CORRELATION OF BLOOD GLUCOSE LEVELS, URIC ACID, AND LIPID PROFILE WITH HAND GRIP STRENGTH: THE ROLE OF AGE AS A CONTROL VARIABLE

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ABSTRACT

Handgrip strength (HGS) is an essential biomarker of muscle strength and physical health, with links to illnesses like cardiovascular disease, metabolic syndrome, and frailty. It is particularly important in aging populations, where physical strength promotes independence and quality of life. Blood glucose, uric acid, and lipid profiles all impact metabolic health, influencing physical performance. Elevated glucose levels, disturbed uric acid metabolism, and aberrant lipid profiles lead to impaired muscle function and increased cardiovascular risk. When combined with age-related alterations such as sarcopenia and metabolic dysregulation, these markers have an even greater impact on HGS. This study investigates the association between these metabolic markers and HGS, hypothesizing that aberrant profiles are associated with lower HGS, independent of age. This cross-sectional study in West Jakarta included 120 adults tested for handgrip strength, hemoglobin, blood sugar, uric acid, cholesterol, HDL, LDL, triglycerides, and the triglycerides-to-HDL ratio. Results showed positive correlations between HGS and hemoglobin, hematocrit, and blood sugar, highlighting their roles in oxygen transport and energy provision. The triglycerides-to-HDL ratio also correlated positively with HGS, indicating the influence of lipid metabolism on muscle performance. Age showed an inverse correlation with HGS, consistent with sarcopenia. This study examines the relationship between physiological factors and handgrip strength in the elderly, stressing the importance of optimizing hemoglobin, blood sugar, and cholesterol levels. Limitations include a cross-sectional design and gender bias, necessitating a long-term, comprehensive future study.

Keywords: Aging, Handgrip Strength, Lipid Profile, Metabolic Health, Sarcopenia.

INTRODUCTION

Handgrip strength (HGS) serves as an essential biomarker of overall muscle strength and physical health, reflecting an individual’s functional status and predicting various health outcomes (Lee, 2021; Miranda et al., 2022). HGS is widely recognized for its association with critical conditions such as cardiovascular disease, metabolic syndrome, and frailty, making it a valuable indicator in clinical and research settings (Pessini et al., 2016). Its relevance is further emphasized in aging populations, where muscle strength plays a pivotal role in maintaining independence and quality of life (Eskandarzadeh et al., 2024).

Metabolic health significantly influences physical performance, with blood glucose levels, uric acid, and lipid profiles emerging as key indicators (Wazir et al., 2023). Elevated blood glucose and insulin resistance impair muscle function (Abdul-Ghani & Defronzo, 2010), while disruptions in uric acid metabolism link to chronic conditions like gout and cardiovascular disease (Saito et al., 2021). Similarly, abnormal lipid profiles, indicative of dysregulated lipid metabolism, contribute to cardiovascular risk and reduced physical performance (Dong et al., 2021). These metabolic markers are intricately linked to age-related changes, such as sarcopenia, glucose intolerance, and metabolic dysregulation, which amplify their impact on muscle strength (Jiang et al., 2023; Kim & Park, 2018).

This study investigates the relationship between metabolic markers and HGS, focusing on their interplay with aging. By controlling for age, the research aims to explore potential mechanisms and modifiable factors that influence muscle strength, providing insights for interventions to enhance physical function and promote healthier aging. We hypothesize that disruptions in metabolic markers are associated with reduced HGS, independent of age-related effects.

