and rural (R) 9-18 year children from 3 states of India revealed that U boys had the highest GS and R girls the lowest; GS was higher at all ages in boys than in girls. GS increased with age in both genders; urban boys had higher GS than rural boys at all ages. In girls, the difference between the U and R girls was less than in boys (no difference in mean GS: 14.9 vs 13.8 kg) and the two curves for girls GS merged at around 16 years. After correcting for muscle mass (ratio of GS/MM), the difference between genders reduced (but still remained, figure 3) especially so between R boys and U and R girls till 15 years; the GS/MM in girls was again much lower after 15 years. After correcting for body size through BMI, difference in GS of U and R boys and girls reduced further. Muscle mass, body size, and life style factors (dietary protein and zinc, physical activity and sunlight exposure) were variably associated with GS in the four groups. MM was the chief determinant of GS in urban children and rural boys; contribution of lifestyle factors to GS (more so in the rural girls) was higher in girls.

Higher grip strength 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 [26, 27], 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 years. To our surprise, the picture was quite different in girls. Overall, the differences in U and R girl's GS were less than in boys and at 15 years, the mean GS was the same in both sets of girls. Once again, later puberty in rural girls may have resulted in the rural girls catching up by 15 years.

Gender differences in GS as observed in our study have also been reported by other researchers [1, 3, 4, 7, 28–31]·[32]. In line with our observations, Serrano et al. and Cohen et al. have also reported a significant sexual dimorphism from the age of 12 years in Spanish and English children [3, 31, 33], while Newman et al. report that girls manifest a linear increase in GS up to 13 years of age after which it remained constant [5]. Studies suggest that on adjusting for MM, gender differencing in GS were nullified [28]. However, we found that although the differences in U and R girls GS/MM ratio were lower and girls' mean GS/MM ratio was closer to the boys curves till 15 years (particularly to the R boys), after this age, the GS/MM ratio for both U and R girls was much lower. Thus, gender differences in GS in our study population could not be explained by MM alone.

Interestingly, although the mean muscle mass percentage was higher in R boys, their GS was lower (Muscle Mass % & GS: U:78%, 21.1 kg R:85%, 18 kg). Even though the differences in GS in U and R boys reduced after correcting for MM (more so after 16 years, possibly once again due to later puberty and later acquisition of MM in R boys), they reduced even further on adjusting for body size. Our results thus imply that nutrition acting through higher total muscle mass and increased body size contributed to the higher GS in U boys, further, the differences were also possibly contributed to by differences in the timing of puberty. After adjusting for body size, the difference between the U and R girls decreased, and the decrease was more pronounced.

Minimal differences in MM and body size corrected GS between U and R girls was an intriguing finding of our study. Like the U boys, U girls also had higher dietary intakes (energy and protein intake/day: UB: 2126 Kcal, 56g; UG: 1806 Kcal, 47 g vs RB: 1762 Kcal, 43 g, RG: 1417 Kcal, 34 g), moderate physical activity, anthropometric parameters and total muscle mass, however, the differences in U and R girls GS (absolute GS, GS/MM and GS/ body size) were minimal, particularly after 15 years. Thus, unlike in boys, a combination of nutritional and lifestyle factors did not result in higher GS in U girls post 15 years, implying that there were other reasons for this lack of U/R differences in girls (variance of grip strength by body composition and lifestyle factors was explained the least in urban girls on the regression analysis). We speculate that socio cultural influences, including but not limited to reduced physical activity after achieving menarche (moderate to vigorous physical activity mean pre vs post menarche [32, 34, 35]: U Girls: 1.4 vs 1.1 hours/day, R Girls: 1.0 vs 0.9 hours/day) may possibly explain reduced GS/MM and GS/body size ratio in girls in comparison with boys and also lack of differences in U and R girls.

We compared mean GS of our study children with reports from other studies with similar methodology from United States of America and Chile (Figure 5a, 5b) [32, 34, 35]. Dodds et al have noted that differences in GS exist with respect to different countries and ethnicities. They also demonstrate in a review that the average grip strength measurements are significantly lower in developing countries as compared to the developed world [4]. Further, in addition to body composition, nutrition, physical activity and sunlight exposure, studies propose that GS may also be determined by genetic factors [4, 36]. We observed that the mean GS of urban boys from our study was close to the Chile boys. However, they were lower than the American children with rural boys having the least GS. Mean GS of urban girls was close to the Chile girls till the age of 12 and was lower after that (figure 5a, 5b) with the rural girls having the lowest GS. The GS in our girls was lower than the American girls at all ages.

