Contagion : Scientific Periodical of Public Health and Coastal Health 7(2)(2025)
e-ISSN : 2685-0389

Sarcopenic Obesity in Postmenopausal Women: Associations Between Fat Mass, Muscle Mass, and Lower Limb Strength in an Indonesian Clinical Cohort

Wendra[1], Teguh Tanuwidjaja[2], Kishanty Hardaningtyas[3], Aulia Rahma Fazamuthi[4]

[1]Department of Basic Anatomy/Pathobiology, Master's Program in Skin Aging and Aesthetics, Faculty of Medicine, Universitas Jenderal Achmad Yani
[2,3]Medical Aesthetics Master's Program in Skin Aging and Aesthetics, Faculty of Medicine, Universitas Jenderal Achmad Yani
[4]Medical Education Study Program, Faculty of Medicine, Universitas Jenderal Achmad Yani

Email correspondence: argiaglobal@gmail.com

Track Record Article

Revised: 21 June 2025
Accepted: 15 August 2025
Published: 31 August 2025

How to cite:
Wendra, Tanuwidjaja, T., Hardaningtyas, K., & Fazamuthi, A. R. (2025). Sarcopenic Obesity in Postmenopausal Women: Associations Between Fat Mass, Muscle Mass, and Lower Limb Strength in an Indonesian Clinical Cohort. *Contagion: Scientific Periodical Journal of Public Health and Coastal*, *7*(2), 183–193.

Abstract

Sarcopenic obesity is an emerging public health concern, particularly among postmenopausal women. This condition is characterized by increased fat mass and reduced muscle mass, both of which negatively impact quality of life and physical function. This study employed an analytical design with a cross-sectional approach, involving 51 obese women aged 45 years and older who received care atthe Nutrition Clinic of Dustira Hospital. Fat and muscle mass were assessed using Bioelectrical Impedance Analysis (BIA), while leg muscle strength was measured with a leg dynamometer. The chi-square test was used to examine associations between variables due to its suitability for categorical data analysis. Results indicated that the majority of participants were aged 45–55 years, with 52.9% classified as having obesity category I. Descriptive analysis revealed that 66.7% of subjects had elevated fat mass, particularly intramyocellular lipid (IMCL); 80.4% exhibited very low muscle mass; and 58.8% demonstrated poor leg muscle strength. Statistical analysis showed significant associations between fat mass and leg muscle strength (p = 0.003), and between muscle mass and leg muscle strength (p < 0.001). Effect sizes measured using Cramer's V indicated a strong strength of association. These findings underscore the importance of resistance training interventions in managing sarcopenic obesity among postmenopausal women. Enhancing muscle mass and reducing fat mass, especially IMCL, may contribute to improved leg muscle strength and overall quality of life.

Keyword: Fat Mass, Leg Muscle Strength, Muscle Mass, Sarcopenic Obesity, Postmenopausal Women.

INTRODUCTION

Sarcopenic obesity is increasingly recognized as a significant health concern, particularly among postmenopausal women. Obesity not only impairs the ability of skeletal muscles to sustain locomotor performance but also contributes to reductions in muscle mass and strength(Astuti & Jatmiko, 2020; Javed et al., 2019; Putri et al., 2023). The extensor muscles of the lower limbs are located in the anterior compartment of the thigh, with their primary functions being knee extension and, to a lesser extent, hip flexion. The principal extensor muscle group is the quadriceps femoris, which comprises four distinct muscles. In Indonesia, the prevalence of obesity has nearly tripled since 1975. In Cimahi City, the obesity rate reached 24.87% in 2018, with women exhibiting a higher prevalence (33.09%) compared to men (16.95%)(Febriyanti et al., 2023). Among women, muscle mass typically begins to decline around age 45 and peaks at age 65 (Fitriani, 2018; Kuryłowicz, 2023). This decline is closely associated with menopause and reduced estrogen levels, which contribute to increased visceral fat and ectopic fat accumulation, particularly within muscle cells(Klein et al., 2022; Pasdar et al., 2019; Sukarno, 2021).

