Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Impact of Glucose Profile, Fasting Insulin, and Renal Function on Sarcopenia in Elderly at Single Centered Nursing Home: A Cross-Sectional Structural Equation Model Analysis

Alexander Halim Santoso[1], Edwin Destra[2], Yohanes Firmansyah[3], Susy Olivia Lontoh[3]

[1]Department of Nutrition, Faculty of Medicine, Tarumanagara University, Jakarta, Indonesia; [2]Master's Program in Biomedical Sciences, Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia; [3]Department of Physiology, Faculty of Medicine, Tarumanagara University, Jakarta, Indonesia

Correspondence: Alexander Halim Santoso, Department of Nutrition, Faculty of Medicine, Tarumanagara University, Jl. Letjen S. Parman No. 1, RT.6/RW.16, Tomang, Kec. Grogol petamburan, Kota Jakarta Barat, Daerah Khusus Ibukota Jakarta, Jakarta, 11440, Indonesia, Email alexanders@fk.untar.ac.id

Background: Sarcopenia, characterized by a progressive decline in muscle mass and strength, poses significant public health challenges for the elderly, impacting physical performance and quality of life. This study aims to investigate the associations between glucose profile, fasting insulin, renal function, and muscle strength among elderly residents of a single-centered nursing home in Indonesia, identifying potential biomarkers for sarcopenia.

Methods: A cross-sectional analysis was conducted on 31 elderly residents of Santa Anna Nursing Home, with muscle strength measured using handgrip dynamometry and biochemical parameters evaluated through standardized laboratory methods.

Results: Structural Equation Modeling-Partial Least Squares (SEM-PLS) analysis revealed strong negative correlations between glucose profile ($\beta = -0.683$, $p < 0.01$) and fasting insulin ($\beta = -0.208$, $p < 0.05$) with muscle strength, while renal function showed a moderate positive relationship ($\beta = 0.295$, $p < 0.05$).

Conclusion: These findings highlight glucose profile, fasting insulin, and renal function as critical predictors of sarcopenia, offering potential pathways for early detection and targeted interventions. Future research should explore longitudinal assessments and molecular mechanisms to refine sarcopenia prevention strategies in aging populations.

Keywords: sarcopenia, elderly, glucose profile, fasting insulin, renal function, biomarkers, muscle strength

Introduction

Aging is an inevitable biological process that affects individuals universally, often leading to significant implications for quality of life. One critical aspect of aging is the decline in muscle strength, a hallmark of sarcopenia, which is associated with reduced physical performance, mobility, and increased frailty. The characteristics of decreased muscle strength include diminished handgrip strength and reduced overall muscle functionality, all of which are measurable and indicative of early muscle deterioration.[1,2] According to estimation from the World Health Organization, sarcopenia impacts 5–13% of people aged 60–70 years and 11–50% of those aged 80 years and older.[3] The prevalence of sarcopenia among elderly in nursing homes ranges from 25% to 73.7%, reflecting a higher incidence of muscle deterioration in institutionalized care. In contrast, among community-dwelling elderly, the prevalence of sarcopenia is lower, ranging from 5.2% to 62.7%. This indicates considerable differences in sarcopenia rates between those living in nursing homes and those residing in the community.[4–6]

Sarcopenia develops due to various risk factors, one of which is age. As an unmodifiable aspect of aging, age plays a significant role in the gradual reduction of muscle mass, strength, and function, which are critical features of sarcopenia and diminished physical capability.[7,8] Research by Robbani et al (2020) identified significant differences between the two age groups: >60 years (n = 73) and 18–40 years (n = 76). Their findings showed that muscle mass decreased by 2.467

Received: 3 September 2024
Accepted: 2 January 2025
Published: 6 March 2025

(SD ± 0.1454) kg/m (t(98.350) = −16.969; $p = 0.000$), handgrip strength by 10.455 (SD ± 1.0983) kg (t(147) = −9.519; $p = 0.000$), and gait speed by 0.4753 (SD ± 0.2808) m/s (t(11.636) = −16.747; $p = 0.000$). These results demonstrate that sarcopenia diagnostic components decline significantly with advancing age.[9] According to the research conducted by Kim et al (2023), we found that muscle strength, as measured by handgrip strength, showed a notable decline with advancing age. Specifically, there was a reduction of 9.32% to 21.01% in grip strength across successive 5-year age brackets ($p = 0.001$) This decline was particularly pronounced in individuals aged 60 and above, indicating a clear association between aging and reduced muscle strength.[10]

The relationship between glucose metabolism, insulin signaling, and muscle health in sarcopenia involves hyperglycemia-induced ROS and cytokines (TNF-α, IL-6), activating proteolytic pathways while suppressing mTOR, resulting in muscle degradation and impaired synthesis.[11,12] Kalyani et al (2014) found that elevated HbA1c levels were linked to reduced lower muscle strength (−4.70 ± 2.30 N · m, $p = 0.02$) and quality (−0.32 ± 0.15 N·m/kg, $p = 0.02$) across HbA1c quartiles.[13] Similarly, Umegaki et al (2015) reported that type 2 diabetes mellitus increases the risk of sarcopenia threefold (OR 3.06, 95% CI 1.42–6.62) after adjusting for confounders.[14] Furthermore, Yin et al (2021) found fasting insulin as a strong sarcopenia predictor (AUC = 0.686), with an inverse association (OR = 0.904, 95% CI: 0.882–0.927, $p = <0.001$).[1]

Albumin supports muscle health, serving as a biomarker for sarcopenia through its antioxidant, protein synthesis, and anti-inflammatory roles, linked to CRP, nitrogen balance, and oxidative stress markers like MDA.[15–17] Ancum et al (2022) found that lower albumin levels were linked to reduced handgrip strength (β = 0.101 kg per 1 g/L decrease, $p < 0.05$) and skeletal muscle mass index (β = 0.022 kg/m² per 1 g/L decrease, $p < 0.05$).[18] Similarly, Snyder et al (2012) reported that older men with significant serum albumin decline (>3 g/L) over 2 years showed a modest reduction in muscle power (−8.9 watts, 95% CI: −25.6, 7.8) compared to those with stable albumin ($p = 0.02$).[19]

