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Correlation between weight, height, and body mass index with hand grip strength among junior high school

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Abstract
The association between body size, diseases, and dysfunction with HGS in adolescents has been widely studied. However, the results are less conclusive due to various influencing factors. This study aimed to investigate the correlation between weight, height, and BMI with HGS and the effect of gender in adolescents. This cross-sectional study was followed by 117 students (66 boys, 51 girls) of Susteran Junior High School Purwokerto in May 2023. Weight and height were measured according to the standard procedure. BMI was calculated based on a standard formula. HGS was examined using a digital hand dynamometer. Independent T-test and Pearson correlation were applied. Significance was set at $p<0.05$. Weight, height, and BMI between genders were not different ($p=0.81$, 0.50, and 0.22, respectively). Boys had stronger HGS than girls (25.0±7.1 vs 19.8±4.3, $p<0.01$). Weight and height had weak correlation with HGS in boys ($p=0.02$, r=0.28, and $p=0.03$, r=0.26), moderate correlation in girls ($p<0.01$, r=0.57 and $p<0.01$, r=0.50), and overall ($p<0.01$, r=0.41 and $p<0.01$, r=0.45). BMI had a moderate correlation with HGS in girls ($p<0.01$, r=0.52) and a weak correlation overall ($p<0.01$, r=0.29). No correlation was found between BMI and HGS in boys. Weight and height correlate with HGS in boys, girls, and overall, but BMI correlates with HGS in girls and overall.

Keywords: Adolescent, anthropometric measure, adiposity, muscle mass, gender difference, hand grip strength

1. Introduction
Adolescence is a period of rapid growth and development that teenagers can use to maintain muscle health [1]. Rapid growth in adolescents is characterized by increases in height and weight, often accompanied by increases in muscle and fat mass. Therefore, rapid growth can change the body dimensions and size of adolescents. Body mass index (BMI) is a numerical value of a person's weight relative to their height, which is a widely used screening tool to categorize weight. BMI provides a rough estimate of body fat and is used to indicate potential health risks associated with abnormal body weight [2].

Handgrip strength (HGS) refers to the force or strength generated by the muscles in the hand and forearm. Hand grip strength can be measured using a hand grip dynamometer. It measures upper muscular strength, mainly the grip and hand movement muscles. Handgrip strength is a simple, practical, irreplaceable indicator of overall muscle strength and function [3].

Handgrip strength is related to health in adolescents. Research has suggested several correlations between handgrip strength and various health outcomes in adolescents. Previous studies reported that HGS had a positive association with blood pressure in children and adolescents [4, 5]. Korean National Health and Nutrition Examination Survey from 2014-18 reported that greater HGS was associated with a lower risk of metabolic syndrome [6]. A study from Brazil indicated that HGS was positively associated with bone mineral density [7]. Other studies demonstrated that HGS was also related to physical and cardiovascular fitness [8, 9].

Several factors are thought to influence HGS value. Sex, age, handedness, nutritional status, and academic performance were reported to influence HGS [10].

HGS was also positively correlated with energy, carbohydrate, and fat intakes, and physical activity score [11]. A previous study reported that HGS was correlated with hand dimension [12]. As body size increases, muscle strength will increase. Previous studies demonstrated the correlation between anthropometric measures and HGS. However, the results were inconclusive. A study in Nigeria showed that HGS, especially right HGS, was correlated with BMI in both genders [13]. However, a conflicting result was also reported. A study in Indonesia concluded that HGS was not correlated with BMI [14]. Lad *et al*. reported that underweight and overweight adolescents had a lower HGS [15].

1.1. Aim of the Study
Therefore, to complete and increase knowledge about BMI and HGS, the present study investigated the correlation between HGS and BMI, height, and weight according to gender.

2. Materials and Methods
2.1. Design of the Study
The design of this study was cross-sectional with analytic description.

2.2. Participants and Criteria
Participants were Purwokerto Susteran Junior High School students in Central Java, Indonesia. One hundred and seventeen students, consisting of 66 boys and 51 girls from grades 1 and 2, participated in this study. Students who did not attend school during examination and data collection were excluded. Unfit students due to acute or chronic illness, students with hand and upper extremity injuries, or students with conditions affecting hand grip strength were excluded.

