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Original article

Hand Grip Strength (HGS) in children aged 9-10 years based on nutritional status

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Abstract. *Background and aim:* Hand grip strength (HGS) is crucial across life stages, reflecting health and function. It influenced by age, gender, and body size. HGS correlates with anthropometric traits like weight and hand dominance. It predicts health outcomes, aids in clinical assessments, and guides early interventions for optimal pediatric health. This study was elaborated to evaluate the HGS difference in children aged 9-10 years based on nutritional status. *Methods:* A cross-sectional study was conducted involving children aged 9-10 years collected using the consecutive sampling method. Handgrip strength was measured using a digital dynamometer. Subjects were categorized based on weight-for-age z-score (WAZ) and height-for-age z-score (HAZ) into groups representing different nutritional statuses. *Results:* The study revealed significant differences in muscle mass percentage across nutritional status groups, namely severely-underweight (16.53%), underweight (18.46%), normal-weight (22.14%), and overweight (31.04%) ($P<0.0001$). Significant differences were also found in right-HGS between boys (14.83 kg) and girls (13.16 kg), $P=0.007$, and in left-HGS between boys (12.78 kg) and girls (10.19 kg) ($P<0.0001$). HGS significantly differed between normal and stunted groups ($P<0.0001$), underweight and normal groups ($P<0.0001$), and underweight and overweight groups ($P=0.001$). *Conclusions*: Handgrip strength (HGS) is pivotal for assessing children's muscle strength and health. Boys typically exhibit greater strength than girls, influenced by age. Normal nutritional status correlates with stronger handgrip compared to stunted children. Anthropometric factors like height, weight, BMI, and muscle mass significantly impact handgrip strength, reflecting overall growth and development. (www.actabiomedica.it)

Key words: hand grip strength, nutritional status, BMI, anthropometric, stunted, wasted

Introduction

Hand grip strength (HGS) plays a pivotal role across various stages of human life, including aging and infection (1), growth and development (2), injury (3) and inpatient settings (4), and rehabilitation (5). As a crucial indicator of hand function, HGS is extensively studied for its ability to reflect overall health status. Establishing normative values for HGS in healthy children is essential for benchmarking normal function and preventing early locomotor impairments (6). However, the measurement of HGS is influenced by factors such as age, gender, and body size, which contribute to its variability across populations. Studies in Egypt (7,8) and India (9–11) have consistently demonstrated strong correlations between HGS and anthropometric traits like weight, height, and hand length. Additionally, hand dominance significantly impacts HGS, with the dominant hand typically exhibiting greater strength than the non-dominant hand. Surprisingly, body mass index (BMI) shows inconsistent effects on HGS compared to other anthropometric variables (12,13). Beyond its anthropometric associations, HGS holds clinical significance by correlating with various functional and medical parameters across different demographic groups. Its non-invasive and cost-effective assessment makes it invaluable for evaluating acute nutritional changes and predicting muscle strength in conditions ranging from juvenile idiopathic arthritis to traumatic hand injuries (14). Objective assessment of HGS through dynamometry enables predictions across diverse health outcomes. Studies consistently highlight its predictive value in assessing cardiovascular health in elderly individuals, determining post-surgery functional capacity, and monitoring muscular development in athletes. HGS serves as a reliable predictor for postoperative complications, cardiovascular mortality, and overall functional decline, emphasizing its utility as a screening tool in clinical practice (15,16). The reliability and validity of HGS measurements further enhance its utility in clinical settings, where it plays a crucial role in evaluating treatment outcomes and assessing upper extremity functional integrity. Grip strength measurements not only facilitate monitoring treatment effectiveness but also serve as an objective marker directly linked to nutritional status. This dual role underscores its importance in therapeutic interventions and preventive care strategies (17,18). HGS transcends its role as a mere physical measure, embodying a multifaceted tool with implications for health monitoring, rehabilitation planning, and predictive medicine (19). Understanding its complex relationship with anthropometric factors and its predictive power across diverse health outcomes underscores the need for continued research, particularly in pediatric populations. Establishing normative HGS values in children can guide early interventions and optimize health outcomes from an early age. The aim of this study is to evaluate the HGS difference in children aged 9-10 years based on nutritional status.

Methods

Study design

A cross-sectional study was conducted involving the elementary school students aged 9-10 years old in Surabaya during October-December 2023 involving subjects without congenital anomaly (cerebral palsy, down syndrome, congenital heart disease, or mental disorders). The inclusion criterion in this study was the parents gave the permission for their children to take part in this study and cooperative for data collection by signing the inform consents and information of consents after the researchers explain the study, the purpose and benefits for the society. The total number of research subjects was 249 children using simple random sampling (total screened subjects was 1080, with stunted and severely stunted children of 110). A total of 8 elementary schools were took part in this study, which determined by simple random sampling.

