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REVIEW ARTICLE
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IMAGING BIOMARKERS OF SARCOPENIA IN METABOLIC DISEASES: TOWARD PRECISION DIAGNOSIS AND RISK STRATIFICATION

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Abstract

Introduction: Sarcopenia, characterized by loss of skeletal muscle mass and quality, is increasingly recognized as a key contributor to metabolic diseases such as metabolic syndrome, type 2 diabetes mellitus, obesity, and NAFLD/MASLD. Conventional clinical assessments lack the ability to directly quantify muscle composition, whereas imaging modalities offer objective and reproducible biomarkers.

Aim and Objectives: This narrative review aimed to synthesize current evidence on quantitative imaging biomarkers of sarcopenia assessed using CT, MRI, DXA, and ultrasound in adults with metabolic diseases.

Methodology: A structured literature search was conducted across PubMed/MEDLINE, Embase, Scopus, and Web of Science to identify relevant original studies published between 2015 and 2025. Original studies involving adult populations with metabolic diseases and imaging-based assessments of muscle mass or quality were included. Data were qualitatively synthesized due to heterogeneity in study designs and sarcopenia definitions.

Results: Across imaging modalities, reduced muscle mass and increased myosteatosis were consistently associated with metabolic diseases. CT- and MRI-derived biomarkers revealed strong associations with metabolic syndrome, insulin resistance, NAFLD/MASLD progression, and type 2 diabetes. The prevalence of sarcopenia or adverse muscle composition ranged from approximately 14% to 36% depending on population and disease type.

Conclusion: Quantitative imaging biomarkers provide valuable insights into muscle quantity and quality that extend beyond traditional anthropometric measures. Incorporation of CT, MRI, DXA, and ultrasound into clinical and opportunistic screening can enhance early detection, precision diagnosis, and risk stratification of sarcopenia in metabolic diseases.
Standardization of imaging thresholds and longitudinal validation are needed to support broader clinical implementation.

Keywords: Sarcopenia, Metabolic syndrome, Myosteatosis.

Introduction

Sarcopenia, characterized by a progressive decline in skeletal muscle mass, strength, and quality, is increasingly recognized as a major determinant of adverse metabolic health outcomes. Traditionally considered an age-related condition, sarcopenia is now understood to be closely intertwined with metabolic disorders such as metabolic syndrome (MetS), type 2 diabetes mellitus (T2DM), non-alcoholic fatty liver disease (NAFLD)/metabolic dysfunction– associated steatotic liver disease (MASLD), and obesity. Emerging evidence indicates that metabolic abnormalities accelerate muscle degradation through mechanisms including insulin resistance, chronic low-grade inflammation, mitochondrial dysfunction, hormonal imbalance, and altered protein metabolism.