LITERATURE REVIEW

Handgrip strength (HGS) has emerged as a practical and inexpensive clinical tool for assessing global skeletal muscle function. Measured with a dynamometer, HGS provides a reliable proxy for overall muscular strength and has been increasingly recognized in clinical and research contexts. A growing body of evidence identifies sarcopenia, progressive loss of muscle mass and function, as a pivotal risk factor for a broad spectrum of chronic conditions, including metabolic syndrome, cardiovascular disease, and cancer. The non-invasive nature and operational simplicity of HGS testing have led to its widespread adoption as both a screening and diagnostic measure in geriatric populations. The assessment procedure is straightforward: patients are seated with the elbow flexed at a 90° angle, and measurements are taken from the dominant hand. Following a practice attempt, three trials are conducted, and the mean value is recorded for analysis (Hao et al., 2020; Pettersson-Pablo et al., 2024)

Multiple determinants influence HGS, notably age, sex, nutritional status, comorbidities, and physical activity levels. Age-related decline in HGS reflects the underlying pathophysiology of sarcopenia. Gender differences are consistently observed, with men generally outperforming women, likely due to greater muscle bulk and androgenic influence. Nutritional adequacy, particularly protein intake, is essential to maintain muscle integrity, and suboptimal intake has been associated with reduced HGS, serving as a marker of possible malnutrition. Additionally, habitual physical activity, as most prominently resistance training, demonstrates a strong positive association with HGS, underscoring its role in preserving muscular function and mitigating sarcopenic progression. (S. Y. Lee, 2021; Lupton-Smith et al., 2022)

Beyond the influence of age, nutrition, and physical activity, alterations in lipid metabolism also play a critical role in shaping skeletal muscle function and handgrip strength. Under physiological conditions, skeletal muscle balances fatty acid uptake and oxidation. When this equilibrium is disrupted, as in skeletal muscle dysfunction, uptake exceeds oxidative capacity, accumulating lipid intermediates within muscle fibers. Such intramuscular lipid deposition contributes to systemic dyslipidemia, typically manifesting as elevated triglycerides (TG) and low-density lipoprotein cholesterol (LDL-C), alongside reductions in high-density lipoprotein cholesterol (HDL-C). These disturbances impair muscle contractility and are reflected in decreased HGS. Clinical evidence supports this mechanistic link: reduced HGS has been associated with higher TG levels, increased blood pressure, and greater waist circumference, although not consistently with lower HDL-C (d’Avila et al., 2024; Kim et al., 2020).

In addition to lipid dysregulation, glucose homeostasis disturbances also profoundly influence skeletal muscle integrity and function. Chronic hyperglycemia has been consistently linked to reduced muscle quality, diminished strength, and impaired physical performance, with the lower extremities appearing more vulnerable than the upper limbs. Consequently, individuals with early-stage glucose dysregulation, such as prediabetes, may not yet demonstrate measurable reductions in handgrip strength (Leenders et al., 2013).

The deleterious effects of hyperglycemia on skeletal muscle are mediated through multiple mechanisms. Prolonged exposure to elevated glucose levels promotes oxidative stress and the accumulation of advanced glycation end-products (AGEs), accelerating sarcopenic changes. Moreover, poor glycemic control impairs glucose utilization by muscle fibers, heightens systemic inflammation through increased interleukin-6, tumor necrosis factor-alpha, and hs-CRP, and induces neuropathic injury to motor neurons. Mitochondrial dysfunction further compounds these processes, leading to progressive muscle mass and function decline. These metabolic and inflammatory disturbances can collectively compromise handgrip strength, underscoring the close interrelationship between glycemic regulation and muscular health (Yoon et al., 2016).

RESEARCH METHODS

This cross-sectional study was conducted in Kelurahan Krendang, West Jakarta, involving 120 participants selected based on specific inclusion and exclusion criteria. Participants were eligible if they were adults aged 18 years or older, willing to provide informed consent, and capable of performing handgrip strength measurements. Individuals with acute illnesses, chronic conditions affecting muscle strength (e.g., neuromuscular disorders), or incomplete data were excluded. The primary outcomes measured were handgrip strength, hemoglobin, hematocrit, blood sugar, uric acid, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides, and the triglycerides-to-HDL ratio.

Hemoglobin, hematocrit, blood sugar, and uric acid levels were assessed using the Fora 6 Plus point-of-care testing device (POCT). Total cholesterol, HDL, LDL, triglycerides, and the triglycerides-to-HDL ratio were measured using the Nesco Lipid Monitoring 5-in-1 device. For each test, a cartridge or strip was inserted into the device, a blood sample was collected via finger prick, applied to the strip, and the results were read directly from the meter. Handgrip strength was measured using the Camry digital dynamometer. Participants performed three trials for each hand, and the average of all six trials was calculated. Normal handgrip strength values were defined based on existing literature, with thresholds of ≥26 kg for men and ≥16 kg for women.