Hand Grip Strength and anthropometric measurements

Handgrip strength (HGS) was measured using a digital dynamometer (Camry, Model EH101, Sensun Weighing Apparatus Group Ltd, Guangdong, China) in a sitting position. The subjects were asked to sit in a comfortable position without arm support. Then the elbow was flexed in 90º, the upper arm and lateral thorax were separated. The subjects were asked to squeeze the handle with the maximal effort for 3-5 second. Between the first to the second, and the third measurements, the subject was given a break for reducing the fatigue (15 second). HGS values were measured in kilograms (1 kilogram = 2.2046 pounds). The measurements were repeated three times and then accounted for the mean value for both hands (left and right). No handle adjustment was needed as the subjects able to grab the handle comfortably. Anthropometry measurement including body weight and body height. Body weight was measured using Tanita RD 803 by asking the subjects to step in on the scale in a barefoot with light clothes and no accessories such as watch, hat, etc. Tanita monitor will display BMI, fat mass (in %), muscle mass (in %) and bone mass (in %) in several minutes when the subjects were step on the scale. Body height was measured using Seca stadiometer 213 (Seca, Germany). by asking the subjects to stand on the base while the eye look forward with straight head. The subjects were asked to step on the stadiometer floor plate in a straight position or in Frankfurt line, and then head positioner were pulled down until it touched the subject's head. The height then recorded according to the scale position. The measurements were repeated 2 times when the difference between the first and second measurements was < 0.1 g for weight, and < 0.1 cm for height. If the differences more than that, the measurements were repeated 3 times, and then accounted for the mean value. The subjects were analyzed based on weight-for-age z-score (WAZ) and height-for-age z-score (HAZ) using WHO Anthroplus (offline version, WHO). According to the anthropometric measurements, the HAZ groups were categorized into three: normal height (Group I), stunted (Group II), and severely stunted (Group III). The WAZ groups were divided into four: severely underweight (Group I), underweight (Group II), normal weight (Group III), and overweight (Group IV).

Statistical analysis

Statistical analysis used in this study including test of normality for interval and ratio data, continued with independent sample T-test or Mann Whitney U test (when dependent variable divided into two groups), One Way Anova or Kruskal Wallis test (when dependent variable divided into more than two groups), depend on the data distribution, followed by Post Hoc test: LSD (normal distribution) or Mann Whitney U test (abnormal distribution). While categorical data was analyzed using chi square test or Fischer's exact test. Receiver operation curve (ROC) was elaborated to determine the cut-off point of HGS in stunted and non-stunted subjects. Cut-off value was determine using Youden Index, the biggest value was the cut-off. All the statistical analysis was running using SPSS ver. 21 (IBM, US).

Ethical clearance

All methods were performed following the guidelines and regulations of the Declaration of Helsinki. Furthermore, this study received approval of the Ethics Committee (309/EC/KEPK/FKUA/2023) released on 2nd November 2023 by the Faculty of Medicine, Airlangga University, Surabaya, Indonesia. Subjects were screened and measured with the approval of their parents and the head of school.

Results

Characteristics of research subjects

Characteristics of the research subjects are shown in Table 1, which are presented in the form of median (minimum-maximum values), as the data did not distribute normally. The gender distribution of the research subjects was 47.38% boys and 52.62% girls.

There was a significant difference in age between boys [110.66 (91 – 120) months] and girls [105.30 (92 – 120) months] (*P*=0.000). Significant differences were also found in muscle mass between boys [22.38 (15.20 – 42.35) %] and girls [19.73 (14.00 – 30.20) %],

Table 1. Characteristics of Research Subjects.

Variable	Boys (n=118) Median (min-max)	Girls (n=131) Median (min-max)	*P* value
Age (months)	110.66 (91 – 120)	105.30 (92 – 120)	<0.000[a*]
Body height (cm)	124.36 (109.8 – 146.8)	122.86 (109.5 – 143.8)	0.108[a]
Body weight (kg)	25.43 (16.20 – 58.40)	23.87 (14.80 – 43.45)	0.090[a]
Muscle mass (%)	22.38 (15.20 – 42.35)	19.73 (14.00 – 30.20)	<0.0001[a*]
Upper arm circumference (cm)	18.91 (9.50 – 30.00)	18.42 (10.50 – 26.00)	0.362[a]
Right-HGS (kg)	14.83 (2.60 – 36.60)	13.16 (2.70 – 79.33)	0.007[a*]
Left-HGS (kg)	12.78 (2.20 – 43.47)	10.19 (3.40 – 67.00)	<0.0001[a*]

[a]Mann Whitney U test; [*]significant in p<0.05

Table 2. Anthropometric Differences Based on HAZ.