Liver dysfunction affects muscle health through reduced protein synthesis (low albumin), impaired amino acid metabolism (BCAAs), decreased hormonal regulation (low IGF-1), and disrupted energy balance (lactate accumulation), leading to impaired mTOR signaling, metabolic stress, and accelerated muscle loss.[15,16] Xiao et al (2023) found that elevated liver enzymes, particularly aspartate aminotransferase (AST) and alanine aminotransferase (ALT), were linked to a higher risk of sarcopenia. Individuals in the highest AST quartile (≥26 IU/L) had significantly increased odds of sarcopenia (OR = 1.53, 95% CI: 1.15–2.04, $p < 0.01$) compared to those in the lowest quartile.[20] Similarly, Kamimura et al (2021) reported that higher liver enzyme levels negatively affects muscle health, with cirrhosis patients exhibiting significantly lower handgrip strength than controls (26.3 ± 8.9 kg vs 35.5 ± 11.3 kg, $p < 0.001$). They also observed an inverse correlation between the Model for End-Stage Liver Disease (MELD) score and handgrip strength (r = −0.32, $p < 0.001$), highlighting the strong connection between liver function and muscle strength.[21]

Renal biomarkers play a crucial role in understanding the relationship between kidney function and muscle health where uremic toxin accumulation, acid-base imbalances, and impaired protein synthesis contribute to sarcopenia, particularly reducing handgrip strength. The underlying mechanisms include increased protein degradation, reduced muscle protein synthesis, and mitochondrial dysfunction, exacerbated by the uremic environment.[1,2] Noce et al (2021) demonstrated a significant positive correlation between handgrip strength and the creatinine/cystatin C ratio (r = 0.376, $p < 0.001$ for men; r = 0.407, $p < 0.001$ for women) in a Chinese population, suggesting its potential as a biomarker for muscle strength in CKD.[22] Watanabe et al (2019) found that a 1-unit increase in the serum cystatin C-to-creatinine ratio raised the risk of sarcopenia, low lean tissue index, and low handgrip strength by 4.6-, 7.2-, and 2.6-fold, respectively ($p = 0.003$, $p < 0.001$, $p = 0.048$).[23]

Uric acid plays a dual role in muscle health and sarcopenia through oxidative stress and inflammation. At physiological levels, it acts as an antioxidant, reducing reactive oxygen species (ROS). Elevated levels, however, can trigger oxidative damage, pro-inflammatory cytokines (IL-6, TNF-α), and protein degradation pathways, impairing muscle strength.[24,25] Kawamoto et al (2016) found a positive association in elderly Japanese women, with significantly higher handgrip strength observed in the upper quartiles of serum uric acid (4.8–5.4 mg/dL and 5.5–9.3 mg/dL) compared to the lower quartiles (0.7–4.7 mg/dL, $p < 0.05$).[26] In contrast, research by Huang et al (2013) demonstrated an inverted J-shaped association between serum uric acid levels and muscle strength in Japanese adult men. They found that grip strength differed significantly between participants with and without hyperuricemia (geometric mean and 95% CI: 40.3 [39.2–41.3] kg vs 41.9 [41.3–42.5] kg; $p = 0.01$). Furthermore, serum UA levels (quartiles) showed an inverted J-shaped

curve with grip strength (mean and 95% CI: Q1, 41.6 [40.6–42.6] kg; Q2, 42.2 [41.2–43.2] kg; Q3, 41.8 [40.8–42.8] kg; Q4, 40.4 [39.3–41.4] kg; p for quadratic trend = 0.05).[27]

The relationship between lipid metabolism and sarcopenia, particularly handgrip strength, involves lipotoxicity, mitochondrial dysfunction, and chronic inflammation. Dysregulated lipid profiles (high LDL, low HDL, elevated triglycerides) cause ectopic fat in muscles, impairing mitochondrial ATP production. Lipid-induced NF-κB activation increases pro-inflammatory cytokines (TNF-α, IL-6), while oxidative stress markers like malondialdehyde (MDA) and reactive oxygen species (ROS) disrupt muscle protein synthesis.[28,29] Jiang et al (2023) examined the relationship between lipid metabolism and sarcopenia in geriatric inpatients, reporting significantly lower total cholesterol (TC) and triglyceride (TG) levels in sarcopenia patients compared to non-sarcopenia patients ($p < 0.01$). Multivariate logistic regression identified low TC and TG levels, alongside elevated LDL as significant risk factors for sarcopenia ($p < 0.05$).[30]

Vitamin D is essential for muscle health, with deficiency linked to sarcopenia and reduced handgrip strength. It regulates calcium homeostasis via parathyroid hormone (PTH), enhances muscle cell proliferation through the PI3K/Akt pathway, and reduces inflammation by suppressing IL-6 and TNF-α. Its effects are mediated by vitamin D receptor (VDR), with biomarkers including 25(OH)D levels, VDR expression, and calcium.[6,31] Research by Minamino et al (2021) found that low 25(OH)D status was significantly associated with a higher prevalence of severe sarcopenia (OR 6.00; 95% CI 1.99–18.08). Furthermore, the study revealed that patients with low vitamin D status had significantly lower measured values of muscle mass, handgrip strength, and gait speed compared to those with sufficient vitamin D levels.[32]

There has not been research that comprehensively examines the potential of various blood parameter examinations and their predictive roles in sarcopenia, particularly in the elderly population in Indonesia. Therefore, the purpose of our study was to investigate the potential of blood parameters as predictive biomarkers for sarcopenia in the Indonesian elderly population, aiming to support early detection and targeted interventions to maintain physical function and improve quality of life in this demographic.

Materials and Methods

Study Design and Sampling

This study utilized a cross-sectional analytical observational design conducted in January 2024. The participants consisted of 70 elderly residents of Santa Anna Nursing Home, selected using a total sampling method. The inclusion criteria required participants to be aged 60 years or older, willing to take part in interviews, provide consent for blood sample collection, and demonstrate the ability to independently perform the handgrip strength test and lift the device without external assistance. Participants were excluded if they had neuro-psychosocial issues, such as cognitive decline (eg, dementia or Alzheimer's disease) that hinder comprehension or cooperation. Individuals with neuro-disorders, including Parkinson's disease, stroke, or severe musculoskeletal conditions like advanced arthritis, which interfered with physical examinations, were also excluded. Additionally, participants were excluded if blood collection was not possible due to skin conditions such as eczema, psoriasis, or severe scarring in the venipuncture area, as these conditions could complicate or prevent sample collection and compromise data quality. The sampling approach ensured a well-defined elderly population, enhancing the study's reliability and applicability to similar demographic groups (Figure 1).

Instruments and Procedures

The variables examined in the sociodemographic category include age, gender, marital status, and education. These data were obtained through a combination of direct interviews with participants, verification of personal identification documents such as identity card, and confirmation from the administrator of the nursing home. This multi-step process ensured that the data collected were accurate, reliable, and validated, minimizing errors and enhancing the study's credibility.