The normal reference ranges for the biochemical parameters were as follows: hemoglobin (13.8–17.2 g/dL for men, 12.1–15.1 g/dL for women), hematocrit (40.7–50.3% for men, 36.1–44.3% for women), blood sugar (70–100 mg/dL), uric acid (3.4–7.0 mg/dL for men, 2.4–6.0 mg/dL for women), HDL (≥40 mg/dL for men, ≥50 mg/dL for women), total cholesterol (<200 mg/dL), LDL (<100 mg/dL), triglycerides (<150 mg/dL), and triglycerides-to-HDL ratio (<2.0).

The study controlled for confounding variables such as age by stratifying analyses and adjusted for potential sources of bias through careful participant selection and standardized measurement protocols. Missing data were addressed by excluding incomplete datasets from analysis. The study size was determined based on feasibility and the need to achieve adequate statistical power for correlational analysis. Quantitative variables were analyzed using Spearman’s correlation to identify relationships between physiological parameters and handgrip strength. Ethical approval for the study was obtained from the Tarumanagara University Human Research Ethics Committee under the Institute of Research and Community Engagement. All participants provided informed consent before participation.

RESEARCH RESULTS

Table 1. Characteristics of Research Respondents

Parameter	Results
Gender	
● Male	11 (9.2%)
● Female	109 (90.8%)
Age	37.55 (10.97)
Hemoglobin	11.22 (1.52)
Hematocrit	33.11 (4.37)
Blood Sugar	92.1 (30.25)
Uric Acid	3.96 (0.69)
Total Cholesterol	185.71 (32.95)
High-density lipoprotein (HDL)	49.14 (13.62)
Low-density lipoprotein (LDL)	110.13 (26.39)
Triglycerides	125.67 (64.21)
Triglycerides/HDL Ratio	4.00 (1.2)

This research was conducted with 120 respondents, whose detailed characteristics can be seen in Table 1. Most of the respondents were women (90.8%). The mean age of the respondents was 37.55 years.

The mean hemoglobin was 11.22 g/dL, and the hematocrit was 33.11%. Respondents had average blood sugar levels of 92.1 mg/dL and 3.96 mg/dL of uric acid. Total cholesterol 185.71 mg/dL, HDL 49.14 mg/dL, LDL 110.13 mg/dL, and triglycerides 125.67 mg/dL. Triglycerides/HDL ratio of 4.00.

Table 2. Correlation of Age, Hemoglobin, Hematocrit, Blood Sugar, Uric Acid, and Lipid Profile with Handgrip Strength

Parameter N =120	Right Handgrip		Left Handgrip		Average Handgrip	
	r-correlation (Spearman)	p-value	r-correlation (Spearman)	p-value	r-correlation (Spearman)	p-value
Age	-0,182	0,047*	-0,230	0,012*	-0,203	0,026*
Hemoglobin	0,409	<0,001**	0,446	<0,001**	0,440	<0,001**
Hematocrit	0,393	<0,001**	0,429	<0,001**	0,423	<0,001**
Blood Sugar	0,270	<0,001**	0,316	<0,001**	0,302	<0,001**
Uric Acid	0,220	0,016*	0,260	0,004**	0,243	0,007
Total Cholesterol	0,065	0,477	0,025	0,789	0,046	0,618
High-density lipoprotein (HDL)	-0,225	0,013*	-0,230	0,011*	-0,234	0,010*
Low-density lipoprotein (LDL)	0,069	0,452	0,084	0,364	0,077	0,404
Triglycerides	0,146	0,111	0,070	0,448	0,119	0,195
Triglycerides/HDL Ratio	0,189	0,038*	0,188	0,039*	0,195	0,033*