Variable	Normal (n=155) Median (min-max)	Stunted (n=88) Median (min-max)	Severely stunted (n=6) Median (min-max)	*P* value
Weight (kg)	26.81 (16.60 – 58.40)	21.18 (14.80 – 30.20)	18.13 (16.50 – 21.50)	<0.0001[a*]
Muscle mass (%)	22.34 (14.40 – 42.35)	18.93 (14.00 – 39.00)	16.38 (14.45 – 19.45)	<0.0001[a*]
Upper arm circumference (cm)	19.44 (9.50 – 30.00)	17.37 (13.50 – 23.00)	16.90 (14.50 – 21.50)	<0.0001[a*]
Right handgrip strength (kg)	14.86 (5.30 – 36.60)	12.38 (2.60 – 79.33)	13.47 (7.67 – 26.20)	0.001[a*]
Left handgrip strength (kg)	12.97 (4.33 - 33.10)	10.06 (2.20 - 67.00)	8.90 (5.70 – 12.73)	<0.0001[a*]

[a]Kruskal Wallis; [*]significant in P<0.05

Table 3. Anthropometric Differences Based on WAZ.

Variable	Severely Underweight (n=21) Median (min-max)	Underweight (n=75) Median (min-max)	Normal (n=141) Median (min-max)	Overweight (n=12) Median (min-max)	*P* value
Height (cm)	138.35 (127.5 – 146.8)	120.06 (110.0 – 127.1)	125.24 (112.5 – 145.6)	138.35 (127.5 – 146.8)	<0.0001[a*]
Muscle mass (%)	16.53 (14.00 – 19.00)	18.46 (14.70 – 28.00)	22.14 (16.45 – 39.00)	31.04 (21.55 – 42.35)	<0.0001[a*]
Upper arm circumference (cm)	16.12 (13.90 – 21.50)	16.62 (13.50 – 19.00)	19.53 (9.50 – 28.00)	25.35 (18.50 – 30.00)	<0.0001[a*]
Right handgrip strength (kg)	16.12 (13.90 - 21.50)	16.62 (13.50 - 19.00)	19.53 (9.50 - 28.00)	25.35 (18.50 - 30.00)	<0.0001[a*]
Left handgrip strength (kg)	9.58 (2.70 - 26.20)	12.57 (5.30 - 68.93)	14.96 (2.60 - 79.33)	18.34 (7.17 - 36.60)	<0.0001[a*]

[a]Kruskal Wallis; [*]significant in P<0.05

P<0.001, in right- HGS between boys [14.83 (2.60 – 36.60) kg] and girls [13.16 (2.70 – 79.33) kg] (*P*=0.007), and in left-HGS between boys [12.78 (2.20 – 43.47) kg] and girls [10.19 (3.40 – 67.00) kg] (*P*<0.001).

Differences in Handgrip Strength (HGS) based on nutritional status

Anthropometric values based on nutritional status are measured with height-for-age z-score (HAZ) and weight-for-age z-score (WAZ), which presented in in Table 2 and Table 3.

The body height in the normal group [126.69 (115.9 – 146.8) cm] was significantly different from the stunted group [118.84 (109.5 – 125.6) cm] and the severely stunted group [109.168 (109.8 – 117.4) cm] (*P*=0.0001). The body weight in the normal group [26.81 (16.60 – 58.40) kg] was significantly different from the stunted group [21.18 (14.80 – 30.20) kg] and the severely stunted group [18.13 (16.50 – 21.50) kg] (*P*<0.0001). Significant differences were also found in muscle mass (*P*<0.0001) and upper arm circumference (*P*<0.0001) among the three groups.

The median values for muscle mass in the severely underweight, underweight, normal, and overweight groups were 16.53%, 18.46%, 22.14%, and 31.04% respectively, with significant differences between the groups (*P*<0.0001). Upper arm circumference also showed significant differences between the groups (*P*<0.0001). The difference of HGS based on HAZ were shown in Table 4. Significant differences were

Table 4. The significancy value of Right- and Left-HGS Based on Nutritional Status of HAZ.