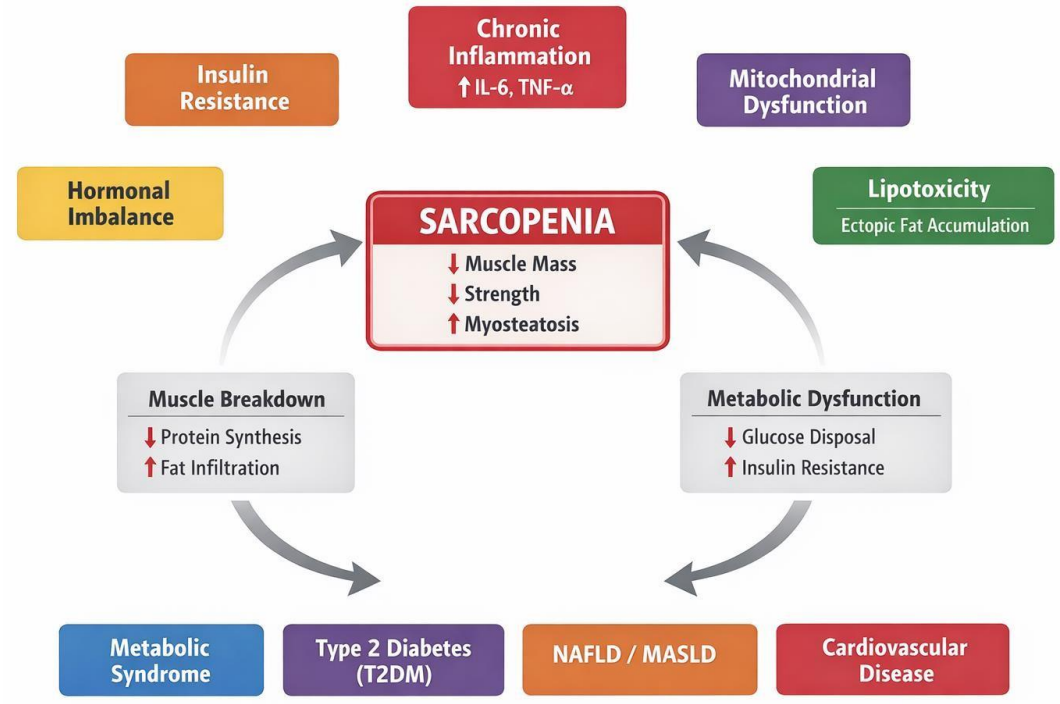

Figure 1 summarizes the complex bidirectional pathophysiological interplay between sarcopenia and metabolic disorders, highlighting shared mechanisms such as insulin resistance, inflammation, and ectopic fat deposition that collectively drive muscle wasting and metabolic deterioration.

Metabolic syndrome is characterized by a cluster of interrelated cardio metabolic risk factors—central obesity, dyslipidaemia, hypertension, and impaired glucose regulation—that collectively increase the risk of cardiovascular disease and type 2 diabetes. Importantly, sarcopenia and MetS share common pathophysiological pathways. Insulin resistance, a hallmark of MetS, directly impairs skeletal muscle glucose uptake and protein synthesis, promoting muscle wasting. Concurrently, inflammatory cytokines and ectopic lipid deposition exacerbate muscle catabolism and fat infiltration, leading to deterioration in muscle quality, a condition often termed myosteatosis. This bidirectional relationship has led to growing recognition of phenotypes such as sarcopenic obesity, which confers a particularly high cardio metabolic risk.

Accurate assessment of sarcopenia is therefore critical for early diagnosis, risk stratification, and targeted intervention in metabolic diseases. While clinical tools such as handgrip strength and gait speed assess functional impairment, they lack the ability to directly quantify muscle mass and composition. Imaging modalities have emerged as objective and reproducible tools for evaluating skeletal muscle quantity and quality. Dual-energy X-ray absorptiometry (DXA) provides widely used measurements of appendicular lean mass and skeletal muscle index, offering a standardized approach for population-level assessment. Computed tomography (CT), particularly at standardized anatomical levels such as the third lumbar vertebra (L3), enables precise measurement of muscle cross-sectional area and muscle attenuation, the latter serving as a surrogate marker of intramuscular fat infiltration. Magnetic resonance imaging (MRI) further advances muscle evaluation by allowing volumetric assessment and quantitative analysis of muscle fat fraction using techniques such as Dixon sequences and proton density fat fraction (PDFF). Ultrasound, a portable and radiation-free modality, has gained increasing attention for measuring muscle thickness and echo-intensity, reflecting muscle mass and quality at the bedside.