The physical examination variables in this study are handgrip strengths from the right and left hands, assessed using a Camry Electronic Hand Dynamometer EH 101. Participants were seated comfortably with feet flat on the floor, back supported, and shoulders relaxed. The arm being tested was positioned at a 90-degree angle with the forearm parallel to the floor. Participants squeezed the hand dynamometer with maximal effort for 3–5 seconds while breathing normally. The test was conducted three times per hand, with 30–60 seconds of rest between trials to prevent fatigue. The highest

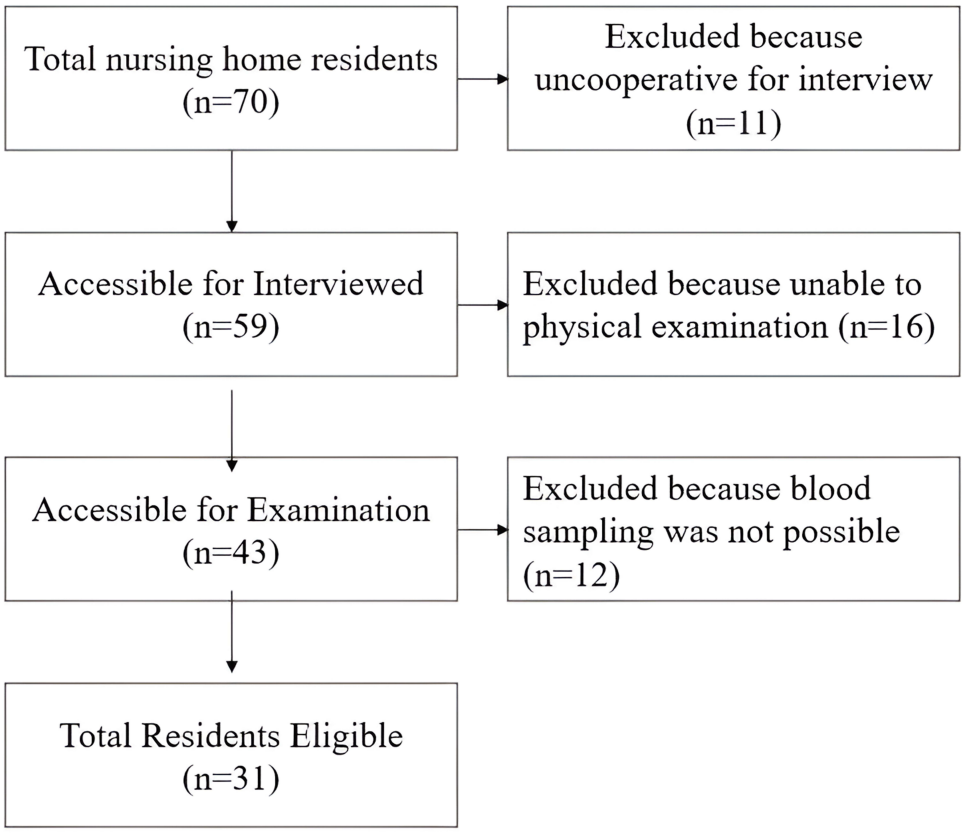

Figure 1 Study Population Analysis.

value recorded, expressed in kilograms (kg), ensured valid and reliable results. Handgrip strength is a critical parameter for diagnosing sarcopenia, as reduced grip strength is a hallmark of muscle weakness associated with this condition.[33,34]

The laboratory examination variables in this study included albumin, liver function (SGOT and SGPT), kidney function (urea and creatinine), uric acid, lipid profile (total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol), glucose profile (FBG and HbA1c), fasting insulin, and vitamin D levels. Blood samples were collected via venipuncture from the vena mediana cubiti, a vein located in the antecubital fossa (elbow crease). To ensure aseptic conditions, the venipuncture site was sterilized using an alcohol swab applied in a circular motion from the center outward. Participants fasted for at least 10 hours prior to sample collection to ensure accurate biochemical measurements. Trained medical personnel conducted the procedure using sterile needles and a vacuum blood collection system while adhering to clinical safety standards.

All samples were processed in a certified medical laboratory using standardized methods tailored to each parameter. Serum albumin was measured with results expressed in grams per deciliter (g/dL). Liver function tests, including SGOT and SGPT, were reported in milligrams per deciliter (mg/dL). Kidney function was evaluated by measuring serum urea and creatinine levels, also expressed in mg/dL. Uric acid levels were determined using enzymatic methods and reported in mg/dL. The lipid profile, encompassing total cholesterol, triglycerides, HDL cholesterol, and LDL cholesterol, was analyzed enzymatically, with results expressed in mg/dL. Glucose profile parameters included fasting blood glucose (FBG), measured in mg/dL, and glycated hemoglobin (HbA1c), expressed as a percentage. Fasting insulin levels were assessed using assay-based methods, with results in micro-international units per milliliter (μIU/mL). Vitamin D status was assessed by measuring serum 25-hydroxyvitamin D (25(OH)D) levels, with results expressed in nanograms per milliliter (ng/mL).

Advanced analytical techniques were utilized to ensure precision and reliability across all tests. These included automated clinical chemistry analyzers for routine biochemical parameters, enzymatic methods for lipid and uric acid analysis, ELISA for fasting insulin measurements and vitamin D assessment.

Statistical Analysis

Data analysis was conducted using Structural Equation Modeling-Partial Least Squares (SEM-PLS) to evaluate the relationships between the variables, including age, muscle strength (right and left hand grip), albumin, liver function (SGOT and SGPT), kidney function (urea and creatinine), uric acid, lipid profile (total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol), glucose profile (FBG and HbA1c), fasting insulin, and vitamin D. SEM-PLS is a robust statistical method that enables simultaneous analysis of measurement models (validating indicators for latent variables) and structural models (assessing relationships between variables). This approach was used to identify key pathways influencing muscle strength and related biomarkers while determining the predictive ability of the biochemical parameters. The analysis provided comprehensive insights into the interactions among variables, ensuring the accuracy and reliability of the findings.

Results

Based on the inclusion and exclusion criteria established for this study, a total of 31 respondents were identified subsequently included in the analysis. The demographic and clinical characteristics of the 31 participants show a mean age of 73.06 years, with 71% women. Most were married (48.4%) and had a senior high school education (51.6%). Physical examination revealed relatively low handgrip strength (right: 15.43 kg, left: 14.6 kg), indicating potential sarcopenia. Laboratory analysis showed adequate liver function (SGOT: 26.06 U/L; SGPT: 23.16 U/L) and kidney function (urea: 24.39 mg/dL; creatinine: 0.81 mg/dL), balanced lipid (total cholesterol: 183.06 (21.87) mg/dL, triglycerides: 85.35 (26.23) mg/dL; HDL cholesterol: 52.83 (11.89) mg/dL; LDL cholesterol: 102.06 (21.86) mg/dL) and glucose profiles (FBG: 94 mg/dL; HbA1c: 6%). However, vitamin D levels were detected low indicating a deficiency state (15.74 ng/mL) (Table 1).