Limited literature is available describing the relationship of lifestyle factors and anthropometric parameters with GS in children and adolescents. The correlation of GS with muscle mass and lifestyle factors in urban and rural boys and girls observed in our study indicates that the 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 [7, 28, 29, 37–40]. Wayako et al have reported an association of GS with vitamin D concentrations in school going children[41]. Although we do not report the vitamin D concentrations, sunlight exposure as a surrogate (of vitamin D concentrations and physical activity) was a determinant of GS especially in urban children. Researchers have also reported significantly greater GS values in children who were physically active than in non-active children[42, 43].

To the best of our knowledge, ours 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 [44]. Given the differences in nutrition and body composition in urban and rural children, we were able to explore important relationships between GS, body composition and lifestyle factors in urban and rural children of both genders. Our study has important public health implications; while nutrition seems to be driving the differences in GS in U and R boys, in addition to nutrition, socio cultural factors may play an important role in girls. Thus, strategies to improve GS in rural boys and girls need to be different.

One of our limitations is that as this was a school based study, we were not able to perform sexual maturity staging, puberty affects body composition and consequently muscle mass and strength. We did record the date of menarche which was earlier in urban girls than in rural girls (11.5 years vs 12.3 years), however, no other puberty related data were available. Further, the physical activity and sunlight exposure data were collected using questionnaires, thus, objective methods of assessment of these parameters were not available. Also, our study was cross-sectional; describing increase in GS with age would be more appropriate using longitudinal data.

To conclude, our multicentre study on Indian children revealed that urban boys had the highest grip strength and rural girls the lowest. Nutrition working though body size and composition was largely responsible for the differences in GS in boys, while, in addition to nutrition, socio cultural factors also possibly impact GS in girls. Strategies to improve nutrition and address socio cultural factors, especially in rural girls are critical.

List Of Abbreviations In Alphabetical Order

BC: Body Composition

BIA: Bioelectrical Impedance Analysis

GS: Grip Strength

HAZ: Height for Age Z-score

ICMR: Indian Council of Medical Research

IQR: Inter Quartile Range

MM: Muscle Mass

R: Rural

RDA: Recommended dietary allowance

U: Urban

WAZ: Weight for Age Z-score

Declarations

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Ethical Approval: This study was approved by the Institutional Ethics Committee.

Consent to participate: A written informed consent and assent (where applicable) for participation was obtained from all participants.

Consent for Publication: A written informed consent and assent (where applicable) for publication was obtained from all participants.

Availability of data and material: The data will be made available on request.

Code Availability: NA

Author's contribution: Authors **Anuradha Khadilkar, Vaman Khadilkar and Veena Ekbote conceptualized the work. Anuradha Khadilkar, Vaman Khadilkar, Veena Ekbote, Prerna Patel, Sonal Kasture, Smruti Vispute and Ketan Gondhalekar were involved in data acquisition, analysis and interpretation. Veena Ekbote, Prerna Patel, Sonal Kasture and Smruti Vispute drafted the manuscript and Anuradha Khadilkar, Vaman Khadilkar and Ketan Gondhalekar critically assessed and corrected it. The submitted version of the article has been approved by all authors.**