Sarcopenic obesity often begins with obesity and the accumulation of fat within muscle cells, known as intramyocellular lipid (IMCL). According to Altajar & Baffy (2020), IMCL contributes to the development of sarcopenia by impairing skeletal muscle contractility and strength. The current definition of sarcopenic obesity, as outlined in the ESPEN/EASO 2023 guidelines, highlights the importance of understanding the interplay between fat mass and muscle mass in relation to overall health. Sarcopenic obesity is characterized by excessive fat accumulation (obesity) alongside a decline in skeletal muscle mass and strength (sarcopenia). While this condition is commonly observed in older adults, it may also affect younger individuals with sedentary lifestyles.

Previous studies, such as Huang et al., (2024), have shown that the relationship between fat mass and muscle strength may differ across populations, particularly between Asian and non-Asian groups. This highlights the need for further research within the Asian context, especially in Indonesia. Huang et al., (Huang et al., 2024) explored the definition and global prevalence of sarcopenia, finding that it is highly prevalent among the elderly, with key risk factors including obesity and reduced physical activity. Zanker et al., (2023), provided guidance on the diagnosis and management of sarcopenia, suggesting that interventions aimed at increasing muscle mass and reducing body fat may be effective in managing the condition in older adults. Chan et al., (2022) analysed the relationship between muscle mass and strength in an Asian population, reporting that greater muscle mass was associated with improved muscle strength, while higher body fat negatively impacted strength. Gimigliano et al., (2018) examined the effects of obesity on muscle strength in postmenopausal women, revealing that those with obesity had lower muscle strength compared to women of normal weight, and confirming a negative correlation between fat mass and muscle strength. Additionally Collins (K. H. Collins et al., 2018) investigated the mechanisms underlying the relationship between body fat and muscle mass, finding that increased adiposity can impair muscle metabolism and contribute to muscle loss through inflammatory and hormonal pathways.

Most previous studies on sarcopenic obesity and the relationship between fat mass, muscle mass, and muscle strength have been conducted in non-Asian populations or lack specificity regarding postmenopausal women. This creates a gap in understanding how these factors interact across different cultural and genetic contexts, particularly in Indonesia. While several studies have identified associations between body fat and muscle mass, the underlying mechanisms remain poorly understood, especially in relation to estrogen deficiency and its effects on myosin heavy chain (MHC) isoform expression and satellite cell activation in postmenopausal women.

Previous studies often fail to differentiate between specific age groups, such as women over 45 years. This study addresses that gap by focusing on this demographic, a critical period marked by hormonal changes and shifts in body composition. The novelty of this research lies in its specific focus on postmenopausal women, a population particularly vulnerable to sarcopenia and obesity. By examining how hormonal changes influence muscle health in this group, the study makes a valuable contribution to the existing literature. It not only investigates the relationship between fat mass and muscle mass, but also evaluates muscle strength as a consequence of this interaction. In doing so, the study offers a more comprehensive understanding of sarcopenic obesity.

The hypothesis proposed in this study is that higher fat mass is associated with reduced leg strength, regardless of age. The aim of the research is to examine the relationship between fat mass, muscle mass, and lower limb strength in obese women over the age of 45 at Dustira Hospital. Additionally, the study seeks to contribute to the existing literature by exploring the impact of fat and muscle mass on lower limb strength, with particular attention to the phenomenon sometimes referred to as "muscle freezing”.

METHODS

This analytical study employed a cross-sectional design. The subjects were 51 obese women aged 45 years and older who received treatment at the Nutrition Clinic of Dustira Hospital and met the inclusion criteria. Participants were eligible if they were female, aged 45 years or older, diagnosed with obesity (Body Mass Index [BMI] ≥ 25 kg/m^2), and willing to participate by completing an informed consent form. The sampling technique used was consecutive sampling, with the recruitment rate reported to evaluate the potential for selection bias.