Table 2 shows the effect size indicators for muscle strength, with an R Square value of 0.648, indicating that 64.8% of the variability in muscle strength is explained by the predictors in the model. The adjusted R Square value of 0.496 reflects a moderate explanatory power after accounting for the number of predictors and model complexity.

Table 3 presents the Heterotrait-Monotrait (HTMT) ratios of parameters, indicating relationships between variables. Key findings include moderate correlations between glucose profile and muscle strength (HTMT = 0.678), glucose profile and liver function (HTMT = 0.7), and age with lipid profile (HTMT = 0.572). Lower correlations were observed between uric acid and vitamin D (HTMT = 0.042) and albumin and renal function (HTMT = 0.06). These results highlight strong interrelationships between glucose profile, liver function, and muscle strength, suggesting these as key contributors to muscle health, while other parameters show weaker associations.

Figures 2 and 3 shows the path coefficients for muscle strength. Glucose profile has a strong negative impact (−0.683), while fasting insulin (−0.208) exhibit moderate negative effects, respectively. Renal function demonstrates

Table 1 Demographic Characteristic of 31 Studied Subjects

Description	Category	N (%)	Mean (SD)
Age (year)			73.06 (9.65)
Gender	Man	9 (29%)	
	Woman	22 (71%)	
Marital Status	Married	15 (48.4%)	
	Not married yet	12 (38.7%)	
	Divorced	4 (12.9%)	
Education	Elementary school	9 (29%)	
	Junior high school	5 (16.1%)	
	Senior high school	16 (51.6%)	
	Bachelor Degree	1 (3.2%)	

(*Continued*)

Table 1 (Continued).

Description	Category	N (%)	Mean (SD)
Muscle Strength	Right Hand Grip (kg)		15.43 (6.37)
	Left Hand Grip (kg)		14.6 (7.54)
Albumin (g/dL)			3.73 (0.38)
Liver Function	SGOT (U/L)		26.06 (13.62)
	SGPT (U/L)		23.16 (13.45)
Kidney Function	Urea (mg/dL)		24.39 (6.52)
	Creatinine (mg/dL)		0.81 (0.23)
Uric Acid (mg/dL)			5.66 (1.54)
Lipid Profile	Total cholesterol (mg/dL)		183.06 (21.87)
	Triglycerides (mg/dL)		85.35(26.23)
	HDL (mg/dL)		52.83 (11.89)
	LDL (mg/dL)		102.06 (21.86)
Glucose Profile	FBG (mg/dL)		94 (34.96)
	HbA1c (%)		6 (0.82)
Fasting Insulin (µIU/mL)			14.53 (7.73)
Vitamin D (ng/mL)			15.74 (1.61)

Table 2 Effect Size Indicators for Muscle Strength

	R Square	R Square Adjusted
Muscle Strength	**0.648**	**0.496**

Table 3 Heterotrait-Monotrait of Parameters

	Age	Albumin	Vitamin D	Glucose Profile	Fasting Insulin	Lipid Profile	Liver Function	Muscle Strength	Renal Function	Uric Acid
Age										
Albumin	0.46									
Vitamin D	0.307	0.462								
Glucose Profile	0.43	0.527	0.388							
Fasting Insulin	0.502	0.012	0.176	0.347						
Lipid Profile_	0.572	0.463	0.302	0.541	0.09					
Liver Function	0.273	0.172	0.256	0.7	0.182	0.366				
Muscle Strength	0.113	0.163	0.273	0.678	0.336	0.167	0.396			
Renal Function	0.364	0.06	0.16	0.459	0.295	0.318	0.399	0.201		
Uric Acid	0.222	0.23	0.042	0.185	0.333	0.157	0.289	0.282	0.471	