**, Correlation is significant at the 0.01 level (2-tailed)
*, Correlation is significant at the 0.05 level (2-tailed)

The normality of the data distribution was assessed using the Kolmogorov-Smirnov test, which is appropriate for sample sizes exceeding 50. The analysis revealed that all variables exhibited a non-normal distribution. This study suggests the important relationship between physiological parameters and handgrip strength in elderly people. Hemoglobin and Hematocrit showed a strong positive correlation with handgrip strength, responsible for oxygen transportation. Furthermore, blood sugar was positively related to handgrip strength, indicating that it provides the energy needed for muscle activity. HDL was negatively correlated with handgrip strength, which indicates that it had a complex relationship with strength. The triglycerides/HDL ratio positively correlated with handgrip strength, meaning that the lipid ratio impacted muscle activity.

Table 3. Correlation of Hemoglobin, Hematocrit, Blood Sugar, Uric Acid, and Lipid Profile with Handgrip Strength with Age as a Control Variable

Parameter N =120	Right Handgrip		Left Handgrip		Average Handgrip	
	r-correlation (Spearman)	p-value	r-correlation (Spearman)	p-value	r-correlation (Spearman)	p-value
Age	0,448	<0,001**	0,470	<0,001**	0,467	<0,001**
Hemoglobin	0,433	<0,001**	0,458	<0,001**	0,454	<0,001**
Hematocrit	0,168	0,068	0,193	0,035*	0,183	0,046*
Blood Sugar	0,369	<0,001**	0,407	<0,001**	0,395	<0,001**
Uric Acid	0,100	0,282	0,050	0,588	0,078	0,401
Total Cholesterol	-0,229	0,012*	-0,241	0,008**	-0,239	0,009**
High-density lipoprotein (HDL)	0,095	0,304	0,081	0,380	0,090	0,329
Low-density lipoprotein (LDL)	0,243	0,008**	0,190	0,038*	0,223	0,015*
Triglycerides	0,268	0,003**	0,258	0,005*	0,268	0,003**
Triglycerides/HDL Ratio	0,448	<0,001**	0,470	<0,001**	0,467	<0,001**

**, Correlation is significant at the 0.01 level (2-tailed)
*, Correlation is significant at the 0.05 level (2-tailed)

Further analysis with age as a control variable, revealed that these correlations were indeed valid. Age was positively correlated with handgrip strength of both right, left, and average handgrip strength (r = 0.448, p <0.001, r = 0.470, p <0.001, r = 0.467, p <0.001, respectively), reflecting the age influence. Hemoglobin remained strongly positively correlated with both right handgrip strength, (r = 0.433, p <0.001) and left handgrip strength, (r = 0.458, p <0.001), indicating the role of hemoglobin in muscle structure. Blood sugar levels remained strongly positively correlated with handgrip strength, indicating their role in providing energy to the muscles. Interestingly, total cholesterol was negatively correlated with handgrip strength, indicating the adverse effect of cholesterol on muscles. The ratio of triglycerides/HDL was positively correlated with handgrip strength, indicating the link between lipid profile and muscles. These results reflect the complex nature of muscles in old age and the improvement of these parameters may lead to improved physical functions in the elderly. (Table 2; Figures 1-3)

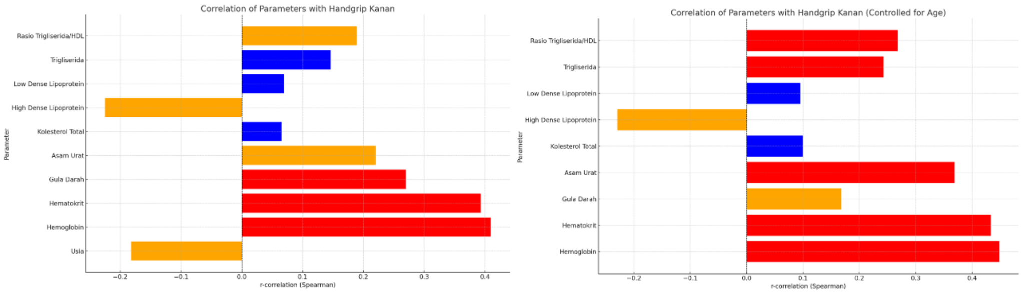

Figure 1. Correlation Between Blood Sugar Levels, Uric Acid, and Lipid Profile on Right Handgrip Strength Without (Left) and With (Right) Age as a Control Variable