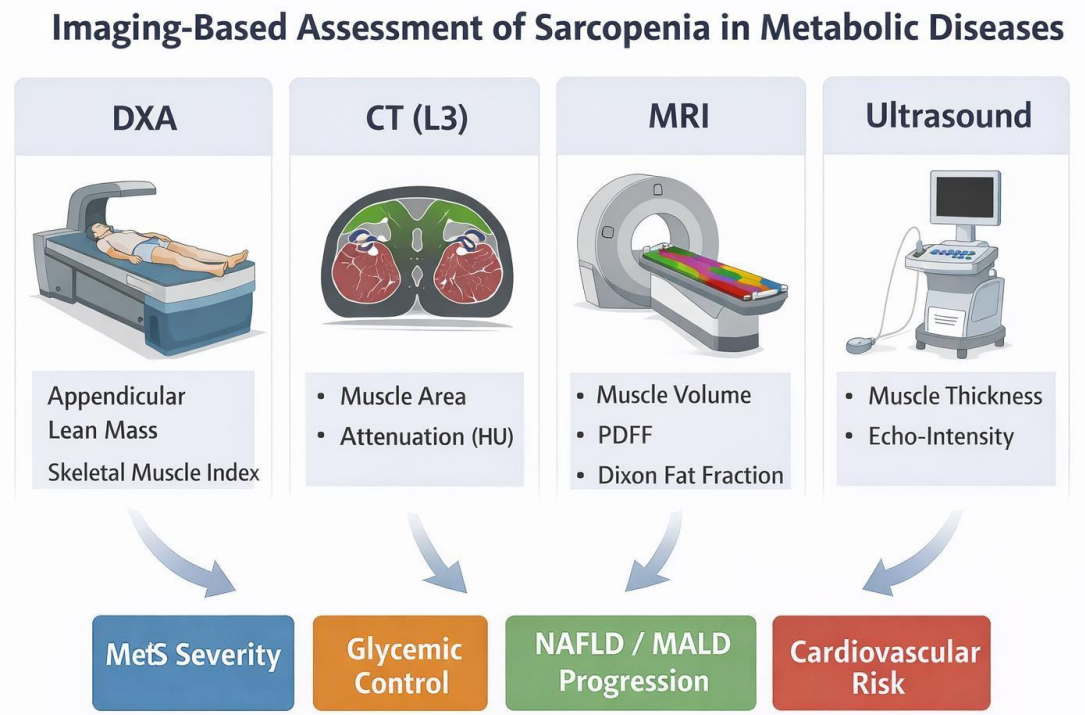

Figure 2 provides an overview of imaging-based techniques and quantitative biomarkers used for sarcopenia assessment in metabolic diseases, emphasizing the complementary roles of DXA, CT, MRI, and ultrasound in evaluating muscle quantity and quality

Recent studies have demonstrated that imaging-derived muscle biomarkers are strongly associated with the presence and severity of metabolic diseases. Reduced muscle mass and increased myosteatosis have been linked to higher prevalence of MetS components, poorer glycemic control, progression of NAFLD, and increased cardiovascular risk. Importantly, several imaging biomarkers have shown predictive value beyond traditional anthropometric indices such as body mass index (BMI), highlighting the limitations of BMI in capturing body composition abnormalities. Moreover, opportunistic imaging—using CT or MRI scans acquired for other clinical indications—offers a unique opportunity for large-scale screening of sarcopenia in metabolic populations without additional radiation exposure or cost.

Despite growing interest, substantial heterogeneity exists across studies regarding sarcopenia definitions, imaging thresholds, and metabolic disease classifications. Furthermore, the relative utility of different imaging modalities and quantitative biomarkers in specific metabolic conditions remains incompletely understood. A comprehensive synthesis of recent evidence is therefore essential to

clarify the role of imaging biomarkers in precision diagnosis and risk stratification of sarcopenia in metabolic diseases.

Accordingly, this narrative review aims to evaluate recent literature (2015–2025) on quantitative imaging biomarkers of sarcopenia assessed using CT, MRI, DXA, and ultrasound in adult populations with metabolic syndrome and related metabolic disorders. By analyzing prevalence estimates, quantitative imaging parameters, and their reported predictive value, this review seeks to highlight the evolving role of imaging in advancing precision medicine approaches for metabolic disease management.

Aim and Objectives

Aim: To synthesize recent evidence on quantitative imaging biomarkers of sarcopenia assessed using CT, MRI, DXA, and ultrasound in adults with metabolic diseases, and to clarify their role in precision diagnosis and cardiometabolic risk stratification.