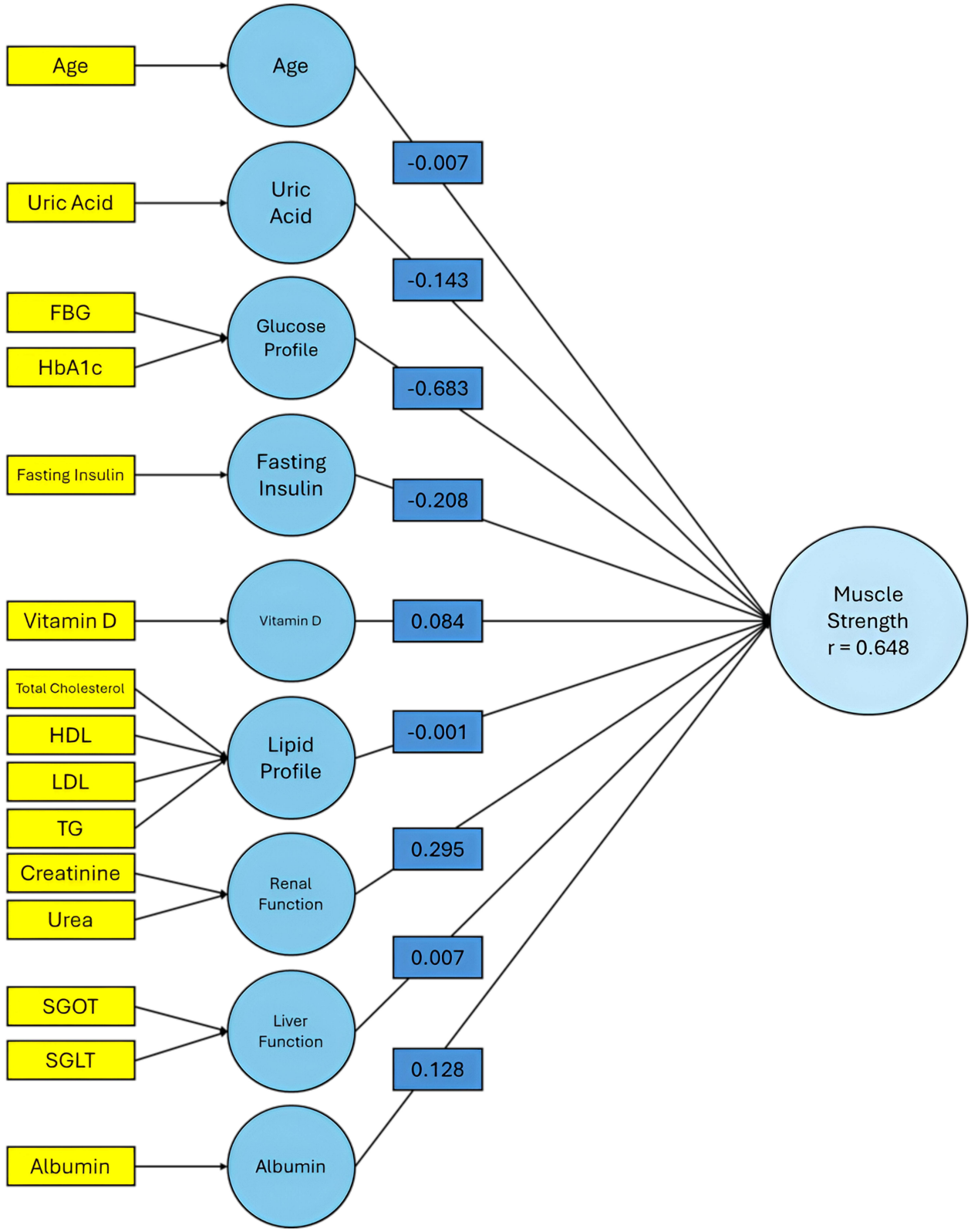

Figure 2 Structural Equation Modeling (SEM) Using Partial Least Squares (PLS) The diagram illustrates the relationships between various clinical parameters and muscle strength (r = 0.648) based on SEM-PLS analysis. Notable parameters include renal function (creatinine, urea) showing a positive correlation, glucose profile (FBG, HbA1c) which demonstrates a strong negative correlation, and fasting insulin, which has a moderate negative correlation (−0.208).

Abbreviations: FBG, fasting blood glucose; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; SGOT, serum glutamic-oxaloacetic transaminase; SGLT, serum glutamic-pyruvic transaminase.

https://doi.org/10.2147/JMDH.S486370

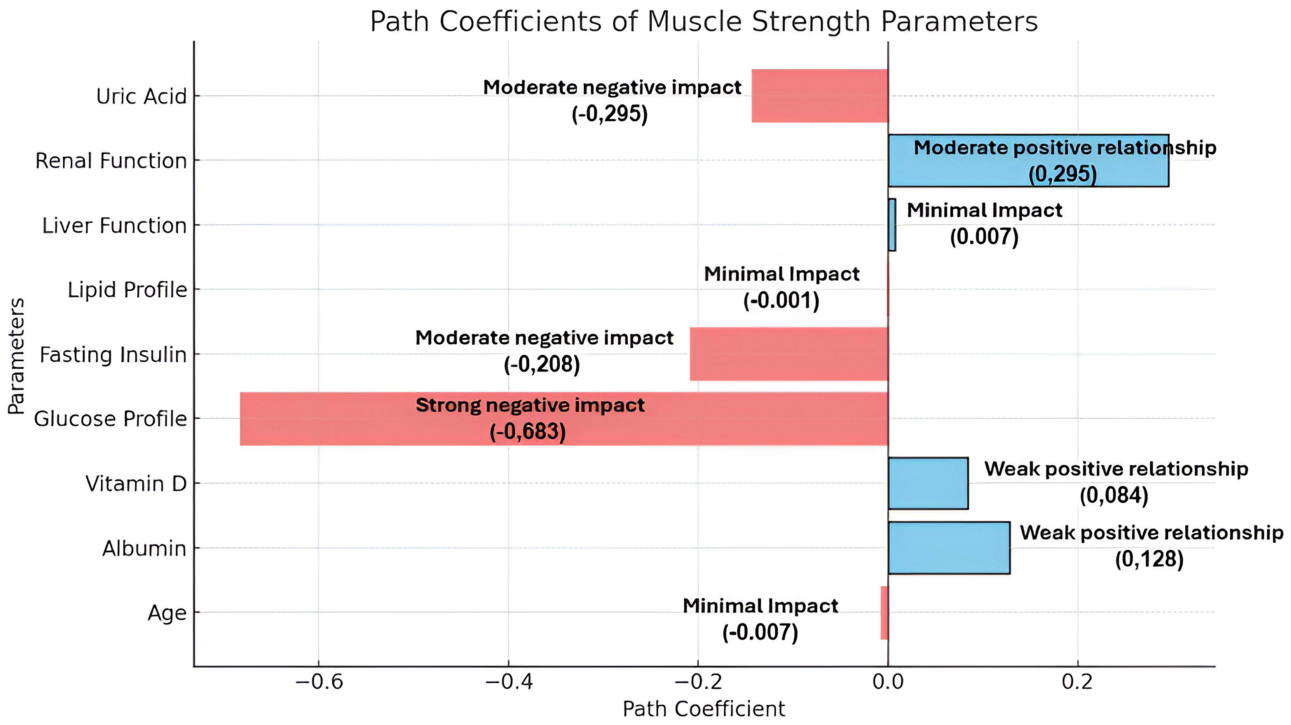

Figure 3 Path Coefficients Parameters of Muscle Strength.

a moderate positive relationship (0.295). Other parameters, including age, lipid profile, and liver function, have minimal impact. These results highlight the significant influence of glucose profile and renal function on muscle strength (Figure 2–3).

Discussion

These findings reveal a strong negative association between glucose profiles and muscle strength, highlighting the significant role of metabolic control in maintaining physical performance. Fasting insulin levels also demonstrate a moderate negative effect on muscle strength, further emphasizing the impact of metabolic factors. Chronic hyperglycemia, indicated by elevated fasting glucose and HbA1c, contributes to sarcopenia through insulin resistance, which disrupts glucose uptake and protein synthesis essential for muscle growth.[35,36] This is compounded by reduced activity of the PI3K/Akt pathway and impaired GLUT4 translocation, limiting energy availability. Excessive glucose promotes advanced glycation end-products (AGEs), which accumulate in muscle tissue, cross-linking structural proteins like collagen, leading to stiffness and loss of function. Hyperglycemia also triggers oxidative stress by increasing reactive oxygen species (ROS) via mitochondrial and NADPH oxidase pathways.[25,37] These ROS damage cellular components, impair mitochondria, and disrupt ATP production, reducing muscle repair. Chronic inflammation driven by hyperglycemia elevates cytokines like TNF-α and IL-6, activating proteolytic systems and suppressing mTORC1 signaling. Vascular damage mediated by protein kinase C reduces perfusion, nutrient delivery, and waste clearance, further impairing muscle health.[38–40]