HGS Values	Normal (n=155)	Stunted (n=88)	Severely Stunted (n=6)
Right HGS			
Normal (n=155)	-	14.86 + 7.19 vs. 12.38 + 10.97. P<0.0001[a*]	14.86 + 7.19 vs. 13.47 + 6.77. P=0.675[a]
Stunted (n=88)	12.38 + 10.97 vs. 14.86 + 7.19. P<0.0001[a*]	-	12.38 + 10.97 vs. 13.47 + 6.77. P=0.265[a]
Severely Stunted (n=6)	13.47 + 6.77 vs. 14.86 + 7.19. P=0.675[a]	13.47 + 6.77 vs. 12.38 10.97. P=0.265[a]	-
Left HGS			
Normal (n=155)	-	12.97 + 6.13 vs. 10.06 + 8.10. P<0.0001[a*]	12.97 + 6.13 vs. 8.90 + 2.92. P=0.840[a]
Stunted (n=88)	10.06 + 8.10 vs. 12.97 + 6.13. P<0.0001[a*]	-	10.06 + 8.10 vs. 8.90 + 2.92. P=0.981[a]
Severely Stunted (n=6)	8.90 + 2.92 vs. 12.97 + 6.13. P=0.840[a]	8.90 + 2.92 vs. 10.06 + 8.10). P=0.981[a]	-

[a] Post Hoc test: Mann Whitney; significant at p<0.05

Table 5. The significancy value of Right and Left Handgrip Strength Based on WAZ.

HGS Values	Severely Underweight (n=21)	Underweight (n=75)	Normal (n=141)	Overweight (n=12)
Right HGS				
Severely Underweight (n=21)	-	9.58 + 4.93 vs. 12.58 + 8.49. P=0.039[a*]	9.58 + 4.93 vs. 14.95 + 9.02. P=0.001[a*]	9.58 + 4.93 vs. 18.35 + 8.95. P=0.001[a*]
Underweight (n=75)	12.58 + 8.49 vs. 9.58 + 4.93. P=0.039[a*]	-	12.58 + 8.49 vs. 14.95 + 9.02. P=0.019[a*]	12.58 + 8.49 vs. 18.35 + 8.95. P=0.010[a*]
Normal (n=141)	14.95 + 9.02 vs. 9.58 + 4.93. P=0.001[a*]	14.95 + 9.02 vs. 12.58 + 8.49. P=0.019[a*]	-	14.95 + 9.02 vs. 18.35 + 8.95. P=0.144[a]
Overweight (n=12)	18.35 + 8.95 vs. 9.58 + 4.93. P=0.001[a*]	18.35 + 8.95 vs. 12.58 + 8.49. P=0.010[a*]	18.35 + 8.95 vs. 14.95 + 9.02. P=0.144[a]	-
Left HGS				
Severely Underweight (n=21)	-	9.43 + 8.22 vs. 9.59 + 4.04. P=0.131[a]	9.43 + 8.22 vs. 12.93 + 7.57. P=0.001[a*]	9.43 + 8.22 vs. 16.28 + 7.21. P <0.0001[a*]
Underweight (n=75)	9.59 + 4.04 vs. 9.43 + 8.22. P=0.131[a]	-	9.59 + 4.04 vs. 12.93 + 7.57. P=0.000[a*]	12.57 (5.30 - 68.93) vs. 16.28 + 7.21. P =0.001[a*]
Normal (n=141)	12.93 + 7.57 vs. 9.43 + 8.22. P 0.001[a*]	12.93 + 7.57 vs. 9.59 + 4.04. P=0.000[a*]	-	12.93 + 7.57 vs. 16.28 + 7.21. P =0.066[a]
Overweight (n=12)	16.28 + 7.21 vs. 9.43 + 8.22. P=0.000[a*]	16.28 + 7.21 vs. 9.59 + 4.04. P=0.001[a*]	16.28 + 7.21 vs. 9.59 + 4.04. P=0.066[a]	-