The independent variables in this study were body fat mass and muscle mass, while the dependent variable was leg muscle strength. Bivariate analysis was conducted using the chi-square test with a 95% confidence level. Prior to measurement, all subjects underwent fasting and adhered to established hydration guidelines. Fat mass and muscle mass were assessed using the InBody 770 model bioelectrical impedance analysis (BIA) device, which had been calibrated according to standard protocols. Leg muscle strength was measured using a leg dynamometer, with the testing protocol consisting of three trials per leg in a seated position. Joint angles were standardized to ensure anatomical consistency throughout the measurements. Ethical clarity was ensured by providing respondents with comprehensive information about the study's purpose and their rights. Nutritional status was assessed using the Body Mass Index (BMI) formula. Bioelectrical Impedance Analysis (BIA) was used to measure visceral and subcutaneous fat by evaluating the body's electrical resistance, with visceral fat typically exhibiting higher resistance than subcutaneous fat. The association with intramyocellular lipid (IMCL) accumulation suggests that increased visceral fat may contribute to IMCL buildup, which is linked to insulin resistance and an elevated risk of type 2 diabetes. During leg dynamometry testing, the dominant leg and specific muscle groups, such as the knee extensors and hip extensors, were identified and assessed according to standardized protocols.

RESULT

An overview of obese women aged 45 years and older at the Dustira Hospital Nutrition Clinic is presented in Table 1.

Table 1. Demographic and nutritional profile of obese women aged 45 years and older at Dustira Hospital Nutrition Clinic, including age distribution, nutritional status, and fat mass measurements

Age	Nutritional Status				Fat Mass								Total	
	Obesity I		Obesity II		Underfat		Healthy		Overfat		Obese			
	n	%	N	n	n	%	N	%	n	%	n	%	N	%
45 - 55 years old	21	47,7	23	0	0	0,0	0	0,0	12	27,3	32	72,7	44	100,0
56 - 65 years old	4	80,4	1	0	0	0,0	0	0,0	4	80,0	1	20,0	5	100,0
>65 years old	2	100,0	0	0	0	0,0	0	0,0	1	50,0	1	50,0	2	100,0
Total	**27**	**52,9**	**24**	**0**	**0**	**0,0**	**0**	**0,0**	**17**	**33,3**	**34**	**66,7**	**51**	**100,0**

The majority of study subjects were aged 45–55 years, totaling 44 individuals. Among them, 27 (52.9%) were classified as having Obesity I, while 24 (47.1%) fell into the Obesity II category. Additionally, five obese women were in the 56–65 year age range, and two were over 65 years old. According to Riskesdas 2018, the prevalence of obesity among adult women aged 18 years and older was 44.4%. Obesity in women is closely linked to menopause, which leads to a decline in estrogen levels. This hormonal change alters body fat distribution, shifting from subcutaneous fat deposits to increased visceral and ectopic fat accumulation (Pasdar et al., 2019).

Of the 51 obese women aged over 45 years who were examined at the Dustira Hospital Nutrition Clinic, 17 (33.3%) were classified in the overfat category, while 34 (66.7%) were categorized as having obese-level fat mass. The decline in estrogen levels during menopause contributes to weight gain and visceral fat accumulation. Obesity is marked by ectopic fat deposition in skeletal muscle, leading to increased intramuscular fat and intramyocellular lipid

(IMCL) accumulation, which is associated with insulin resistance and metabolic risk (Moore et al., 2020; Roh & Choi, 2020; Straight et al., 2021; Wiranata & Inayah, 2020).

Muscle mass characteristics of obese women aged over 45 at the Nutrition Clinic of Dustira Cimahi Hospital are presented in Table 2.