Conversely, renal function shows a moderate positive relationship with muscle strength, suggesting its supportive role in muscular performance. The seemingly paradoxical positive relationship between elevated renal markers, such as creatinine and urea, and improved handgrip strength in the elderly provides a fascinating insight that challenges conventional interpretations. This association likely stems from interconnected metabolic pathways and molecular mechanisms linking these biomarkers to muscle mass and function.[41,42] Creatinine, a byproduct of muscle metabolism, is traditionally used as a marker of kidney function but is also strongly associated with muscle mass.[43,44] Higher serum creatinine levels may reflect preserved or greater muscle mass rather than kidney dysfunction, as creatinine production is proportional to muscle tissue. The observed correlation with enhanced handgrip strength suggests that elevated creatinine

levels might indicate better muscle quality and metabolic activity.[11,45] Similarly, urea, while primarily reflecting renal excretory function, is influenced by protein metabolism and nutritional status. Elevated urea in individuals with strong muscle function may indicate higher protein turnover and adequate nutrition, both vital for maintaining muscle integrity and strength.[46–48]

Several molecular pathways can be used to underscore this relationship. The mTOR (mechanistic target of rapamycin) pathway, crucial for muscle protein synthesis and hypertrophy, is activated by amino acids and energy availability, linking dietary protein metabolism to muscle growth.[48–50] Concurrently, the AMPK (AMP-activated protein kinase) pathway, sensitive to cellular energy stress, regulates catabolic and anabolic processes, ensuring efficient muscle metabolism under varying energy conditions. Elevated creatinine and urea may signify an active balance in these pathways, supporting muscle maintenance.[24,51] The IGF-1 (Insulin-like Growth Factor-1) signaling pathway, critical for muscle regeneration and growth, further explains the positive association, as individuals with higher muscle mass likely exhibit enhanced IGF-1 activity, fostering muscle strength and metabolic turnover.[40,52] These findings suggest that elevated creatinine and urea in elderly individuals with preserved renal function may reflect a physiological state of robust muscle metabolism rather than renal impairment. However, careful interpretation is necessary, further exploration into these pathways could differentiate the metabolic contributions of muscle mass and renal function in aging populations, offering insights into the interplay between nutrition, metabolism, and physical performance.

This study has several limitations that may influence its findings and interpretation. First, the participants were informed of the upcoming physical examinations and biochemical assessments several months in advance, potentially encouraging behavioral modifications such as improved diet and physical activity, which could artificially enhance muscle strength or alter metabolic markers like glucose and insulin. This preparation might obscure the baseline relationship between the studied variables and sarcopenia. The use of fasting glucose and HbA1c as markers of glucose metabolism, while reliable, provides only an average reflection of glycemic control over time and may not capture acute glucose fluctuations. Including parameters such as postprandial glucose or continuous glucose monitoring could provide a more comprehensive assessment of glycemic variability and its impact on muscle health.[53–55] The potential for symptom overlap between metabolic conditions and sarcopenia presents challenges in disentangling their effects. For example, insulin resistance, often associated with hyperglycemia, can independently contribute to sarcopenia through proteolytic and inflammatory pathways, complicating the attribution of observed effects solely to glucose profiles.[16,56,57] The study's cross-sectional design limits the ability to infer causality between the biochemical parameters and muscle strength. Longitudinal studies are needed to establish temporal relationships and explore the progression of sarcopenia in elderly populations. Despite these limitations, the findings provide valuable insights into the interplay between metabolic health and muscle strength in aging populations.

Conclusions and Recommendations

Glucose profile, fasting insulin, and renal function are essential biomarkers for sarcopenia in elderly populations. Hyperglycemia and insulin resistance negatively impact muscle strength, while creatinine and urea positively correlate with muscle metabolism. These findings support using these markers for early detection and targeted interventions to improve muscle health and quality of life.

Study Limitation and Future Research

This study exclusively focused on the elderly population to examine the impact of laboratory examination such as glucose profile, fasting insulin, and renal function on sarcopenia, without accounting for other variables that may influence muscle health, such as physical activity, nutrition, and comorbidities. Furthermore, the cross-sectional design limits the ability to assess temporal relationships and causality between these biomarkers and sarcopenia progression. The lack of detailed molecular analyses also restricts insights into the precise pathways linking these variables to muscle deterioration. Future research should incorporate longitudinal designs, broader variables, and advanced molecular assessments to establish causal pathways and develop targeted interventions for sarcopenia prevention and management.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical Clearance

Ethical Clearance for this study was obtained from Universitas Tarumanagara Human Research Ethics Committee Institute of Research and Community Engagement (Number of Letter: 013-UTHREC/UNTAR/VI/2024)

Inform Consent

The research was conducted in line with the Helsinki Declaration. Each patient and their legal guardian were involved in the consent process, as deemed appropriate, to ensure that participants fully understood the study's objectives, procedures, and potential implications. This additional step was undertaken to facilitate clear and effective communication and to ensure informed decision-making, while strictly adhering to ethical standards and respecting the autonomy of each participant.

Funding

This project was supported by a grant from Tarumanagara University.

Disclosure

The authors declared that they have no conflicts of interest.

