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Demographic Factors and Total Muscle Mass are Associated with Handgrip Strength in Selected Indonesian Adults

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***Abstract*—Muscle strength has important implications for health and can be used to predict the progression of disease linked to muscular function. Handgrip strength (HGS) is a measurement method that can be used to assess muscle strength. The association between demographic factors, anthropometry, lifestyle, and ethnicity on HGS is not yet clear. This study aims to evaluate various demographic determinants of HGS. We performed a cross-sectional study on 66 employees aged 19 to 50, who worked in a private institution in West Jakarta, Indonesia. The chi-square test was used to determine the differences in HGS based on categorizations of age, sex, body mass index (BMI), physical exercise, and muscle mass. We enrolled 51.5% male and 48.5% female subjects. A considerable number of subjects were obese (45.5%) and had low muscle mass (47.0%) and perform physical exercises regularly (65.2%). The distribution of HGS is 39.4% weak, 33.3% normal, and 27.3% strong. The strongest HGS was observed in the 31 – 40 age group, in men, and in those who claim to regularly exercise. In conclusion, HGS had a significant association with age (p=0.021), sex (p=0.006), physical exercise (p=0.004), and muscle mass (p=0.042), but not with BMI (p=0.728).**

Keywords— handgrip strength, body mass index, muscle mass, physical exercise.

I. INTRODUCTION

Handgrip strength (HGS) is measured as the maximum strength of the hand muscle to squeeze an object which is measured using a hand-grip dynamometer [1]. HGS is a widely used indicator of health because it is easy to perform at a low cost [2]. HGS is used to evaluate muscular disorders in patients' hands in association with diseases, post-traumatic disorders, or postoperative procedures [1]. HGS is an indicator of several diseases related to muscular function, such as heart [3,4] and lung disorders [5], or to assess the progression of sarcopenia characterized by an overall decrease in muscle mass and strength [2].

Low grip strength in healthy adults indicates limitations in functional mobility, causing difficulties in carrying out daily activities ranging from simple activities such as eating, drinking, bathing, to more complex ones such as writing, driving, and exercising [6]. The human hand has a complex structure and has both motoric and sensory functions. The motoric function determines the ability to perform movement and motions. The sensory function delivers information to the brain regarding the temperature, shape, and texture of objects. Grip strength is also a predictor of overall health, cerebrovascular disease, disabling conditions, cognitive decline, and fracture risk [7,8].

The human body consists of four primary components, namely total body fat tissue, free-fat mass, bone minerals, and body fluids [9]. Each of these components is usually expressed as a percentage and can be measured using a body composition scale. The percentage of muscle mass is calculated from the ratio of muscle mass to body mass in kilograms expressed in percent (%) [9].

Muscle mass is calculated as the total muscle weight, including skeletal muscle, smooth muscle, and cardiac muscle. In addition to performing locomotive functions, muscles store glycogen and determine the body posture [7]. Research conducted by Nurfadhilah et al. in a group of young adults in Indonesia found that 25.78% of the subjects had a low percentage of muscle mass [10]. The percentage of muscle mass is associated with gender, protein intake, physical activity, and age. According to the World Health Organization (WHO), the normal values for total body muscle mass are categorized into low, normal, high, and very high. One of the factors affecting grip strength is muscle mass. The higher the muscle mass, the more muscle fibers can contract to match the applied weight [11]. Previous study showed that muscle mass was not directly related to muscle function as assessed by HGS, but rather had an indirect relationship [12]. The decrease in muscle mass has an impact on an individual's overall physical ability, as in the case of sarcopenia patients which is characterized by a decrease in HGS.

HGS can be affected by anthropometric factors such as age, gender, waist circumference, waist circumference ratio, and hip circumference [13]. Studies have also shown an association between HGS and BMI [14], vitamin D levels [15], and nutritional intake [16]. Men generally had higher HGS than women [17]. HGS peaks on average around the age of 30-40 years and subsequently declines with age regardless of gender, although the decrease was more rapid in men than women [17]. Research conducted by Lam et al. showed that there is a significant association between age and HGS [18].