Table 2. Muscle Mass Profile of Study Subjects

Age	Muscle Mass									
	Very Low		Low		Good		Increased		Total	
	n	%	n	%	n	%	n	%	n	%
45 - 55 years old	35	79,5	9	20,5	0	0,0	0	0,0	44	100,0
56 - 65 years old	5	100,0	0	0,0	0	0,0	0	0,0	5	100,0
>65 years old	1	50,0	1	50,0	0	0,0	0	0,0	2	100,0
Total	**41**	**80,4**	**10**	**19,6**	**0**	**0,0**	**0**	**0,0**	**51**	**100,0**

Based on the results presented in Table 2, among the 51 obese women aged over 45 years, 41 (80.4%) were classified in the very low muscle mass category. Analysis revealed a significant relationship between reduced muscle strength and muscle fiber atrophy. Leg strength is particularly affected by the atrophy of fast-twitch (type II) muscle fibers, which play a crucial role in generating force and explosive power in the lower limbs. In postmenopausal women, increased rates of muscle protein synthesis and breakdown contribute to an imbalance between protein production and degradation. This imbalance can lead to muscle fiber atrophy, resulting in decreased muscle mass and strength (Chidi-Ogbolu & Baar, 2019; Lamusu & Lamusu, 2021).

As shown in Table 3, leg muscle strength among obese women over 45 years of age at the Dustira Hospital Nutrition Clinic was predominantly categorized as low, with 30 individuals (58.8%) falling into this group.

Table 3. Leg Muscle Strength Profile of Study Subjects

Age	Limb Muscle Strength											
	Very Good		Good		Medium		Less		Very Less		Total	
	n	%	n	%	N	%	N	%	n	%	n	%
45 - 55 Tahun	0	0,0	0	0,0	9	20,5	25	56,8	10	22,7	44	100,0
56 - 65 Tahun	0	0,0	0	0,0	1	20,0	3	60,0	1	20,0	5	100,0
>65 Tahun	0	0,0	0	0,0	0	0,0	2	100,0	0	0,0	2	100,0
Total	**0**	**0,0**	**0**	**0,0**	**10**	**19,6**	**30**	**58,8**	**11**	**21,6**	**51**	**100,0**

A reduction in the number and size of muscle fibers, along with atrophy in certain fibers and an increase in fatty tissue, leads to diminished muscle strength, reduced flexibility, slower reaction times, and decreased functional capacity. In women, age-related declines in muscle strength are further exacerbated by reduced estrogen levels during menopause (B. C. Collins et al., 2019; Fitriani, 2018).

Based on the results of the chi-square statistical test, the probability value (p-value) was 0.003 (Table 4), indicating a statistically significant association between fat mass and leg muscle strength.

Table 4. Effect of fat mass on leg muscle strength

Fat Mass	Limb Muscle Strength										Total	p- value
	Very Good		Good		Medium		Less		Very Less			
	N	%	n	%	n	%	n	%	n	%	N	
Underfat	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,003
Healthy	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	
Overfat	0	0,0	0	0,0	7	41,2	10	58,8	0	0,0	17	
Obesitas	0	0,0	0	0,0	3	8,8	20	58,8	11	32,4	34	
Total	**0**	**0,0**	**0**	**0,0**	**10**	**19,6**	**30**	**58,8**	**11**	**21,6**	**51**	

Progressive accumulation of intramyocellular lipids (IMCL) contributes to increased oxidative stress, insulin resistance, and inflammation, ultimately leading to reduced muscle mass and strength(Cleasby et al., 2016; Li et al., 2022). Oxidative stress in skeletal muscle impairs insulin signaling and disrupts related pathways, thereby heightening the risk of insulin resistance. Under insulin-resistant conditions, glucose uptake is significantly diminished, which contributes to a decline in muscle strength. Additionally, IMCL accumulation can trigger inflammation within skeletal muscle, limiting its regenerative capacity. This inflammatory response damages muscle fibers, resulting in further reductions in muscle mass and strength(Shou et al., 2020; Sukarno, 2021).

Based on the results of the chi-square statistical test, the probability value (p-value) was 0.000 (Table 5), indicating a statistically significant association between muscle mass and leg muscle strength.