References

1. Yin M, Zhang H, Liu Q, et al. Diagnostic performance of clinical laboratory indicators with sarcopenia: results from the west china health and aging trend study. *Front Endocrinol*. 2021;12:. doi:10.3389/fendo.2021.785045
2. Dent E, Morley JE, Cruz-Jentoft AJ, et al. International clinical practice guidelines for sarcopenia (ICFSR): screening, diagnosis and management. *J Nutr Heal aging*. 2018;22(10):1148–1161.
3. Cristian C, Soto BGZ, Lozano CC, Zúñiga C. Automatic classification of sarcopenia level in older adults: a case study at tijuana general hospital. *Int J Environ Res Public Health*. 2019;16(18):3275. doi:10.3390/ijerph16183275
4. Liu J, Zhu Y, Tan JK, Ismail AH, Ibrahim R, Hassan NH. Factors associated with sarcopenia among elderly individuals residing in community and nursing home settings: a systematic review with a meta-analysis. *Nutrients*. 2023;15(20):4335. doi:10.3390/nu15204335
5. Chen X, Hou L, Zhang Y, Dong B. Analysis of the prevalence of sarcopenia and its risk factors in the elderly in the Chengdu community. *J Nutr Heal Aging*. 2021;25(5):600–605. doi:10.1007/s12603-020-1559-1
6. Lontoh SO, Santoso AH, Lumintang VG, Alvianto F, Destra E, Firmansyah Y. Program pengabdian masyarakat tentang pentingnya skrining vitamin D dalam mencegah sarkopenia pada lanjut usia. *Sejah J Inspirasi Mengabdi Untuk Negeri*. 2024;3(3):21–29. doi:10.58192/sejahtera.v3i3.2277
7. Lee WJ, Liu LK, Peng LN, Lin MH, Chen LK. Comparisons of sarcopenia defined by IWGS and EWGSOP criteria among older people: results from the I-Lan longitudinal aging study. *J Am Med Dir Assoc*. 2013;14(7):528.e1–528.e7. doi:10.1016/j.jamda.2013.03.019
8. Rodríguez-Rejón AI, Artacho R, De-la-O A, Zúñiga Á, Ruiz-López MD. Diagnosis of sarcopenia in long-term care homes for the elderly: the sensitivity and specificity of two simplified algorithms with respect to the EWGSOP consensus. *J Nutr Heal Aging*. 2018;22(7):796–801. doi:10.1007/s12603-018-1004-x
9. Robbani YT, Widajanti N, Sulistiawaty NN. Comparison of sarcopenia diagnostic component between two age groups in men. *Heal Notions*. 2020;4(6):180–186. doi:10.33846/hn40604
10. Heo SJ, Jee YS. Characteristics of age classification into five-year intervals to explain sarcopenia and immune cells in older adults. *Medicina*. 2023;59(10):1700. doi:10.3390/medicina59101700
11. Rose SP, Srinivas A, Prashant A, Periera P, Nataraj SM, Shivashankar KK. Inflammation, muscle health and aging: calf circumference as a cost-effective diagnostic indicator of sarcopenia. *Arch Gerontol Geriatrics Plus*. 2024;1(3):100046.
12. He X, Song Y, Ma L, Ainsworth BE, Liu Y, Chen N. Prevalence and factors influencing sarcopenia among community-dwelling older adults using the asian working group for sarcopenia definition. *Clin Interv Aging*. 2022;17:1707–1727. doi:10.2147/CIA.S388319
13. Kalyani RR, Metter EJ, Egan JM, Golden SH, Ferrucci L. Hyperglycemia predicts persistently lower muscle strength with aging. *Diabetes Care*. 2014;38(1):82–90. doi:10.2337/dc14-1166
14. Umegaki H. Sarcopenia and diabetes: hyperglycemia is a risk factor for age-associated muscle mass and functional reduction. *J Diabetes Investig*. 2015;6(6):623–624. doi:10.1111/jdi.12365
15. da S AT, de O DYA, Santos JLF, Wong R, Lebrão ML. Prevalence and associated factors of sarcopenia among elderly in Brazil: findings from the SABE study. *J Nutr Heal Aging*. 2014;18(3):284–290. doi:10.1007/s12603-013-0413-0
16. Lo Buglio A, Bellanti F, Vendemiale G. The aging muscle: sarcopenia, mitochondrial function, and redox biology. *J Gerontol Geriatr*. 2024;72(1):1–10.