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Tables

Table 1: Baseline characteristics of the study group

Parameters	Urban				Rural			
	Boys (n=552)		Girls (n=476)		Boys (n=482)		Girls (n=468)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Anthropometric Parameters								
Age (years)	13.3	2.2	13.1^{*c}	2.1	13.6	2.1	13.5	2.2
Height (cms)	155.0$^{*b, c, d}$	13	150.1^{*d}	8.8	150.6^{*d}	13.2	147.8$^{*a, b, c}$	9.3
Weight (kg)	46.8$^{*b, c, d}$	16.5	42.7$^{*a, c, d}$	11.1	39.1$^{*a, b}$	12.5	39.2$^{*a, b}$	10.5
BMI (kg/m^2)	18.9$^{*c, d}$	4.4	18.7$^{*c, d}$	3.8	16.8$^{*a, b, d}$	3.2	17.7$^{*a, c, d}$	3.5
HAZ (% Below -2)	0.04$^{b, c, d}$ (2)$^{*c, d}$	1.03	-0.01$^{*a, c, d}$ (3)$^{*c, d}$	1.0	-0.73$^{*a, b, d}$ (10)$^{*a, b}$	1.02	-0.51$^{*a, b, c}$ (6)$^{*a, b}$	1.0
BAZ (% Below -2)	-0.04$^{*c, d}$ (4)	1.16	-0.12$^{*c, d}$ (2)^{*d}	1.12	-0.74$^{*a, b, d}$ (8)	1.03	-0.52$^{*a, b, c}$ (7)^{*b}	1.06
Body Composition and Grip Strength								
Muscle mass (kg)	35.3$^{*b, c, d}$	9.4	29.6	4.6	32.6	8.5	28.2	5
Muscle Mass Percentage	78$^{*b, c, d}$	11.6	70.5$^{*a, c, d}$	9	84.6$^{*a, b, d}$	8	73.9$^{*a, b, c}$	7.9
Fat Mass (kg)	9.7$^{*b, c}$	9	11.9$^{*a, c, d}$	7.3	5.0$^{*a, b, d}$	5.4	9.2$^{*b, c}$	5.9
Fat Percentage	17.8$^{*b, c, d}$	12.2	25.4$^{*a, c, d}$	9.4	11.0$^{*a, b, d}$	8.4	21.8$^{*a, b, c}$	8.3
Grip strength (kg)	21.1$^{*b, c, d}$	9.7	14.9$^{*a, c}$	5.2	17.8$^{*a, b, d}$	8.3	13.8$^{*a, c}$	5.5
Grip Strength/Muscle Mass Ratio	0.59$^{*b, c, d}$	0.2	0.51$^{*a, c}$	0.1	0.54$^{*b, c, d}$	0.2	0.50$^{*a, c}$	0.2
Grip Strength/BMI	1.12$^{*b, d}$	0.4	0.82$^{*a, c}$	0.3	1.07$^{*b, d}$	0.4	0.81$^{*a, c}$	0.3
Dietary Intake								
Energy (kcal/Day)	2126$^{*b, c, d}$	591	1806$^{*a, d}$	532	1762$^{*a, d}$	606	1417$^{*a, b, c}$	500
Protein (g/Day)	56$^{*b, c, d}$	18	47$^{*a, c, d}$	16	43$^{*a, b, d}$	18	34$^{*a, b, c}$	14
Fat (g/Day)	72$^{*b, c, d}$	28	60$^{*a, c, d}$	24	51$^{*a, b, d}$	26	41$^{*a, b, c}$	20
Carbohydrate (g/Day)	313$^{*b, c, d}$	87	267$^{*a, c, d}$	77	281$^{*a, b, d}$	95	228$^{*a, b, c}$	78
Zinc (mg/Day)	6$^{*b, c, d}$	2	5$^{*a, d}$	2	5$^{*a, d}$	2	4$^{*a, b, c}$	1
Iron (mg/Day)	11$^{*b, c, d}$	4	9$^{*a, d}$	4	9$^{*a, d}$	5	7$^{*a, b, c}$	4

HAZ: Height for age Z-score, BAZ: BMI for age Z-score.

a: significantly different than Urban boys; b: significantly different than Urban Girls;

c: significantly different than Rural Boys; d: Significantly different than Rural Girls;

**p* <0.05

Table 2: Correlation coefficients of grip strength with body composition parameters

Parameters	Urban Boys	Rural Boys	Urban Girls	Rural Girls
Muscle Mass (kg)	0.823	0.734	0.526	0.423
Age (years)	0.786	0.775	0.589	0.544
Proteins (g/day)	0.232	0.128	NS	0.103
Zinc (mg/day)	0.266	NS	NS	NS
Iron (mg/day)	0.236	NS	NS	NS
Sunlight Exposure (minutes/day)	0.216	0.126	0.185	NS
Light Activity (minutes/week)	NS	NS	NS	0.244

All correlations were significant (*p* <0.05)