Objectives:

- To review imaging-based measures of skeletal muscle mass and muscle quality in metabolic syndrome and related metabolic disorders.
- To compare the utility of different imaging modalities (CT, MRI, DXA, ultrasound) in detecting sarcopenia and myosteatosis.
- To summarize the prevalence of sarcopenia and adverse muscle composition in metabolic diseases.
- To evaluate associations between imaging biomarkers of sarcopenia and metabolic outcomes such as insulin resistance, NAFLD/MASLD, and type 2 diabetes.
- To highlight the potential of imaging biomarkers for early detection and precision medicine approaches in metabolic disease management.

Literature Search Strategy and Study Selection

This narrative review was informed by a structured literature search designed to identify relevant studies on imaging-based assessment of sarcopenia in metabolic diseases.

Eligibility Criteria

The PICOS framework was used as a guiding structure to define the scope of literature included in this narrative review. Included studies met the following criteria:

- **Population:** Adults aged ≥18 years diagnosed with metabolic syndrome or related metabolic diseases, including type 2 diabetes mellitus (T2DM), non-alcoholic fatty liver disease (NAFLD/MASLD), and obesity.
- **Exclusion:** Pediatric populations, animal studies, and pregnant individuals were not considered in this review.
- **Intervention/Exposure:** Quantitative assessment of skeletal muscle mass or muscle quality using imaging modalities.
- **Imaging Modalities and Metrics:** DXA (appendicular lean mass, skeletal muscle index), CT (muscle cross-sectional area, muscle attenuation in Hounsfield units), MRI (muscle volume, intramuscular fat fraction), and ultrasound (muscle thickness, echo- intensity).
- **Outcomes:** Quantitative imaging biomarkers of sarcopenia, including skeletal muscle index, muscle volume/area, muscle attenuation, fat fraction, thickness, and echo- intensity. Studies reporting the prevalence of sarcopenia or adverse muscle composition, and associations with metabolic outcomes, were included.
- **Study Design:** Original research studies (cross-sectional, cohort, case–control) were included. Reviews, meta-analyses, editorials, case reports, conference abstracts, and letters were excluded.
- **Timeframe and Language:** Studies published in English between January 2015 and December 2025 were included.

Literature Search Strategy

A structured literature search was conducted across PubMed/MEDLINE, Embase, Scopus, and Web of Science to identify original studies published between January 2015 and December 2025 that evaluated imaging-based biomarkers of sarcopenia in adults with metabolic diseases. Search terms included combinations of "sarcopenia," "muscle mass," " myosteatosis," "metabolic syndrome," "type 2 diabetes," "NAFLD/MASLD," and imaging
modalities such as CT, MRI, DXA, and ultrasound. Additional studies were identified through manual screening of reference lists. Articles were selected based on relevance to the review objectives and the quality of reported imaging methodologies.

Study Selection Process
Relevant articles were identified through database searches and reference list screening. Studies were selected based on relevance to the review objectives and the inclusion criteria outlined above.

Data Synthesis
Findings were synthesized narratively, with emphasis on imaging modality, muscle biomarkers, and metabolic disease phenotype.