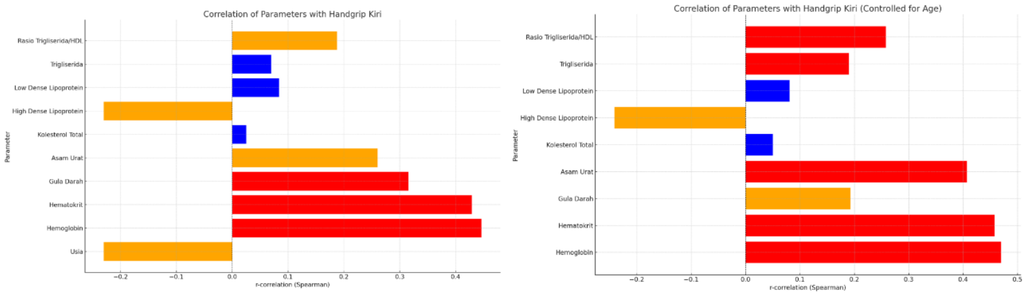

Figure 2. Correlation Between Blood Sugar Levels, Uric Acid, and Lipid Profile on Left Handgrip Strength Without (Left) and With (Right) Age as a Control Variable

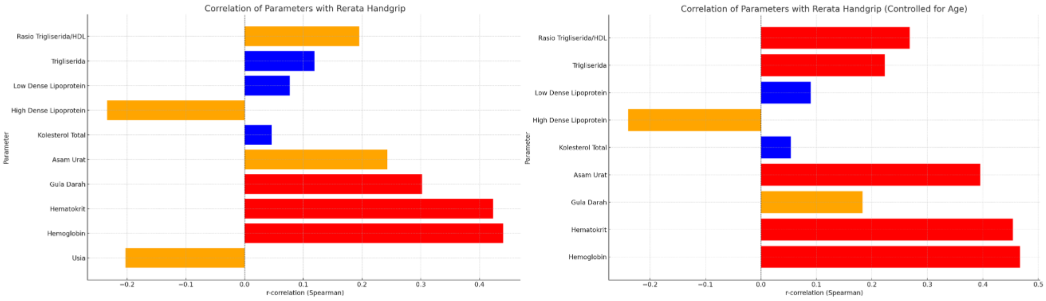

Figure 3. Correlation Between Blood Sugar Levels, Uric Acid, and Lipid Profile on Average Handgrip Strength Without (Left) and With (Right) Age as a Control Variable

DISCUSSION

This study highlights the intricate relationships between physiological parameters and handgrip strength, emphasizing the multifactorial nature of adult muscle function. It provides insights into the physiological mechanisms influencing muscle performance and physical function by examining hemoglobin, hematocrit, blood sugar levels, uric acid, and lipid profiles, and their correlations with handgrip strength.

Hemoglobin and hematocrit demonstrated strong positive correlations with handgrip strength, reinforcing their role in muscle oxygen delivery. Hemoglobin, a critical component of red blood cells, facilitates the efficient transport of oxygen to tissues, supporting aerobic metabolism and ATP production, which are essential for sustained muscle contraction and endurance (Spires et al., 2011). Hematocrit, representing the proportion of red blood cells in blood, serves as a surrogate marker of oxygen-carrying capacity (Otto et al., 2013). These findings align with established physiological principles, where the oxygen cascade from atmospheric air to mitochondrial utilization relies heavily on hemoglobin’s capacity to bind and release oxygen efficiently. During physical exertion, the Bohr effect enhances oxygen offloading in active tissues, a mechanism crucial for maintaining muscle performance under increased metabolic demand. Reduced hemoglobin or hematocrit levels, as seen in anemia, impair oxygen delivery and compromise muscle strength (Benner et al., 2023).