Table 3: Multiple Linear Regression models for grip strength

	Urban Boys				Urban Girls				Rural Boys				Rural Girls		
Model R^2	**74.3**				**46.2**				**67**				**48.7**		
Predictors	β	SE	t	*p*	B	SE	T	*p*	β	SE	t	*p*	β	SE	t
Block 1 R^2	71.3				36				61				25.3		
Muscle Mass (kg)	0.655	0.060	10.865	0.000	0.341	0.074	4.592	0.000	0.492	0.061	8.021	0.000	0.483	0.076	6.338
Fat Mass (kg)	NS	NS	NS	NS	NS	NS	NS	NS	-0.164	0.059	-2.773	0.006	-0.188	0.056	-3.367
Block 2 R^2	3.0				10.2				6.0				23.4		
Age (years)	1.195	0.215	5.568	0.000	0.831	0.134	6.190	0.000	1.483	0.211	7.033	0.000	0.784	0.132	5.931
Proteins (g/Da)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.141	0.044	3.244
Zinc (mg/Day)	0.453	0.193	2.347	0.020	0.710	0.235	3.020	0.003	NS	NS	NS	NS	NS	NS	NS
Sunlight Exposure (Minutes/Day)	0.023	0.008	2.728	0.007	0.026	0.011	2.503	0.013	NS	NS	NS	NS	NS	NS	NS
Light Activity (Minutes/week)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.001	0.000	2.678
Vigorous Activity (Minutes/week)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.002	0.001	2.075

Figures

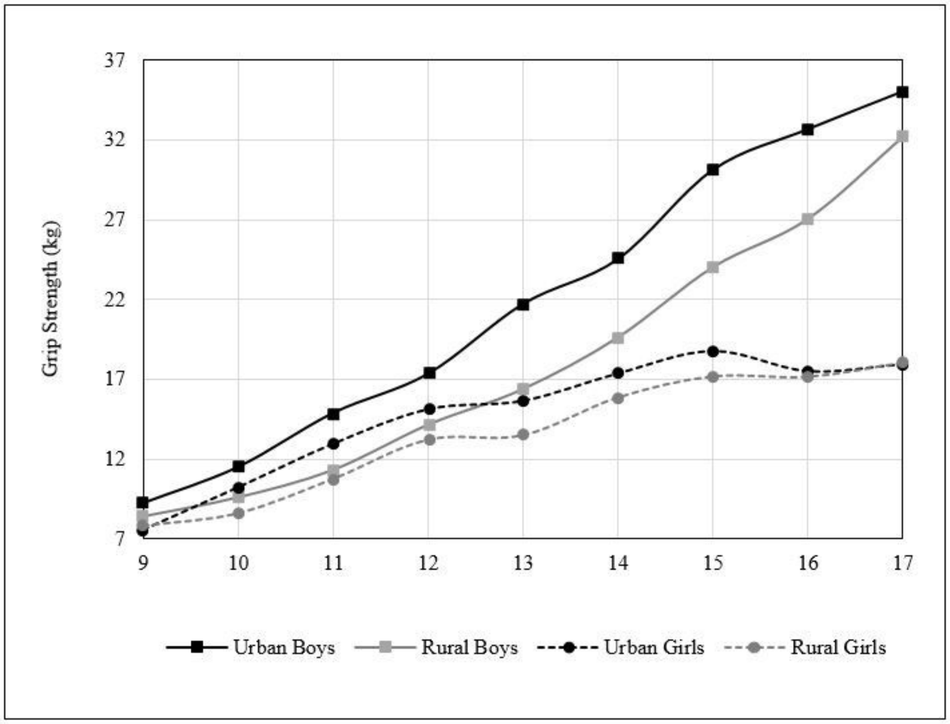
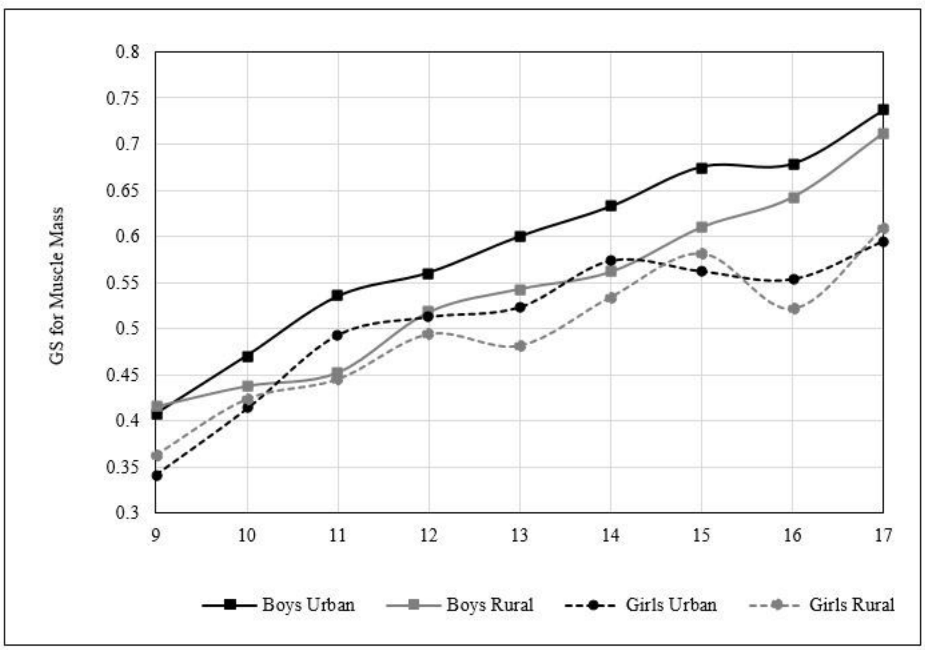