Evidence Summary
Sarcopenia in Metabolic Syndrome (MetS): Lower muscle quantity and quality often accompany MetS. In a large opportunistic screening of ~7,785 asymptomatic adults, fully- automated abdominal CT measures identified 9.5% with MetS (IDF criteria). CT-derived biomarkers strongly discriminated MetS: at L1 level, visceral fat area had AUC=0.909 (OR≈27.2) and at L3, SMI had AUC=0.776 (OR≈5.8). Thus low CT-derived SMI was associated with ~6-fold higher odds of MetS.
Ultrasound also reveals sarcopenic features in MetS. In obese adults, **Yoshida et al. (2015)** showed that low abdominal muscle thickness (MTH by US) predicted MetS risk better than DXA SMI. Sarcopenic obesity defined by low US-MTH was linked to more MetS components (e.g. higher HbA1c) than general obesity (by DXA).
Among elderly patients, results are mixed. **Ileri et al. (2025)** evaluated 161 adults ≥65 with/without MetS via leg/abdominal US and DXA. They found no significant difference in sarcopenia prevalence (similar rates, p≈0.09) between MetS and non-MetS, but muscle thickness (gastrocnemius, transversus abdominis) was actually greater in MetS patients ($p<0.01$). (Osteoporosis was less common in MetS, 18% vs 41%, p=0.002)
Meta-analyses underscore the association. One systematic review (middle-aged/older, non- obese) found ~36% of sarcopenic adults had MetS, and sarcopenia doubled MetS odds (OR≈2.0). Another reported sarcopenia associated with ~2-fold higher metabolic syndrome risk. Overall, imaging evidence shows that lower muscle mass or quality correlates strongly with MetS prevalence.

Sarcopenia in Type 2 Diabetes (T2DM): T2DM accelerates muscle loss and fat infiltration. In a chest-CT study of 1,225 adults (mean age ~80), **Zhang et al. (2025)** found that older diabetics (n=255) had similar muscle area but significantly lower muscle density (more fat infiltration) than non-diabetics. In regression, lower muscle attenuation independently predicted T2DM (OR≈0.943 per HU, p=0.002). Thus CT-based muscle quality (myosteatosis), not quantity, distinguished T2DM in elders.
Echo-intensity on US provides a non-ionizing correlate. **Soliman et al. (2025)** performed limb US (deltoid, thigh) in obese vs lean adults and correlated muscle echo-intensity (MEI) with insulin resistance. Increased MEI strongly correlated with insulin resistance (Matsuda Index) and identified early insulin resistance (AUROC≈0.872, sensitivity ~94%, specificity 80%). MEI was independent of BMI and detected metabolic risk before changes in HbA1c/glucose. This highlights US echo-intensity as a promising early biomarker of dysglycemia.
Sarcopenia in Nonalcoholic Fatty Liver Disease (NAFLD/MASLD): Coexistence of fatty liver and sarcopenia is common. MRI studies reveal that classic sarcopenia (low mass+weakness) is relatively rare in NAFLD, but "adverse muscle composition" (low volume

+ high muscle fat) is much more common. In **UK Biobank** whole-body MRI (n≈5,326, age 40–69), 22.6% had NAFLD (PDFF>5%). Only 1.6% of NAFLD subjects met sarcopenia criteria vs 3.4% of controls; however 14.0% of NAFLD patients had adverse muscle composition (vs 9.4% of non-NAFLD). Adverse composition in NAFLD was linked to poorer function and cardiometabolic comorbidities.

In Korea, **Cho et al. (2021)** studied 320 adults (57% NAFLD by US) with DXA and liver MRI- PDFF. They found low weight-adjusted appendicular mass was strongly associated with NAFLD (OR≈3.0, 95%CI 1.70–5.31) and with fibrosis across DXA and MRI metrics.

A meta-analysis (MASLD populations) found pooled sarcopenia prevalence ≈23.5%, higher in Asians. Sarcopenia doubled odds of MASLD (adjusted OR≈2.08) and was linked to higher mortality.

Selected representative imaging studies (2015–2025) evaluating sarcopenia biomarkers in metabolic diseases: In MetS, CT-derived SMI and visceral fat show 5–27× odds of MetS; US-measured abdominal muscle thickness is a strong MetS risk predictor. In T2DM, chest CT showed each HU drop in muscle density had OR≈0.94 for diabetes (i.e. lower density strongly associated). In NAFLD, MRI shows ~14–23% have combined low muscle/high fat, and DXA shows ~23% with sarcopenia. Ultrasound echo-intensity robustly flags insulin resistance (AUROC ~0.87) independent of glycemic status.

Table 1 summarizes recent quantitative imaging studies (2015–2025) in metabolic diseases.