BMI is an indicator to assess a person's nutritional status based on weight and height. Although it does not accurately describe the proportion of body fat, BMI can be used to estimate the ideal body weight associated with height. BMI the most frequently used diagnostic instrument to assess whether an individual is underweight, ideal, or obese because it is easy to measure. There is contradictive evidence regarding the association between BMI and handgrip strength [13,14].

HGS can also be affected by lifestyle factors, such as nutritional intake, physical activity, and exercise habits. Individuals with a sedentary lifestyle (low mobility) such as office employees generally had lower muscle mass. A sedentary lifestyle was also associated with health status, regardless of the level of physical activity. Longer sitting time in office workers is associated with higher fat mass and weaker grip strength [19,20].

This study aims to determine the relationship between HGS with age, sex, muscle mass, BMI, and exercise habits. Various studies on the association between demographic and anthropometric factors with HGS have not shown conclusive results. This study contributes to represent the different ethnicity which vary in terms of demography and anthropometry.

II. METHODS

A. Study design and enrollment

This study is an observational analytic study with a cross-sectional design conducted from November to December 2020. The selection of research subjects was carried out by consecutive sampling on all male and female employees working at a private institution in West Jakarta, Indonesia. Inclusion criteria are the ability to communicate and give consent to participate. Exclusion criteria were people with extreme disability or handicap, history of stroke, or other motoric disorders such as tremors.

B. Sample size estimation

The sample size is calculated statistically based on data by Nurfadhilah et al [10], where the proportion of the population with low muscle mass is 25.78%, at a significance level of 95%. Using the formula for a difference in 2 groups in infinite population as in:

$$n = Z\alpha \ (p \ x \ q) \ / \ d2 \qquad (1)$$

The recommended sample size (n) is 294 individuals. For a finite population of 70 individuals, given a drop-out rate of 15%, and the formula as in (2), the required sample size is 66 individuals.

$$n = Z\alpha \ (p \ x \ q) \ / \ d2 \qquad (2)$$

C. Demographic and lifestyle data collection

Demographic data were obtained using questionnaires and interviews. Age and sex were determined at enrollment. Bodyweight was measured using an Omron Karada Scan Body Composition Monitor digital scale with an accuracy of 0.1 kg. Height was measured using a stature high meter (GEA medical-SH-2A) with a maximum measurement of 2 meters and an accuracy of 0.1 cm. Body mass index (BMI) was determined by measuring body weight (kg) and height (m) calculated as the subject's body weight (kg) for every squared height (m^2). We determined obesity based on WHO ' s recommended cutoff points for the Asian-Pacific region, which categorized our subjects into lean (BMI <18.5), normal (18.5 -24.9), and obese (BMI $\geqslant$25) [21].

D. Muscle mass measurement

The percentage of muscle mass was measured using an Omron Karada Scan Body Composition Monitor scale. Research subjects were asked to stand barefoot on the available electrode panels, then hold the lever off the main panel with both hands in a 90 position and hold still until the measurement was automatically completed. The results of the measurement of muscle mass were categorized into three groups: low, normal, and high muscle mass. Men and women have different cutoff values, as recommended by WHO. For men, the cutoff points are <33.3% (low), 33.3 – 39.3% (normal), and $\geqslant$39.4% (high). For women, the cutoff points are <24.3% (low), 24.3 – 30.3% (normal), and $\geqslant$30.4% (high) [22].