[a] Post Hoc test: Mann Whitney; significant at p<0.05

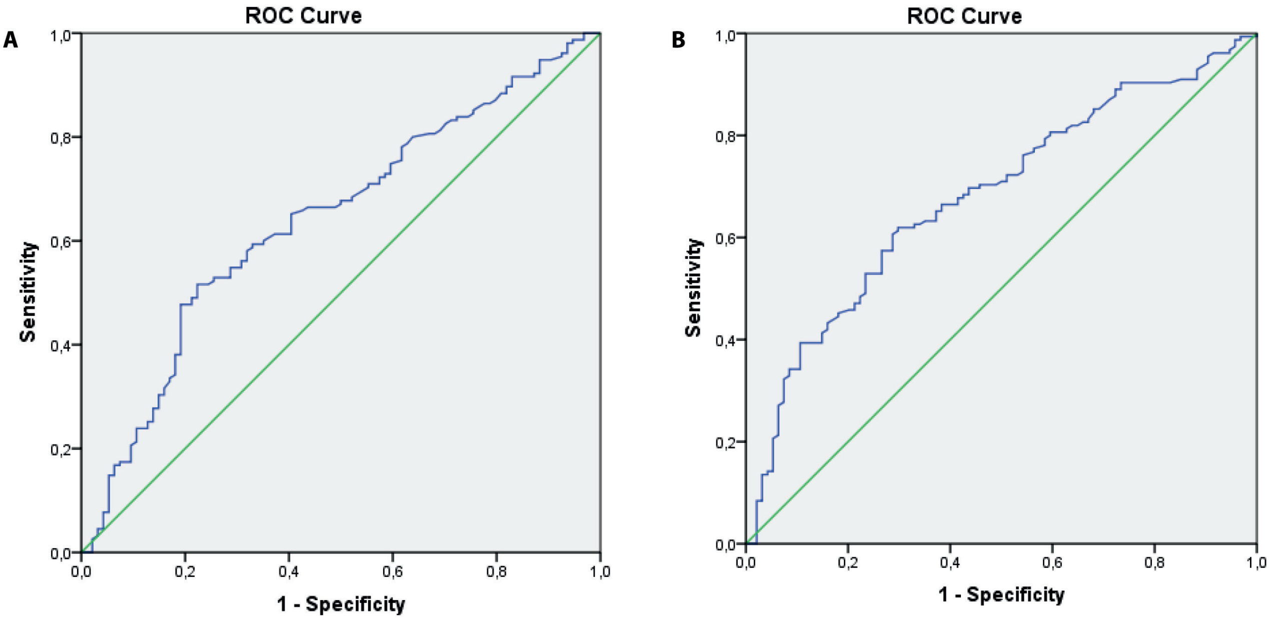

Figure 1. Right-HGS (a) and left-HGS (b) predictor for the long-term impact of stunting in children aged 9-10 years (boys and girls).

found in HGS among the different nutritional status groups, particularly a significant difference in right- and left-HGS between the normal group and the stunted group (*P*<0.0001) (Table 5).

This study also found significant differences in right-HGS values between the severely underweight group and the underweight group (*P*=0.039), the normal group (*P*=0.001), and the overweight group (*P*=0.001). Significant differences were also found between the underweight group and the normal group (*P*=0.019), and the overweight group (*P*=0.010). On the other hand, this study also found significant differences in left-HGS values between the severely underweight group and the normal group (*P*=0.001), and the overweight group (*P*<0.0001). Significant differences were also found between the underweight group and the normal group (*P*<0.0001), and the overweight group (*P*=0.001).

Hand Grip Strength (HGS) as the predictor for long-term impact of stunting

Hand grip strength (HGS) is associated with nutritional status in children. The evaluation of HGS as a predictor of the long-term impact of stunting in children was assessed using receiver operational curve (ROC) to determine the area under curve (AUC) and cut-off value between normal and stunted group. Figure 1 summarize the predictor of HGS of the subjects. The AUC for right-HGS in children aged 9-10 years as a predictor of the long-term impact of stunting is 0.641 (95% CI [0.570-0.711], *P*<0.0001), with a cut-off value > 9.35 (sensitivity 67.7%, specificity 50.0%). While the AUC for left-HGS as a predictor of the long-term impact of stunting in children aged 9-10 years is 0.680 (95% CI [0.613-0.747], *P*<0.0001). The cut-off value for left-HGS in detecting stunting is >7.98 (sensitivity 71.0%, specificity 50.0%).

Figure 2 reflecting the right-HGS in boys and girls. The AUC for right-HGS in boys aged 9-10 years as a predictor of the long-term impact of stunting was 0.723 (95% CI [0.630-0.816], p=0.000), with a cut-off value > 9.90 (sensitivity 74.6%, specificity 53.2%). While AUC for right-HGS in girls as a predictor of the long-term impact of stunting in girls aged 9-10 years was 0.579 (95% CI [0.476-0.682], p=0.134). The cut-off value for right-HGS in detecting stunting was >9.20 (sensitivity 60.7%, specificity 51.1%).