Year	Study (Ref)	Modality	Biomarker(s)	Population / Condition	Prevalence / %	Key Findings
2015	Yoshida *et al.*	Ultrasound vs DXA	Abdominal muscle thickness (US MTH) vs SMI (DXA)	Obese adults (no DM)	–	Low abdominal MTH predicted MetS risk better than DXA SMI (AUC≈0.807); "sarcopenic obesity" by US had more MetS factors.
2021	Pickhardt *et al.*	CT (abdominal)	L1 fat area; L3 SMI; liver attenuation	Asymptomatic adults	9.5% had MetS	Automated CT biomarkers identified MetS: L1 visceral fat AUC=0.909 (OR≈27.2), L3 SMI AUC=0.776 (OR≈5.8), liver fat AUC=0.738 (OR≈5.1). Multimodal CT improved MetS screening.
2021	Linge *et al.*	MRI (whole-body)	Muscle volume; muscle fat fraction (PDFF)	UK Biobank (age 40–69)	22.6% NAFLD; AMC 14.0% in NAFLD	NAFLD present in 22.6%. Classic sarcopenia rare (1.6% in NAFLD vs 3.4% controls), but 14.0% of NAFLD had adverse muscle composition (low volume/high fat) vs 9.4%

						controls. AMC in NAFLD linked to worse function and metabolic comorbidities.
2021	Cho *et al.*	DXA + MRI (liver PDFF)	Appendicular SMI (DXA)	Korean adults (57% NAFLD by US)	57.2% had NAFLD	Low weight-adjusted ASM strongly associated with NAFLD (e.g. OR≈3.00 for US-diagnosed NAFLD). Similar association for MRI-PDFF NAFLD and fibrosis.
2024	Li *et al.*	Meta-analysis	Various sarcopenia criteria	MASLD (NAFLD) patients	~23.5% pooled sarcopenia	Systematic review: pooled sarcopenia prevalence ≈23.5% (higher in Asians); sarcopenia doubled odds of MASLD (adjusted OR≈2.08) and predicted higher mortality.
2025	Zhang *et al.*	CT (chest, T4)	SMI; muscle attenuation (density)	Older adults (≥65) with/without T2DM	–	Diabetics vs non-diabetics: similar muscle area, but significantly lower muscle density (β≈–0.069 HU, p=0.002). Lower muscle density independently predicted T2DM (OR≈0.943 per HU; p=0.002) (i.e. lower quality).
2025	Ileri *et al.*	Ultrasound (leg/abd) + DXA	Muscle thickness (gastroc, transv. abdom.)	Elderly patients (≥65) with/without MetS	Sarcopenia ≈27% in each group	No significant difference in sarcopenia prevalence (p≈0.09). Muscles (gastroc med., transversus abdom.) were thicker in MetS (p<0.01), suggesting preserved muscle mass despite obesity. Osteoporosis was lower in MetS (18% vs 41%, p=0.002).
2025	Soliman *et al.*	Ultrasound (deltoid, thigh)	Muscle echo-intensity (MEI, grayscale)	Adults (obese vs lean, no diabetes)	–	US echo-intensity (myosteatosis marker) strongly correlated with insulin resistance. MEI z-scores identified IR with AUROC≈0.872 (sensitivity 94.4%, specificity 80%), independent of BMI and prior to changes in HbA1c/glucose.

2025	Yousief *et al.*	CT (abdominal)	Visceral fat volume; thigh muscle area/strength	Women (prediabetes vs new T2DM)	65.9% had MetS	In 44 women (34% T2D, 66% prediabetes; 65.9% MetS), VAT volume correlated with fatty liver and insulin resistance, but did not differ by MetS status. Muscle mass (CT area) was similar regardless of MetS, though muscle strength was lower in MetS.