The positive correlation between blood sugar levels and handgrip strength underscores the importance of glucose as a primary energy source for muscle activity. Glucose metabolism provides the ATP necessary for muscle contractions, particularly during activities requiring quick bursts of strength. The role of blood sugar in muscle performance is well-documented, with glucose acting as a substrate for both anaerobic and aerobic energy pathways. Efficient glucose utilization ensures a sustained energy supply and delays muscle fatigue (Devulapally et al., 2018).

Maintaining optimal blood sugar levels is critical for physical function and muscle health (Williams et al., 2013). Hypoglycemia, or low blood sugar, deprives the body of its primary energy source, leading to reduced muscular endurance, fatigue, and impaired motor coordination (Kelly et al., 2010). Since muscles rely heavily on glucose for efficient contraction, prolonged hypoglycemia can result in muscle weakness and cramps (Mohseni, 2014). On the other hand, hyperglycemia, or high blood sugar, poses its own set of challenges. Chronic hyperglycemia increases oxidative stress and inflammation, which can damage muscle cells, reduce repair mechanisms, and degrade muscle proteins over time (González et al., 2023). It is often associated with insulin resistance, which limits glucose uptake by muscles and impairs recovery after exercise (Shannon et al., 2022). Additionally, hyperglycemia can lead to vascular complications, reducing oxygen and nutrient delivery necessary for muscle function (Umegaki, 2015).

Conversely, the triglycerides-to-HDL ratio positively correlated with handgrip strength. This ratio is a marker of lipid metabolism efficiency and has been linked to energy availability for muscle activity (Huang et al., 2023). Triglycerides serve as a key energy substrate during prolonged physical activity, and an optimal balance between triglycerides and HDL may support muscle performance (Muscella et al., 2020). Triglycerides, stored in adipose tissue and muscle, are a crucial source of energy during physical activity, particularly in prolonged or endurance tasks (Johnson et al., 2004). Muscle contraction requires significant energy input, and the ability to mobilize and utilize triglycerides effectively ensures sustained performance and delays fatigue (Editors et al., 2023).

An optimal triglycerides-to-HDL ratio may indicate a balance in lipid homeostasis, reflecting efficient energy substrate utilization (Marotta et al., 2010). This ratio could serve as a proxy for assessing the metabolic readiness of muscles to meet energy demands (Lin et al., 2023). Higher triglycerides, within a healthy range, contribute directly to muscle energetics, while HDL facilitates reverse cholesterol transport and maintains vascular health, ensuring effective oxygen and nutrient delivery (Luna-Castillo et al., 2022). However, the observed positive correlation raises interesting physiological questions. While HDL is typically associated with cardiovascular benefits, the interplay between high triglycerides and low HDL in this context might reflect adaptive metabolic states where triglyceride availability becomes a more immediate determinant of muscle strength (Mezincescu et al., 2024).

Age showed a significant inverse correlation with handgrip strength, consistent with the well-documented decline in muscle mass and function, termed sarcopenia. This decline is influenced by a combination of factors, including decreased levels of anabolic hormones, heightened oxidative stress, and the presence of chronic inflammation (Maldonado et al., 2023).

CONCLUSION

This research highlights the complex interplay between physiological parameters and handgrip strength in the elderly. The results emphasize the benefits of optimizing hemoglobin, blood sugar, and lipid balance to enhance physical function. These findings suggest opportunities for targeted interventions, such as nutritional strategies or physical activity programs, to improve muscle strength and promote healthier aging.This study acknowledges several limitations. The cross-sectional design prevents establishing causal relationships between the physiological parameters and handgrip strength. The high proportion of female respondents introduces gender bias, which may limit the generalizability of the findings to a broader population. The study also excludes self-reported health status and lifestyle factors, which could influence the observed correlations.

Future research will address these limitations by using longitudinal designs to explore causal pathways and by recruiting a more balanced gender representation to strengthen the findings' applicability. Researchers will also include additional variables, such as physical activity levels, dietary intake, and comorbidities, to provide a more comprehensive understanding of the factors influencing muscle strength in aging populations.

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