17. Frisca F, Santoso AH, Warsito JH, et al. Edukasi dan penilaian kadar albumin pada kelompok lanjut usia dalam pencegahan sarkopenia. *Sewagati J Pengabdi Masy Indones*. 2024;3(2):91–99. doi:10.56910/sewagati.v3i2.1524
18. Van AJM, Tuttle C, Koopman R, et al. Albumin and C-reactive protein relate to functional and body composition parameters in patients admitted to geriatric rehabilitation after acute hospitalization: findings from the RESORT cohort. *Eur Geriatr Med*. 2022;13(3):623–632. doi:10.1007/s41999-022-00625-5
19. Snyder CK, Lapidus J, Cawthon PM, Dam TT, Sakai LY, Marshall LM. Serum albumin in relation to change in muscle mass, muscle strength, and muscle power in older men. *J Am Geriatr Soc*. 2012;60(9):1663–1672. doi:10.1111/j.1532-5415.2012.04115.x
20. Xiao L, Dai M, Zhao F, et al. Assessing the risk factors associated with sarcopenia in patients with liver cirrhosis: a case–control study. *Sci Rep*. 2023;13(1):21845.
21. Kamimura H, Toshihiko S, Natsui K, et al. Molecular mechanisms and treatment of sarcopenia in liver disease: a review of current knowledge. *Int J Mol Sci*. 2021;22(3):1425.
22. Noce A, Marrone G, Ottaviani E, et al. Uremic sarcopenia and its possible nutritional approach. *Nutrients*. 2021;13(1):147. doi:10.3390/nu13010147
23. Watanabe H, Enoki Y, Maruyama T. Sarcopenia in chronic kidney disease: factors, mechanisms, and therapeutic interventions. *Biol Pharm Bull*. 2019;42(9):1437–1445. doi:10.1248/bpb.b19-00513
24. Riviati N, Legiran L, Indrajaya T, Saleh I. Role of IL-6 and IGF-1 in sarcopenia. *J Aisyah J Ilmu Kesehat*. 2023;8(1):179–86.
25. Xu Q, Li F, Shen S, Xj Y, Zhou J, Chen X. Increased serum level of IL-1β is associated with sarcopenia in elderly people. 2023.
26. Kawamoto R, Ninomiya D, Kikuchi A, et al. Serum uric acid to creatinine ratio is a useful predictor of renal dysfunction among diabetic persons. *Diabetes Metab Syndr Clin Res Rev*. 2019;13(3):1851–1856. doi:10.1016/j.dsx.2019.04.023
27. Huang C, Niu K, Kobayashi Y, et al. An inverted J-shaped association of serum uric acid with muscle strength among Japanese adult men: a cross-sectional study. *BMC Musculoskelet Disord*. 2013;14(1). doi:10.1186/1471-2474-14-258.
28. Lopez-Ruiz A, Kashani K. Assessment of muscle mass in critically ill patients: role of the sarcopenia index and images studies. *Curr Opin Clin Nutr Metab Care*. 2020;23(5):302–311. doi:10.1097/MCO.0000000000000673
29. Landi F, Liperoti R, Russo AM, et al. Association of anorexia with sarcopenia in a community-dwelling elderly population: results from the ilSIRENTE study. *Eur J Nutr*. 2012;52(3):1261–1268. doi:10.1007/s00394-012-0437-y
30. Jiang Y, Xu B, Zhang K, et al. The association of lipid metabolism and sarcopenia among older patients: a cross-sectional study. *Sci Rep*. 2023;13(1). doi:10.1038/s41598-023-44704-4.
31. Kressel H, Matsakas A. Current research on vitamin D supplementation against sarcopenia: a review of clinical trials. *Int J Sports Med*. 2023;44:843–856. doi:10.1055/a-2116-9240
32. Minamino H, Katsushima M, Torii M, et al. Serum vitamin D status inversely associates with a prevalence of severe sarcopenia among female patients with rheumatoid arthritis. *Sci Rep*. 2021;11(1). doi:10.1038/s41598-021-99894-6.
33. Amin Z, Gutierrez G, True L. Concurrent validity and test-retest reliability of squegg^{tm} - smart dynamometer and handgrip trainer in healthy individuals. *Hand Ther*. 2024;29(2):68–74. doi:10.1177/17589983231223868
34. Kim S, Lim DH, Cho YH. Analysis of the reliability of the make test in young adults by using a hand-held dynamometer. *J Phys Ther Sci*. 2016;28(8):2238–2240. doi:10.1589/jpts.28.2238
35. Rentflejsz J, Wojszel ZB. Diabetes mellitus should be considered while analysing sarcopenia-related biomarkers. *J Clin Med*. 2024;13(4):1107. doi:10.3390/jcm13041107
36. Bozzetti F. Age-related and cancer-related sarcopenia: is there a difference? *Curr Opin Clin Nutr Metab Care*. 2024;27(5):410–418. doi:10.1097/MCO.0000000000001033
37. Jang JY, Kim DH, Kim ND. Pathogenesis, intervention, and current status of drug development for sarcopenia: a review. *Biomedicines*. 2023;11(6):1635. doi:10.3390/biomedicines11061635
38. Balakrishnan R, Thurmond DC. Mechanisms by which skeletal muscle myokines ameliorate insulin resistance. *Int J Mol Sci*. 2022;23(9):4636. doi:10.3390/ijms23094636
39. Cannavò A, Carandina A, Corbi G, Tobaldini E, Montano N, Arosio B. Are skeletal muscle changes during prolonged space flights similar to those experienced by frail and sarcopenic older adults? *Life*. 2022;12(12):2139. doi:10.3390/life12122139
40. Ding J, Yang G, Sun W, et al. Association of interleukin-6 with sarcopenia and its components in older adults: a systematic review and meta-analysis of cross-sectional studies. *Ann Med*. 2024;56(1). doi:10.1080/07853890.2024.2384664.
41. Lin Y, Zhang Q, Yang Y, Zhou J. A combination of serum biomarkers in elderly patients with sarcopenia: a cross-sectional observational study. *Int J Endocrinol*. 2022;2022:1–7.
42. Liang J, Zhang H, Zeng Z, et al. Lifelong aerobic exercise alleviates sarcopenia by activating autophagy and inhibiting protein degradation via the AMPK/PGC-1α signaling pathway. *Metabolites*. 2021;11(5):323. doi:10.3390/metabo11050323
43. Malmgren L, Grubb A. Muscle mass, creatinine, cystatin c and selective glomerular hypofiltration syndromes. *Clin Kidney J*. 2023;16(8):1206–1210. doi:10.1093/ckj/sfad086
44. Golino G, Danzi V, Rosa SD. Serum creatinine, muscle mass, and nutritional status in intensive care. *InBiomarkers Bioanal Overview*. 2021;2021:1.
45. Prajapati P, Kumar A, Chaudary R, Mangrulkar SV, Arya M, Kushwaha S. A comprehensive review of essential aspects of molecular pathophysiological mechanisms with emerging interventions for sarcopenia in older people. *Curr Mol Pharmacol*. 2023;17: e080323214478.
46. Mankhong S, Kim S, Moon S, Kwak H, Park DH, Kang J. Experimental models of sarcopenia: bridging molecular mechanism and therapeutic strategy. *Cells*. 2020;9(6):1385. doi:10.3390/cells9061385
47. Therdyothin A, Phiphopthatsanee N, Isanejad M. The effect of omega-3 fatty acids on sarcopenia: mechanism of action and potential efficacy. *Mar Drugs*. 2023;21(7):399. doi:10.3390/md21070399
48. Lopes KG, Farinatti P, Bottino D, et al. Sarcopenia in the elderly versus microcirculation, inflammation status, and oxidative stress: a cross-sectional study. *Clin Hemorheol Microcirc*. 2022;80(2):185–195. doi:10.3233/CH-211202
49. Lopes KG, Das GC de SM, da CT BM, et al. Effects of physical training on physical and functional fitness, physical activity level, endothelial function, hemodynamic variables, bone metabolism, and quality of life of post-bariatric patients: study protocol for a randomized controlled trial. *Trials*. 2022;23(1). doi:10.1186/s13063-022-06677-z.

50. Cisterna B, Malatesta M. Molecular and structural alterations of skeletal muscle tissue nuclei during aging. *Int J Mol Sci*. 2024;25(3):1833. doi:10.3390/ijms25031833
51. Kjøbsted R, Hingst JR, Fentz J, et al. AMPK in skeletal muscle function and metabolism. *FASEB J*. 2018;32(4):1741–1777. doi:10.1096/fj.201700442R
52. He Y, Duan W, Xu P, et al. Exploring the impact of interleukins on sarcopenia development: a systematic review and meta-analysis. *Exp Gerontol*. 2024;193:112480. doi:10.1016/j.exger.2024.112480
53. Hanefeld M, Sulk S, Helbig M, Thomas A, Köhler C. Differences in glycemic variability between normoglycemic and prediabetic subjects. *J Diabetes Sci Technol*. 2014;8(2):286–290. doi:10.1177/1932296814522739
54. Röhling M, Martin T, Wonnemann M, et al. Determination of postprandial glycemic responses by continuous glucose monitoring in a real-world setting. *Nutrients*. 2019;11(10):2305. doi:10.3390/nu11102305
55. Chon S, Lee YJ, Fraterrigo G, et al. Evaluation of glycemic variability in well-controlled type 2 diabetes mellitus. *Diabetes Technol Ther*. 2013;15(6):455–460. doi:10.1089/dia.2012.0315
56. Komici K, Dello IA, De LA, et al. Adiponectin and sarcopenia: a systematic review with meta-analysis. *Front Endocrinol*. 2021;12: 576619.
57. Purnamasari D, Tetrasiwi EN, Kartiko GJ, Astrella C, Husam K, Laksmi PW. Sarcopenia and chronic complications of type 2 diabetes mellitus. *Rev Diabet Stud*. 2022;18(3):157–165. doi:10.1900/RDS.2022.18.157