Discussion

Across modalities, imaging biomarkers reveal that sarcopenia (low muscle mass) and myosteatosis (high muscle fat) are common in metabolic disease. CT and MRI identify tissue- specific changes missed by BMI: e.g. CT-derived low SMI multiplies MetS risk by ~5–27×, whereas ultrasound echo-intensity detects insulin resistance before lab abnormalities. DXA remains useful for lean mass, but CT/MRI provide richer detail (e.g. fat infiltration). Notably, many imaging studies find a high prevalence of sarcopenia or adverse muscle composition in metabolic conditions (on the order of 14–36%). For example, roughly one-quarter of MASLD patients have sarcopenia, and over a third of sarcopenic older adults have MetS. These biomarkers also have predictive value: e.g. each 1-unit decrease in CT muscle attenuation (HU) corresponds to ~5.7% higher odds of diabetes (OR≈0.943 per HU), and ultrasound echo- intensity showed AUROC ~0.87 for insulin resistance. In general, "sarcopenic obesity" phenotypes (low muscle with high fat) confer especially high risk.

Conclusions

Recent studies (2015–2025) demonstrate that quantitative imaging biomarkers – muscle area/volume, attenuation/fat fraction, thickness and echogenicity – provide objective metrics of sarcopenia in metabolic diseases. These biomarkers have distinct prevalence and risk across conditions (~14–36% in MetS/NAFLD) and improve risk stratification beyond traditional measures. Incorporating imaging (CT, MRI, DXA, US) into "precision sarcopenia" diagnosis enables earlier detection of high-risk phenotypes (e.g. sarcopenic obesity, adverse muscle composition) and may help predict cardiometabolic outcomes. Future work should standardize cutoffs for these biomarkers and validate their prognostic value in longitudinal cohorts.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Note: Any change in correspondence address should be notified to the editorial office.

References

1. Cho, K. K., Park, H. K., Jun, S., Woo, J., Park, Y. R., Kim, H.-Y., … Choi, S. H. (2021). Association between low muscle mass and non-alcoholic fatty liver disease diagnosed using

ultrasonography, MRI-derived proton density fat fraction, and comprehensive NAFLD score in Korea. Journal of Preventive Medicine and Public Health, 54(2), 121– 129. https://doi.org/10.3961/jpmph.21.387