Figure 1

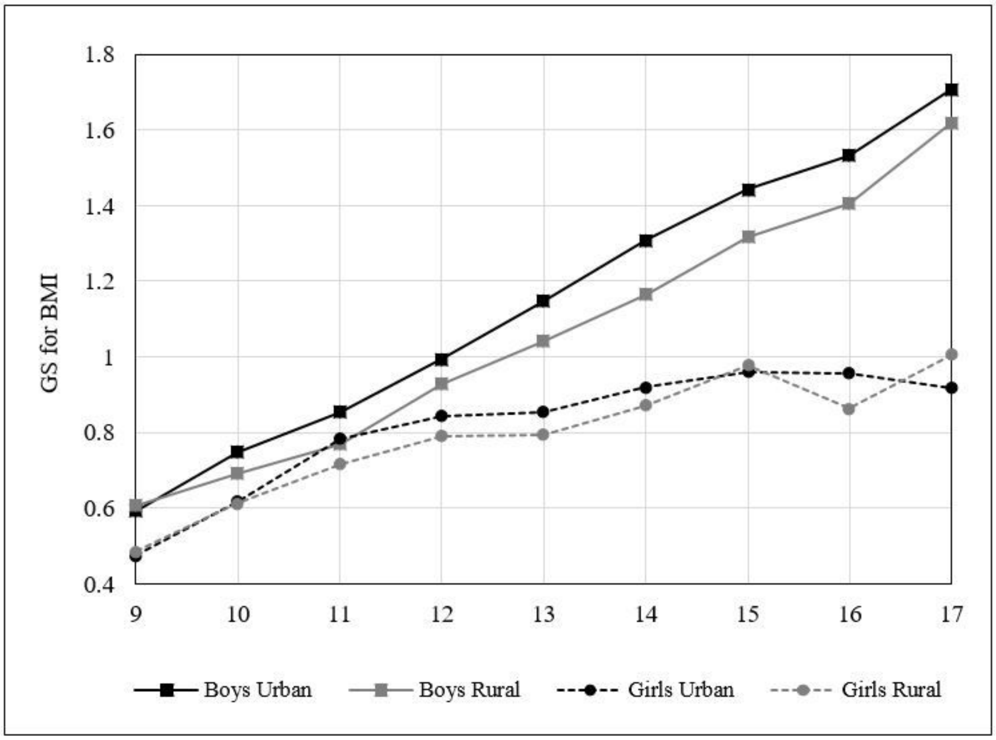
Increase in mean grip strength with age in boys and girls from urban and rural areas