Table 5. Effect of muscle mass on leg muscle strength

Muscle Mass	Limb Muscle Strength										Total	p- value
	Very Good		Good		Medium		Less		Very Less			
	n	%	n	%	n	%	n	%	n	%	n	
Very Low	0	0,0	0	0,0	3	7,3	27	65,9	11	26,8	41	0,000
Low	0	0,0	0	0,0	7	70,0	3	30,0	0	0,0	10	
Good	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	
Increased	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	
Total	**0**	**0,0**	**0**	**0,0**	**10**	**19,6**	**30**	**58,8**	**11**	**21,6**	**51**	

Reduced muscle mass and strength can significantly impair functional ability. Leg muscles play a vital role in daily activities such as walking, running, and jumping. According to Mustafa, there is a significant correlation between leg muscle strength and the risk of falls among the elderly. A decline in leg muscle strength may lead to difficulties in performing everyday tasks, thereby increasing the likelihood of injuries and falls. This condition also affects the ability to maintain body balance, both static and dynamic, further compromising mobility and safety (Astuti & Jatmiko, 2020; Moore et al., 2020; Mustafa et al., 2022).

Furthermore, reduced muscle strength affects not only mobility but also overall quality of life. Women experiencing muscle weakness often face limitations in physical activity, which can contribute to social isolation and an increased risk of depression. Therefore, implementing appropriate interventions, such as strength training programs and adequate nutritional support, is essential to mitigate the adverse effects of muscle mass and strength loss in postmenopausal women. Continued research is needed to identify effective prevention and rehabilitation strategies that enhance muscle health and improve quality of life in this population.

DISCUSSION

Lower extremity strength is significantly influenced by specific muscles, including the vastus lateralis, rectus femoris, and other components of the quadriceps group (Kojic et al., 2021). These muscles play a vital role in functional movements such as walking, running, and climbing stairs. A reduction in muscle mass within this group can lead to diminished lower limb strength and function, increasing the risk of falls and injuries in postmenopausal women. Muscle architecture, particularly fiber pennation angle and fascicle length, also contributes to overall muscle strength. Fat infiltration, especially intramyocellular lipid (IMCL) accumulation, can disrupt these structural features by altering muscle fiber composition and reducing contractile capacity. Excess fat within the muscle may decrease the pennation angle, thereby impairing the strength and efficiency of muscle contraction.

The accumulation of intramyocellular lipids (IMCL) can lead to mitochondrial dysfunction, contributing to the formation of reactive oxygen species (ROS). ROS damage cellular components, including lipids, proteins, and DNA, thereby accelerating muscle aging and the onset of sarcopenia. Additionally, estrogen deficiency impairs the regulation of muscle protein turnover, particularly through the ubiquitin–proteasome pathway and the autophagy–lysosome system (Pang et al., 2023). This disruption accelerates muscle protein degradation and inhibits synthesis, resulting in muscle mass loss. Anatomical degradation of extensor muscles, such as the quadriceps, can reduce functional capacity, increase the risk of falls, and cause muscle weakness (Venturelli et al., 2018). The decline in muscle strength may impair an individual's ability to perform daily activities, ultimately diminishing quality of life and elevating the risk of injury.

Studies such as Muscle Lipid Infiltration and Insulin Signaling by Goodpaster et al. have demonstrated that fat infiltration into muscle tissue can disrupt insulin signaling, a process essential for glucose metabolism and overall muscle health(Saltiel, 2021). Additionally, a study by Sancho-Muñoz et al., (2021) titled Muscle Strength and Satellite Cell Depletion in Sarcopenia, found that a reduction in satellite cell numbers impairs muscle regeneration, contributing to the decline in muscle strength among older adults.

Comparing the results of these studies to younger age groups can help highlight age-specific effects on muscle mass and strength. The findings suggest that both low muscle mass and high fat mass contribute to strength loss, with high fat mass often serving as the primary driver. Intramyocellular lipid (IMCL) accumulation may impair muscle contractility by disrupting lipid droplet migration from myofibrils. Excess lipid within muscle tissue can interfere with the interaction between actin and myosin, proteins essential for efficient muscle contraction, ultimately leading to reduced muscle strength and endurance.