2.3. Time and Location
Data acquisition was held in May 2023, with one visit only. All data acquisition activities were conducted in Susteran Junior High School, Purwokerto. For time effectiveness and efficiency, measurements and examinations were held out simultaneously by creating checkpoints for each type of measurement and examination. Students were directed to an empty checkpoint to undergo measurements.

2.4. Measurements
Height was measured in Frankfort's standing position using an infrared-based-digital height meter without footwear (HT721, GEA medical, China). Height was expressed in cm to the closest 0.1 cm. In a standing position, weight was measured using a digital scale (SECA Robusta 813, Germany). To avoid problems related to modesty, students kept wearing their uniforms during weigh-ins. Weight was expressed in kg to the nearest 0.1 kg. BMI was obtained from weight (kg) divided by square height (m) and expressed as kg/m^2.

Hand grip strength was measured using a digital handgrip dynamometer (Camry EH101, China). Participants underwent the HGS test in a standing position, with their feet shoulder apart. Participants were instructed to hold the hand dynamometer with their dominant hand. The handle of the dynamometer should rest against the base of the fingers, and the thumb should be on the opposite side. Participants were instructed to squeeze the dynamometer with maximum force for a few seconds. Participants must repeat the maneuver three times, with a short rest between trials, to obtain the best result. The best result was recorded in kg to the nearest 0.1 kg.

2.5. Statistical Analysis and Data Processing
Numerical data was presented as mean ± standard deviation (SD). Categorical data was presented as frequency (%). Comparison between two numerical variables was analyzed using an unpaired T-test. The correlation between height, weight, BMI, and HGS was evaluated using Pearson's correlation. Statistical test was considered significant if $p< 0.05$. Data and statistical tests were analyzed using SPSS version 19.0

2.6. Ethical Consideration and Permission
The study protocol was approved by the Human Ethics Committee of Atma Jaya Catholic University of Indonesia (approval No. 37/05/KEP-FKIKUAJ/2023). Data retrieval permission was obtained from the school principal of Susteran Junior High School, Purwokerto.

3. Results and Discussion
3.1. Results
The participants' characteristics are displayed in Table 1. Boys are more than girls. Mean height for age in boys was at +1 SD z-score line, but slightly below 0 SD z-score line in girls according to the WHO standard 2007. The mean BMI for age in boys was at +1 SD z-score line but above 0 SD z-score line in girls according to WHO standards.

Table 1: The characteristics of the participants

Variables	Number of participants	
	N (%)	$\bar{x}$ ±SD
Gender		
Boys	66 (56.4)	-
Girls	51 (43.6)	-
Age (years)		13.1±5.0
Body weight (kg)	-	53.1±13.7
Boys	-	56.1±13.7
Girls	-	49.1±12.8
Body height (m)	-	159.3±0.1
Boys	-	162.4±0.1
Girls	-	153.3±0.1
BMI (kg/m^2)	-	21.1±5.5
Boys	-	21.5±6.1
Girls	-	20.6±4.5
HGS (kg)	-	22.7±6.5
Boys	-	25.2±7.1
Girls	-	19.8±4.3

Abbreviation. BMI-body mass index; HGS-hand grip strength

Table 2. compares weight, height, BMI, and HGS between genders. Weight, height, and BMI between genders were comparable (all $p>0.05$). However, boys had greater HGS than girls ($p< 0.01$).

Table 2: The comparison of weight, height, and HGS between gender

Characteristic	Boys	Girls	*p*-value
Weight (kg)	56.1±13.7	49.1±12.8	0.81
Height (cm)	161.4±0.1	154.3±0.2	0.50
BMI (kg/m^2)	21.5±6.1	20.6±4.5	0.22
HGS (kg)	25.2±7.1	19.8±4.3	<0.01

Abbreviation. BMI-body mass index; HGS-hand grip strength

Table 3. describes the analysis of correlation between weight, height, and BMI with HGS. Weight and height had a modest correlation with HGS in girls and an overall weak correlation with HGS in boys. BMI had a moderate correlation with HGS in girls and a weak correlation overall but had no correlation

with HGS in boys.