GS: Grip Strength

Figure 2

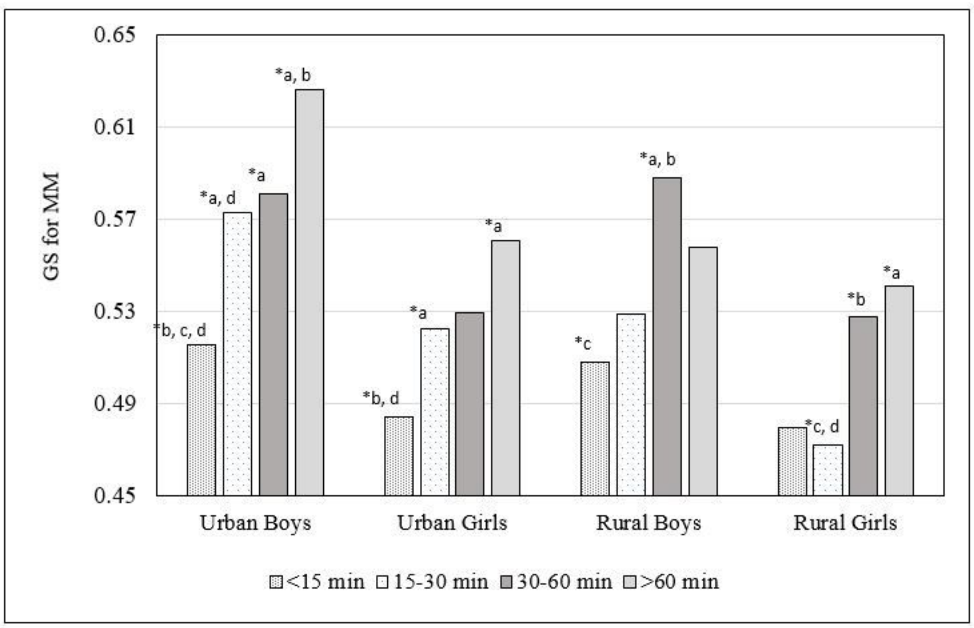
GS to Muscle Mass ratio across age groups



GS: Grip Strength; BMI: Body Mass Index

Figure 3

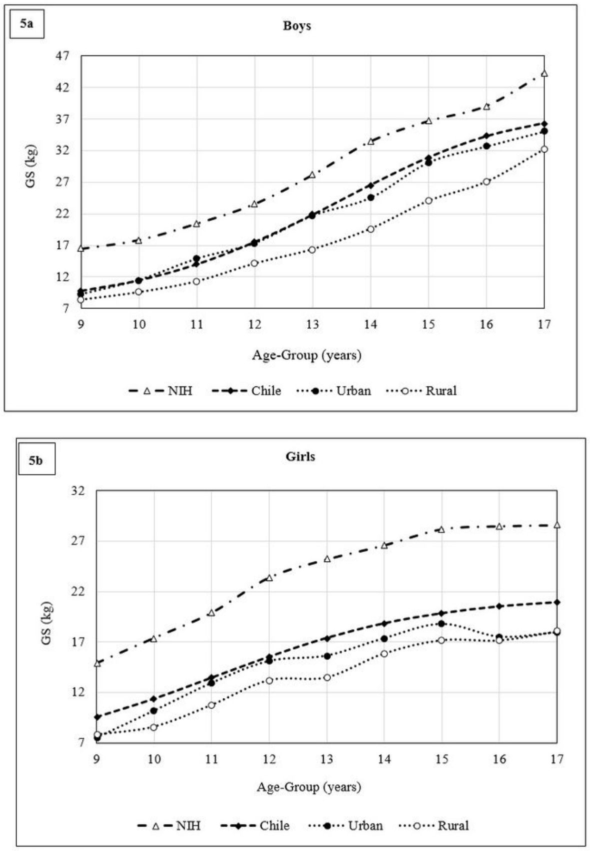
GS to BMI ratio across age groups



GS: Grip Strength; MM: Muscle Mass; a: significantly different than sunlight exposure group < 15 minutes; b: significantly different than sunlight exposure group 15 to 30 minutes; c: significantly different than sunlight exposure group 30 to 60 minutes; d: significantly different than sunlight exposure group > 60 minutes; *p<0.05

Figure 4

Sunlight Exposure and Grip Strength in Rural and Urban Boys and Girls



GS: Grip Strength

Figure 5

Comparison of the mean GS of study boys (a) and girls (b) with other reported GS Data