E. Handgrip strength measurement

A handgrip dynamometer (JAMAR hydraulic hand evaluation kit-081028950) was used to measure HGS, which can measure grip strength in kilogram (kg). Subjects were asked to stand with feet hip-width apart, looking forward with the elbow bent at 90^o angle. Subjects were asked to squeeze the dynamometer with maximum strength for 3 seconds, starting with the dominant hand first and then alternately followed by the other hand with an interval of 60 seconds. The measurement results show the maximal grip strength (kg) of both hands, and the average value was taken to categorize the subjects as having weak, normal, and strong HGS. The categorization uses different cutoff values between men and women. For men, the HGS cutoff points are <35.0 kg (weak), 35.0-55.8 kg (normal), and >55.8 kg (high). For women, the cutoff points are <21.5 kg (weak), 21.5 – 35.3 kg (normal), and >35.3 kg (high) [11,23].

F. Statistical analysis

Univariate analysis was used to describe the distribution of measured variables. The relationship between various variables on handgrip strength was analyzed using Chi-Square test with a significance level of $p<0.05$. All statistical tests were performed using SPSS v.26.

G. Ethics

This study has received ethical approval from the Universitas Trisakti Faculty of Medicine Research Ethics Committee No. 26/KER-FK/10/2020

III. RESULT AND DISCUSSION

A. Characteristics of studied subjects

TABLE I. CHARACTERISTICS OF STUDIED SUBJECTS

Variables	n	%
Age		
19-30years	20	30.3%
31-40years	27	40.9%
41-50years	19	29.8%
Sex		
Male	34	51.5%
Female	32	48.5%
BMI (kg/m²)		
Lean	15	22.7%
Normal	21	31.8%
Obese	30	45.5%
Physical Exercise		
No	23	34.8%
Yes	43	65.2%
Muscle mass		
Low	31	47.0%
Normal	19	28.8%
High	16	24.2%
Handgrip strength		
Weak	26	39.4%
Normal	22	33.3%
Strong	18	27.3%

[a] n, sample size. %, proportion in percent. BMI, body mass index.

A total of 66 people met the inclusion criteria to participate in this study. Subject categorization into demographic groups was summarized in "Table I". The age of studied subjects ranged between 19 years and 50 years old. Subjects were divided into three groups based on age with an interval of 10 years. The highest number of subjects was between the age of 31 and 40 years old (n=27, 40.9%). There was an equal number of male (n=34, 51.5%) and female subjects (n=32, 48.5%). Almost half of the subjects were obese with BMI≥25 (n=30, 45.5%). Most of the subjects admitted to exercising regularly (n=43, 65.2%).

Following measurement of total muscle percentage with body composition scale, we found 31 individuals (47.0%), 19 individuals (28.8%) and 16 individuals (24.2%) with low, normal, and high muscle mass, respectively. Measurement of HGS with dynamometer showed that there were 26 individuals (39.4%), 22 individuals (33.3%), and 18 individuals (27.3%) categorized as having a low, normal, and strong HGS.

B. Association with demographic factors and muscle mass

The relationship between various demographic variables on HGS in "Table II " showed a significant association to age (p=0.021), sex (p=0.006), physical activity (p=0.004), and muscle mass (p=0.042). Meanwhile, the association between BMI and HGS was not significant (p=0.728).

The highest grip strength in our study was found in individuals between the age of 31 and 40 years. There are 11 individuals (49.7%) with strong HGS in this group, which was significantly higher compared to the 19 – 30 years and the 41 – 50 years age group (p=0.021).This data agrees with the study by Kim et al. [1] in Taiwan, where the highest HGS values for both men and women were found in the age group of 34-39 years and subsequently decline with age. The decline of HGS in men after reaching its peak was 0.7-1.1% at the age of 45-65, and it was 2.6-3.2% over the age of 65. In women, the decline of HGS was 0-0.07% at the age of 40-54, and it was 0.5-3.0% at the age of 55-59 [1]. The difference in the rate of decline between men and women has not been explained, but it is likely related to hormones. Menopausal women are known to have greater changes in hormonal levels. Ibeneme et al. [24] found that postmenopausal women showed an increase in body mass fat (BMF) with a decrease in HGS compared to premenopausal women. Menopause is accompanied by a decrease in estrogen levels suggests an increase in BMF along with a decrease in muscle mass, and thus it lowered muscle strength and by extension HGS. This study also supports the finding by Lam et al. [18] that there was a significant relationship between age and HGS for both right and left hands in the elderly group in Malaysia, while the younger age group showed a higher mean of HGS value. The study also showed the different levels of HGS due to ethnicity and geography. The mean value of HGS is different in the Malaysian, Indian, and Chinese populations, while the mean HGS value was higher in individuals living in rural areas compared to urban areas.