In the context of postmenopausal obesity, a dual intervention involving weight loss and resistance training is strongly recommended. Weight loss can help reduce visceral and intramyocellular fat accumulation, while resistance training promotes increases in muscle mass and strength. This combination offers substantial benefits for the health and quality of life of postmenopausal women and helps lower the risk of obesity-related diseases. By understanding the underlying mechanisms linking fat mass, muscle mass, and muscle strength, and by implementing targeted interventions, we can enhance the overall well-being of women in this age group.

CONCLUSION

These findings indicate that fat mass and muscle mass significantly influence leg muscle strength in obese women aged 45 years and older at the Nutrition Clinic of Dustira Hospital. The relationship between fat mass, muscle mass, and leg muscle strength in this population can be explained by several physiological and metabolic mechanisms. Aging is associated with a decline in muscle mass (sarcopenia) and an increase in fat mass, particularly visceral fat. Visceral fat negatively affects metabolic processes, including insulin resistance, which impairs the body's ability to build and maintain muscle tissue. Fat accumulation around internal organs can disrupt hormonal and metabolic functions, further contributing to reduced muscle strength. Additionally, visceral fat is linked to elevated levels of pro-inflammatory cytokines, which interfere with muscle protein synthesis and accelerate muscle degradation. Chronic inflammation hampers muscle regeneration, ultimately leading to diminished muscle strength.

Suggestions for Clinical Practice and Public Health Interventions include implementing resistance training programs and promoting education on balanced, protein-rich diets to support muscle protein synthesis and reduce fat accumulation. Utilizing anatomically based assessment tools, such as Bioelectrical Impedance Analysis (BIA) or Dual-Energy X-ray Absorptiometry (DXA), to monitor changes in body composition over time can provide valuable insights for both patients and healthcare professionals. These tools can aid in tailoring intervention programs to meet individual needs effectively.

Future directions for this research could include longitudinal studies utilizing imaging techniques such as Dual-Energy X-ray Absorptiometry (DXA) or Magnetic Resonance Imaging (MRI) to gain deeper insights into changes in body composition over time. Emphasizing the use of anatomically based assessment tools is essential, as they offer more precise information on the distribution of fat and muscle mass. This, in turn, can support the development of more targeted and effective interventions aimed at improving the health outcomes of obese women in this age group.

CONFLICT OF INTEREST

The researcher declares that there is no conflict of interest in the preparation and writing of this scientific work.

REFERENCES

Altajar, S., & Baffy, G. (2020). Skeletal Muscle Dysfunction in the Development and Progression of Nonalcoholic Fatty Liver Disease. *Journal of Clinical and Translational Hepatology*, *8*(4), 1–10. https://doi.org/10.14218/JCTH.2020.00065

Astuti, S. D., & Jatmiko, T. (2020). Pengaruh Latihan Squat Dan Lunges Terhadap Kekuatan Otot Tungkai Mahasiswa Universitas Negeri Surabaya. *Jurnal Prestasi Olahraga*, *3*(3).

Chan, J., Lu, Y.-C., Yao, M. M.-S., & Kosik, R. O. (2022). Correlation between hand grip strength and regional muscle mass in older Asian adults: an observational study. *BMC Geriatrics*, *22*(1), 206.

Chidi-Ogbolu, N., & Baar, K. (2019). Effect of Estrogen on Musculoskeletal Performance and Injury Risk. *Frontiers in Physiology*, *9*. https://doi.org/10.3389/fphys.2018.01834

Cleasby, M. E., Jamieson, P. M., & Atherton, P. J. (2016). Insulin resistance and sarcopenia: mechanistic links between common co-morbidities. *Journal of Endocrinology*, *229*(2), 67–81. https://doi.org/10.1530/JOE-15-0533

Collins, B. C., Laakkonen, E. K., & Lowe, D. A. (2019). Aging of the musculoskeletal system: How the loss of estrogen impacts muscle strength. *Bone*, *123*, 137–144. https://doi.org/10.1016/j.bone.2019.03.033