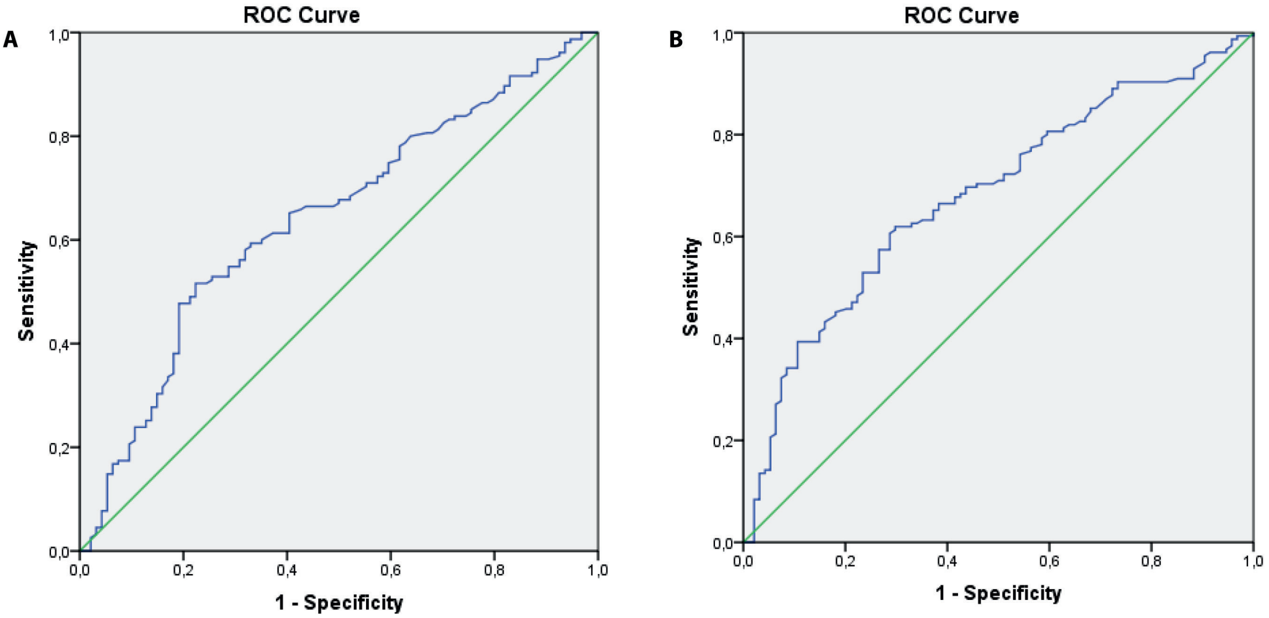

Figure 2. Right-HGS predictor for boys as a long-term impact of stunting in boys (a) and girls (b) aged 9-10 years.