The relationship between sex and HGS was found significant in this study, in which most female had low HGS (n=19, 59.4%), while fewer male had low HGS (n=7, 20.6%). Most men had normal HGS (n=15, 44.1%) or strong HGS (n=12, 35.3%), despite men having higher cut-off HGS value than female (p=0.006). Differences in hormones and body composition between male and female are believed to be the primary cause of this difference. A study by Liao et al. [17], conducted in Taiwan, showed similar results to this study, in which sex showed the strongest significant relationship compared to the effect of height, weight, and BMI on HGS. Alahmari et al. [13] reported that HGS was negatively correlated with age in healthy men aged 20 – 74. This difference is likely due to the study being conducted on a wide range of ages, and thus the association was confounded by the disparity in muscle mass between the young and the elderly group.

The result of this study did not find a significant association between BMI and HGS, neither the lean groups and the obese group showed specific distribution for HGS (*p*=0.728). A study by Liao [17] assessed the relationship between HGS and demographic factors based on low, normal, and high BMI categorization, and showed that there was a significant relationship with age, gender, height, and weight. The HGS showed the strongest correlation to body weight and height in the group with high BMI. We did not find a significant relationship between BMI and HGS in this study, which was in line with the findings by Sirajudeen et al. [25] and Oseloka et al. [14] that reported a strong positive correlation between HGS and weight and height, and a weak correlation with BMI. However, studies by Palacio-Agüero et al.[26] found that adolescent individuals with overweight nutritional status and abdominal obesity had significantly lower HGS values. A study by Ling et al. [27] which was performed on the elderly (>85 years old) agreed that HGS was significantly related to height, weight, and BMI. The contradiction with our findings might be caused by the differences in the age of the studied populations. Individuals who are very late in life generally have a decreased muscular function as a concomitant factor.

TABLE II. ANTROPOMETRIC AND DEMOGRAPHIC FACTORS ASSOCIATED WITH HANDGRIP STRENGTH

	Handgrip strength (HGS)			
Characteristics	***Weak n(%)***	***Normal n(%)***	***Strong n(%)***	***P***[a]
Age				
19-30years	13(68.4%)	5(26.3%)	1(5.3%)	0,021[b]
31-40years	7(26.0%)	9(33.3%)	11(49.7%)	
41-50years	6(30.0%)	8(40.0%)	6(30.0%)	
Sex				
Male	7(20.6%)	15(44.1%)	12(35.3%)	0,006[b]
Female	19(59.4%)	7(21.9%)	6(18.7%)	
BMI (kg/m^2)				
Lean	7(46.7%)	6(40.0%)	2(13.3%)	
Normal	8(38.1%)	6(28.6%)	7(33.3%)	0,728
Obese	11(36.7%)	10(33.3%)	9(30.0%)	
Physical Exercise				
No	14(60.9%)	8(34.8%)	1(4.3%)	0,004[b]
Yes	12(28.0%)	14(32.5%)	17(39.5%)	
Muscle Mass				
Low	18(58.1%)	7(22.5%)	6(19.4%)	0,042[b]
Normal	6(31.6%)	7(36.8%)	6(31.6%)	
High	2(12.5%)	8(50.0%)	6(37.5%)	

n, sample size. %, proportion in percent. BMI, body mass index. [a], p values obtained with Chi-square test. [b], significant variables (p<0.05)

We found that subjects who claimed to be exercising regularly were observed with stronger HGS (n=17, 39.5%), which is higher compared to those who did not regularly exercise (n=1, 4.3%); (p=0.004). Physical activity is associated with muscle strength, so it can be used as a predictor for the ability to perform daily activities. Bann et al. [28] found that previous strenuous workers and light physical exercises were significantly related to HGS in the elderly, but the relationship was not significant in women. There is a negative correlation between physical activity and BMI, while a sedentary lifestyle which is characterized by a decrease in physical activity is associated with an increase in BMI accompanied by changes in body fat composition that led to obesity.