Collins, K. H., Herzog, W., MacDonald, G. Z., Reimer, R. A., Rios, J. L., Smith, I. C., Zernicke, R. F., & Hart, D. A. (2018). Obesity, metabolic syndrome, and musculoskeletal disease: common inflammatory pathways suggest a central role for loss of muscle integrity. *Frontiers in Physiology*, *9*, 112. https://doi.org/10.3389/fphys.2018.00112

Febriyanti, H., Utami, I. T., Saputri, A. Y., Anafika, A., Antika, A., & Rahayu, S. (2023). Upaya Peningkatan Kualitas Kesehatan Wanita Menopause Tentang Perubahan Pada Masa Klimakterum. *SELAPARANG: Jurnal Pengabdian Masyarakat Berkemajuan*, *7*(1), 636–639. https://doi.org/10.31764/jpmb.v7i1.13536

Fitriani, D. (2018). Peran Estrogen dan Leptin dalam Homeostasis Energi. *Jurnal Ilmu Kedokteran Dan Kesehatan*, *5*(2), 123–131. https://doi.org/10.33024/.v5i2.794

Gimigliano, F., Moretti, A., de Sire, A., Calafiore, D., & Iolascon, G. (2018). The combination of vitamin D deficiency and overweight affects muscle mass and function in older post-menopausal women. *Aging Clinical and Experimental Research*, *30*, 625–631.

Huang, N., Shankar, V., Rezler, Z., Vittal, R., Pachipala, K., Ali, S., Huang, R., Srinivasan, M., Palaniappan, L., & Long, J. (2024). The Prevalence and Risk Factors for Presarcopenia among Young and Middle-aged Asian Americans: A Cross-Sectional Study using NHANES data. *Journal of Asian Health*, *4*(1).