Table 3: Correlation between weight, height, BMI, and HGS

Variables		Hand Grip Strength (kg)		
		Boys	Girls	Overall
Weight (kg)	Coefficient correlation (r)	0.28	0.57	0.41
	p-value	0.02	<0.01	<0.01
Height (cm)	Coefficient correlation (r)	0.26	0.5	0.45
	p-value	0.03	<0.01	<0.01
BMI (kg/m^2)	Coefficient correlation (r)	0.2	0.52	0.29
	p-value	0.12	<0.01	<0.01

Abbreviation. BMI-body mass index; HGS-hand grip strength

3.2. Discussion

Hand grip strength is a fitness indicator and physiological variable used to determine the functional limitations in older patients and muscle function in young adults. Many previous studies have investigated the HGS and its association with fitness and the risk of diseases, mostly in adult people. Several studies also examined the correlation between anthropometric measures and HGS, but only a few in adolescents. However, the result could have been more conclusive and controversial, so further research is necessary [16]. The different results could occur due to differences in measurement methods and subject characteristics. Our study seeks to complement those previous results. Our findings demonstrated that the correlation between anthropometric measures and HGS in adolescents is gender dependent. Weight, height, and BMI moderately correlated with HGS in girls. In boys, weight and height had a weak correlation with HGS, but BMI did not.

The correlation between weight and height with HGS has been investigated. Several studies reported a positive correlation between weight, height, and HGS [17, 18, 19]. Heavier weight had stronger HGS than lighter. Heavier weight was linked to greater muscle mass, increasing squeezing force [20]. Taller height is also related to stronger HGS. Taller height is associated with longer extremities such as arms, hands, and fingers [17, 21]. Longer extremities, mainly hand fingers, will create larger levers and produce greater force [21, 22].

Although many studies have been conducted on the association between BMI and HGS, the results vary significantly between those studies. This discrepancy in findings may be caused by several things, for example, the character of the subject, such as age, gender, fitness, and health status. The measurement method and equipment used might contribute to the distinct results. Our results showed that BMI was correlated with HGS. Several previous studies also support this finding. A study by Zaccagni *et al*. reported that BMI had a modest correlation to HGS [23]. A study in Brazil also reported that BMI and HGS were correlated [24]. A similar finding was also reported from Indonesia, which found a positive correlation between BMI and HGS [25]. The association between the BMI and HGS can be explained by the fact that the BMI only indicates body mass without including fat mass. Thus, BMI cannot differentiate the weight change due to an increase or decrease in muscularity or body fat percentage [26].

Gender is one of the factors that influences the correlation between BMI and HGS. Our finding showed that the correlation between weight and height with HGS was weak, but BMI was not in boys. Other studies also reported similar findings. A study by Kolev *et al*. in India demonstrated that gender influenced HGS [27]. This finding was supported by Agtuahene *et al*., who concluded that HGS was influenced by gender [28]. No definite explanation could explain this phenomenon. A possible explanation is that during adolescence, the physical growth of boys tends to coincide, leading them to become physically and physiologically homogenous.

Our study is not free from limitations. First, body composition was not analyzed. Body composition analysis is essential to examine the role of muscle mass in HGS. Second, participants with different weight or BMI classifications are needed to examine the effect of fatness on HGS. Third, a larger sample is needed to improve the power of the study. Fourth, the age of the participants is too homogeneous, so it cannot be used as a reference for age groups of teenagers.

4. Conclusion

Our study showed that HGS is correlated with height, weight, and BMI. The correlation of HGS with anthropometric measures is gender dependent. Based on these findings, it is recommended that height, weight, BMI, and gender should be taken into consideration when assessing HGS for research and clinical purposes. However, our findings should be interpreted with caution due to limitations. Further study with a larger sample, broader age range, body composition assessment, and different weight or BMI classification is recommended.

5. Acknowledgment

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6. Conflict of Interest: None.

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