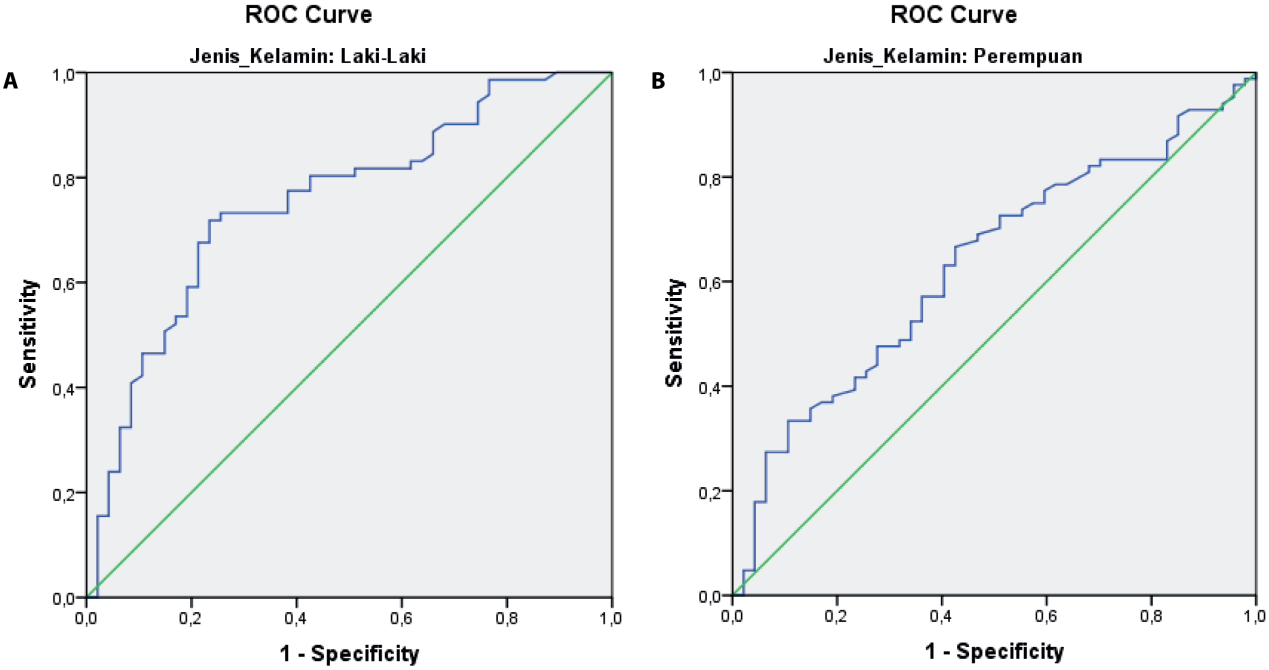

Figure 3. Left-HGS predictor for boys as a long-term impact of stunting in boys (a) and girls (b) aged 9-10 years.

Figure 3 summarized the left-HGS between boys and girls. The AUC for left-HGS in boys aged 9-10 years as a predictor of the long-term impact of stunting was 0.755 (95% CI [0.666-0.844], p=0.000), with a cut-off value > 8.66 (sensitivity 80.3%, specificity 57.4%). The AUC for left-HGS in girls aged 9-10 years as a predictor of the long-term impact of stunting was 0.632 (95% CI [0.535-0.729], p=0.013), with a cut-off value > 7.30 (sensitivity 69.0%, specificity 53.2%).

Discussion

Handgrip strength (HGS) is an indicator of physical strength, serving as a non-invasive marker of muscle strength, muscle mass, and nutritional status. Previous research has compared HGS in children based on sex, age, hand dominance, anthropometric profile, and nutritional status. Currently, HGS is a predictor and biomarker of health. Low HGS in children and adolescents is associated with poor cardiometabolic and bone health outcomes (20). A study in children aged 4-15 years old proved that boys had stronger HGS than girls for both dominant and non-dominant hands across all age groups. The curve for boys' HGS tends to be higher but remains parallel to that of girls until the age of 12, after which boys' handgrip strength accelerates more rapidly than girls, likely due to the differences in the growth spurts (21). To support this, a study found significant differences between boys and girls (*P*=0.02) (22). Other reported that boys had a significantly higher muscle mass percentage than girls for all age groups (23). Muscle strength depends on height and is significantly correlated (22). These results also align with this study's findings, where muscle mass in boys was higher than in girls. Other study found that HGS was increase along with the age increment in both boys (*P*<0.0001) and girls (*P*<0.0001) (23), in which the differences becoming more pronounced from age 13 onwards (24). This suggesting that beside correlated with sex, HGS also correlated with age. To support this findings, a study showed a correlation between handgrip strength and chronological age (25), while other also found a significant positive linear trend in HGS along with age for both boys and girls (*P*<0.001 for each gender) (26). A study also access that other anthropometric measurements was correlated with HGS, including weight (r=0.57), height (r=0.63), upper arm circumference (r=0.5), triceps skinfold (r=0.25), arm fat area (r=0.33), and arm muscle area (r=0.37), all with *P*<0.01 (27). The mean HGS for boys were 15.2 ± 3.0 kg and girls 13.8 ± 4.0 kg for girls (p=0.04), with age distribution of 9 to 10 years old (28). All the findings from the previous studies supported our findings, where boys had stronger HGS than girls for the same age group, and the right hand, being the dominant hand for most of the study sample, had higher HGS in boys than girls, with a significant difference between the two groups. Left-HGS in boys was [12.78 (2.20 - 43.47)] and in girls was [10.19 (3.40 - 67.00)], also showing a significant difference between the two groups (*P*<0.0001). The difference in boys' HGS is influenced by diet and play activities that promote muscle development. Boys aged 9-10 years showed higher physical activity intensity than girls (29). Also other stated that differences in HGS between age groups and genders were largely explained by differences in muscle mass, total body mass, and stature, while others such as genetic factors, diet, or physical activity also took parts on the difference between races and countries (30). Hand grip strength (HGS) also influenced by other anthropometric: midstylion-dactylion and acromiale-radiale lengths, fat mass, lean mass, and bone mineral content (BMC). Height is directly related to HGS likely due to its close association with lean body mass. Increased lean mass generally results in increased HGS, as the capacity of muscle to generate force is proportional to its cross-sectional area (31). A systematic analysis of HGS found a moderate increase of 19.4% (95% CI 18.4-20.4) or 3.8% per decade (95% CI 3.6-4.0). The increase was greater in children aged 9-12 years compared to adolescents aged 13-17 years, influenced by health and sociodemographic indicators (32). A study conducted on hospitalized and outpatient children aged 6-14 years using mixed-model ANCOVA analysis found a significant correlation between HGS and age group (*P*<0.0001), height z-score (*P*<0.0001), dominant hand (*P*<0.0001), and mean upper arm circumference (MUAC) z-score (*P*=0.0462). HGS was stronger in participants with higher height and BMI z-scores, and it increased with age. The study also found a correlation between HGS and MUAC z-score, with stronger HGS in participants with higher MUAC z-scores. MUAC is more sensitive to the changes in fat and muscle mass than BMI in adults and is a better indicator of malnutrition risk in young children. Measurements of MUAC and HGS are also independent of fluid changes reflected in body weight, which is common in hospitalized patients (33). Muscle strength in children is related to age and sex as muscle strength increases with maturation due to changes in muscle mass and fiber size. Therefore, muscle mass is largely determined by height and weight (34). A study on children aged 6-10 found that basic anthropometric parameters (height and BMI) were stronger predictors of handgrip strength than specific anthropometric parameters (finger span, length, and perimeter) in pre-pubertal children. Age increase contributed to increased anthropometry and handgrip strength, with these predictors being stronger for boys than girls. Additionally, a significant increase in height was statistically found in older children ($P<0.001$). Increased age, followed by increased height and BMI, will result in increased of HGS. The dominant hand will have stronger HGS than the non-dominant hand (35). These findings align with this study, in which normal nutritional status children and significantly taller heights also had significantly higher HGS than stunted and severely stunted children ($P<0.001$). The study added that the relationship between BMI and HGS might be explained by the additional load from high BMI when children move. Neurological factors such as motor unit recruitment and synchronization may contribute to higher handgrip strength in preschool children with higher BMI and waist circumference (36). The study also indicated that Chilean children have a higher BMI than children from other countries. This difference may affect the measurement of nutritional status. Despite this, research results showed that HGS was positively correlated with BMI (30).