https://doi.org/10.59448/jah.v4i1.51
Javed, A. A., Mayhew, A. J., Shea, A. K., & Raina, P. (2019). Association Between Hormone Therapy and Muscle Mass in Postmenopausal Women. *JAMA Network Open*, *2*(8), e1910154. https://doi.org/10.1001/jamanetworkopen.2019.10154
Klein, S., Gastaldelli, A., Yki-Järvinen, H., & Scherer, P. E. (2022). Why does obesity cause diabetes? *Cell Metabolism*, *34*(1), 11–20. https://doi.org/10.1016/j.cmet.2021.12.012
Kojic, F., Đurić, S., Ranisavljev, I., Stojiljkovic, S., & Ilic, V. (2021). Quadriceps femoris cross-sectional area and specific leg strength: Relationship between different muscles and squat variations. *PeerJ*, *9*, e12435. https://doi.org/10.7717/peerj.12435
Kuryłowicz, A. (2023). Estrogens in Adipose Tissue Physiology and Obesity-Related Dysfunction. *Biomedicines*, *11*(3), 690. https://doi.org/10.3390/biomedicines11030690
Lamusu, A., & Lamusu, Z. (2021). Strength Training of Abdominal Muscles for Increasing the Ability of the Kayang. *Jambura Journal of Sports Coaching*, *3*(1), 39–47. https://doi.org/10.37311/jjsc.v3i1.9672
Li, C., Yu, K., Shyh-Chang, N., Jiang, Z., Liu, T., Ma, S., Luo, L., Guang, L., Liang, K., Ma, W., Miao, H., Cao, W., Liu, R., Jiang, L., Yu, S., Li, C., Liu, H., Xu, L., Liu, R., … Liu, G. (2022). Pathogenesis of sarcopenia and the relationship with fat mass: descriptive review. *Journal of Cachexia, Sarcopenia and Muscle*, *13*(2), 781–794. https://doi.org/10.1002/jcsm.12901
Moore, B. A., Bemben, D. A., Lein, D. H., Bemben, M. G., & Singh, H. (2020). Fat Mass is Negatively Associated with Muscle Strength and Jump Test Performance. *The Journal of Frailty & Aging*, *9*(4), 214–218. https://doi.org/10.14283/jfa.2020.11
Mustafa, D. G., Thanaya, S. A. P., Adiputra, L., & Saraswati, N. (2022). Hubungan antara kekuatan otot tungkai bawah dengan risiko jatuh pada lanjut usia di desa dauh puri klod, denpasar barat. *Majalah Ilmiah Fisioterapi Indonesia*, *10*(1), 22–27. https://doi.org/10.24843/MIFI.2022.v10.i01.p05x
Pang, X., Zhang, P., Chen, X., & Liu, W. (2023). Ubiquitin-proteasome pathway in skeletal muscle atrophy. *Frontiers in Physiology*, *14*, 1289537. https://doi.org/10.3389/fphys.2023.1289537
Pasdar, Y., Darbandi, M., Mirtaher, E., Rezaeian, S., Najafi, F., & Hamzeh, B. (2019). Associations between muscle strength with different measures of obesity and lipid profiles in men and women: results from RaNCD cohort study. *Clinical Nutrition Research*, *8*(2), 148. https://doi.org/10.7762/cnr.2019.8.2.148
Putri, S., Corniawati, I., & Imamah, I. N. (2023). Pengaruh Pendidikan Kesehatan Reproduksi Terhadap Pengetahuan dan Sikap Wanita Pra-Lansia Dalam Menghadapi Masa Menopause di Kelurahan Muara Komam. *Humantech: Jurnal Ilmiah Multidisiplin Indonesia*, *2*(4), 750–758.
Roh, E., & Choi, K. M. (2020). Health Consequences of Sarcopenic Obesity: A Narrative Review. *Frontiers in Endocrinology*, *11*. https://doi.org/10.3389/fendo.2020.00332
Saltiel, A. R. (2021). Insulin signaling in health and disease. *The Journal of Clinical Investigation*, *131*(1). https://doi.org/10.1172/JCI142241
Sancho-Muñoz, A., Guitart, M., Rodríguez, D. A., Gea, J., Martínez-Llorens, J., & Barreiro, E. (2021). Deficient muscle regeneration potential in sarcopenic COPD patients: Role of satellite cells. *Journal of Cellular Physiology*, *236*(4), 3083–3098. https://doi.org/10.1002/jcp.30073
Shou, J., Chen, P.-J., & Xiao, W.-H. (2020). Mechanism of increased risk of insulin resistance in aging skeletal muscle. *Diabetology & Metabolic Syndrome*, *12*(1), 14. https://doi.org/10.1186/s13098-020-0523-x
Straight, C. R., Toth, M. J., & Miller, M. S. (2021). Current perspectives on obesity and skeletal muscle contractile function in older adults. *Journal of Applied Physiology*, *130*(1), 10–16.

https://doi.org/10.1152/japplphysiol.00739.2020
Sukarno, D. A. (2021). Pengaruh Latihan Fisik terhadap Perbaikan Resistensi Insulin. *Keluwih: Jurnal Kesehatan Dan Kedokteran*, *2*(2), 110–114. https://doi.org/10.24123/kesdok.V2i2.4033
Venturelli, M., Reggiani, C., Richardson, R. S., & Schena, F. (2018). Skeletal muscle function in the oldest-old: the role of intrinsic and extrinsic factors. *Exercise and Sport Sciences Reviews*, *46*(3), 188–194. https://doi.org/10.1249/JES.0000000000000155
Wiranata, Y., & Inayah, I. (2020). Perbandingan Penghitungan Massa Tubuh Dengan Menggunakan Metode Indeks Massa Tubuh (IMT) dan Bioelectrical Impedance Analysis (BIA). *Jurnal Manajemen Kesehatan Yayasan RS.Dr. Soetomo*, *6*(1), 43. https://doi.org/10.29241/jmk.v6i1.280
Zanker, J., Sim, M., Anderson, K., Balogun, S., Brennan-Olsen, S. L., Dent, E., Duque, G., Girgis, C. M., Grossmann, M., & Hayes, A. (2023). Consensus guidelines for sarcopenia prevention, diagnosis and management in Australia and New Zealand. *Journal of Cachexia, Sarcopenia and Muscle*, *14*(1), 142–156. https://doi.org/10.1002/jcsm.13115