The results of this study showed a significant relationship between muscle mass and HGS (p=0.042). We found that the group with low muscle mass was also categorized as having a weak HGS (n=18, 58.1%), which is significantly different compared to those with high muscle mass but weak HGS (n=2, 12.5%). Choe et al. [29] reported similar results, in which HGS was significantly associated with muscle mass, although it was carried out in elderly people aged 60 – 90. Mankowsky et al. [30] reported that body composition was influenced by age. Older people experience changes in muscle quality and strength, which was also found associated with an increased risk of metabolic disorders. Decreased muscle mass in conjunction with increased fat mass will increased the risk of developing sarcopenia, which is characterized by low muscle mass and physical weakness. Meskers et al. [31] reported that in the elderly group, HGS was associated with subject dependency in performing daily activities. Old age increases the risk of sarcopenia which has an impact on dependency in daily living activities. A decrease in HGS can be used as a predictor to assess the decrease in muscle mass accompanied by physical frailty in patients with sarcopenia.

Our data suggest that the relationship between BMI factors, physical activity, muscle mass, and muscle strength with HGS showed that these factors are intercorrelated. Increased physical activity is associated with increased energy expenditure which can reduce the proportion of body fat and lower the risk for obesity. Physical activity also plays a role in increasing muscle mass and can also increasing muscle strength, and by extension HGS. Our findings also suggest that age and gender can affect HGS through different, but interrelated, aspects of hormonal changes. Aging is associated with hormonal changes that affect muscle strength. Decreased testosterone levels in older men and decreased estrogen levels in older women are related to changes in body composition characterized by an increase in fat mass and a decrease in muscle mass, which results in a decrease in muscle strength and HGS.

Factors such as demographic, anthropometric, lifestyle, and disease can influence HGS. A longitudinal cohort study conducted in Finland by Stenholm et al. [32], involving individuals aged 30 – 73 followed for 22 years, showed that the decrease in muscle strength assessed by HGS is age-related, but not significantly different by gender. This long-term study also highlighted the influence of lifestyle changes, the presence of coexisting chronic diseases, and work history. A more sedentary lifestyle, having chronic diseases, and subjects with a history of strenuous works showed a faster decline in HGS. Vermeluen et al. [6] also reported that the elderly who maintained light physical activity such as walking in a slow gait showed a slower decrease in muscle strength than the group with a sedentary lifestyle.

This study has limitations related to the design and measurement of HGS. The cross-sectional design could not validate a causal relationship. HGS is a surrogate indicator of muscle strength, while the HGS itself is procedurally performed by assessing the strength of the hand to squeeze objects, and thus only represents the muscle strength in the upper limb. The HGS also does not have a standardized measurement method (either performed while standing or in a sitting position) and can alter the measurement results. Many studies that carried out HGS measurements show variable results, and this brings uncertainties regarding the cutoff values for the weak, normal, or strong HGS. There are confounding factors not accounted for in this study, such as ethnic diversity and locality (urban vs rural), that might alter the associations between demographic factors and HGS. A further study that takes into account various confounding factors is needed.

IV. CONCLUSION

We found that various demographic factors were associated with muscle strength measured by handgrip strength. These factors include age, sex, physical exercise habit, and muscle mass. The relationship between handgrip strength with BMI was not significant in our study.

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CONFLICT OF INTEREST

All authors declared no conflict of interest.

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