Nutritional status affects growth and development in children. Malnutrition will delay the growth of skeletal muscles, resulting in smaller muscle size, fewer muscle fibers, and decreased muscle strength. Children aged 4-5 years with normal nutritional status had stronger HGS than malnourished children, with a significant difference ($P<0.001$). HGS increased with age, weight, and height (37). This aligns with the findings of this study, where normal nutritional status was significantly higher in boys (67.30%) and girls (71.90%) compared to stunted and severely stunted children ($P=0.007$). A similar study found stronger HGS in children with normal nutritional status compared to malnourished children. Right-HGS increased with age in boys and girls, with a significant positive correlation toward nutritional status ($P<0.05$). Left-HGS was also stronger in children with normal nutritional status compared to malnourished children, with a significant positive correlation with age for boys ($P<0.05$) and girls ($P<0.01$) (38). Another study found a significant positive correlation between BMI and HGS for both right ($P=0.014$) and left hands ($P=0.022$) (39). All of those findings supporting our results in which showed that normal nutritional status had stronger HGS in boys and girls compared to stunted and severely stunted children (p=0.007). Right-HGS in boys with normal nutritional was stronger than in stunted boys and severely stunted boys. Right-HGS in girls with normal nutritional status was stronger than stunted girls and severely stunted girls. Left-HGS in boys with normal nutritional status was stronger than in stunted boys and severely stunted boys. Left-HGS in girls with normal nutritional status was stronger than in stunted girls and severely stunted girls. The reason why children with normal nutritional status will have stronger HGS than malnourished children because normal nutritional status will support optimal growth and development, including muscle development, whereas stunted and severely stunted nutritional status will cause growth and development disorders, resulting in smaller muscle size, fewer muscle fibers, and decreased muscle strength. Children with good nutritional status tend to have higher HGS than children with poor nutritional status (40).

Strength and limitations

The study to investigate HGS in healthy children population is still limited in Indonesia. This study describes that undernutrition, especially stunting preadolescent children had lower HGS than normal children with the similar age. This information can be used for improving HGS for those undernourished children during the growth spurt period (adolescents). This study was performed in preadolescent period, with limited demographic factors. More information related demographic factors needed to explore to investigate the HGS in Indonesia, especially in high-risk population of nutritional disturbances, such low-income populations.

Conclusion

Handgrip strength (HGS) is pivotal for assessing children's muscle strength and health. Boys typically exhibit greater strength than girls, influenced by age. Normal nutritional status correlates with stronger handgrip compared to stunted children. Anthropometric factors like height, weight, BMI, and muscle mass significantly impact handgrip strength, reflecting overall growth and development.

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