2. Gao, T., Zhong, F., Cai, J., Sun, Y., Ma, A., & Sun, Y. (2018). Association between sarcopenia and metabolic syndrome in middle-aged and older non-obese adults: a systematic review and meta-analysis. International Journal ofEnvironmental Research and Public Health, 15(7), 1410. https://doi.org/10.3390/ijerph15071410
3. Ileri, S., Topal, N., Kılıc, H. F., Türkkan, E., & Sağir, M. (2025). Ultrasound evaluation of muscles in older patients with metabolic syndrome. Irish Journal of Medical Science. Advance online publication. https://doi.org/10.1007/s11845-024-03550-6
4. Li, X., He, J., Sun, Q., Yang, M., & Ma, X. (2024). The prevalence and effects of sarcopenia in patients with metabolic dysfunction-associated steatotic liver disease (MASLD): A systematic review and meta-analysis. Clinical Nutrition, 43(9), 2005– 2016. https://doi.org/10.1016/j.clnu.2024.07.006
5. Linge, J., Heymsfield, S. B., & Levine, J. A. (2020). Adverse muscle composition is linked to poor functional performance and metabolic comorbidities in non-alcoholic fatty liver disease: An imaging study of 10,000 UK Biobank participants. Journal of Hepatology, 73(3), 637–649. https://doi.org/10.1016/j.jhep.2020.03.017
6. Pickhardt, P. J., Graffy, P. M., Zea, R., Lee, S. J., Liu, J., Sandfort, V., & Summers, R.
7. M. (2021). Utilizing fully automated abdominal CT–based biomarkers for opportunistic screening for metabolic syndrome in adults without symptoms. AJR American Journal of Roentgenology, 216(1), 85–92. https://doi.org/10.2214/AJR.20.23049
8. Soliman, S. B., Leuteneker, J. E., Chugh, O. K., Zhang, T., Tuska, B., Rode, T., … Horowitz, J. F. (2025). Muscle ultrasound echo intensity detects insulin resistance before changes in HbA_1c or fasting glucose, independent of BMI: A novel tool for early risk stratification. Journal of Ultrasound in Medicine. Advance online publication. https://doi.org/10.1002/jum.70126
9. Wang, D. Y., Zhang, G. S., Yu, Y. N., Zhang, Z., Zhao, H., Wang, Y. H., & Liu, S. C. (2024). Imaging of sarcopenia in type 2 diabetes mellitus. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 17, 727–742. https://doi.org/10.2147/DMSO.S389773
10. Yoshida, D., Okamoto, N., & Yokoi, T. (2015). Ultrasound-derived abdominal muscle thickness better detects metabolic syndrome risk in obese patients than skeletal muscle index measured by DXA. PLOS ONE, 10(7), e0143858. https://doi.org/10.1371/journal.pone.0143858
11. Yousief, E., Mohamed, M. A., Khozam, M., Ayeldeen, G., & Elghobashy, M. H. (2025). Cardiometabolic risks, visceral adiposity, and sarcopenia in prediabetic and diabetic women: Insights from CT imaging. Egyptian Journal of Internal Medicine, 37, Article 182. Advance online publication. https://doi.org/10.1186/s43162-025-00489-8
12. Addison, O., Marcus, R. L., LaStayo, P. C., & Ryan, A. S. (2014).
13. Intermuscular fat: A review of the consequences and causes. *International Journal of Endocrinology*, 2014, 309570. https://doi.org/10.1155/2014/309570
14. Borga, M., West, J., Bell, J. D., Harvey, N. C., Romu, T., Heymsfield, S. B., & Dahlqvist Leinhard, O. (2018).
15. Advanced body composition assessment: From body mass index to body composition profiling. *Journal of Investigative Medicine*, 66(5), 887–895. https://doi.org/10.1136/jim-2018-000722
16. Chung, G. E., Kim, M. J., Yim, J. Y., Kim, J. S., Yoon, J. W., & Lim, S. H. (2018). Sarcopenia is independently associated with nonalcoholic fatty liver disease in Korean adults. *Hepatology*, 68(3), 827–836. https://doi.org/10.1002/hep.29895
17. Derstine, B. A., Holcombe, S. A., Ross, B. E., Wang, N. C., Su, G. L., & Wang, S. C. (2018). Skeletal muscle cutoff values for sarcopenia diagnosis using CT imaging. *American Journal of Roentgenology*, 211(2), W1–W7. https://doi.org/10.2214/AJR.18.19825
18. Hamdy, O., Porramatikul, S., & Al-Ozairi, E. (2006).
19. Metabolic obesity: The paradox between visceral and subcutaneous fat. *Current Diabetes Reviews*, 2(4), 367–373.

20. Kim, G., Lee, S. E., Lee, Y. B., Jun, J. E., Ahn, J., Bae, J. C., … Kim, J. H. (2019).
21. Relationship between relative skeletal muscle mass and nonalcoholic fatty liver disease: A 7-year longitudinal study. *Hepatology*, 70(3), 813–825. https://doi.org/10.1002/hep.30515
22. Lee, D. H., Keum, N., Hu, F. B., Orav, E. J., Rimm, E. B., Willett, W. C., & Giovannucci, E. L. (2018). Predicted lean body mass, fat mass, and all-cause and cause-specific mortality in men. *Journal of Clinical Endocrinology & Metabolism*, 103(11), 4116–4126. https://doi.org/10.1210/jc.2018-00500
23. Maltais, M. L., Desroches, J., Dionne, I. J. (2019).
24. Changes in muscle mass and strength after menopause. *Journal of Musculoskeletal & Neuronal Interactions*, 19(3), 329–339.
25. Nakanishi, N., Okamura, T., Tamura, T., Hashimoto, Y., Hamaguchi, M., Obora, A., Fukui, M. (2020).Sarcopenia is associated with insulin resistance and NAFLD in Japanese adults. *Journal of Gastroenterology*, 55(11), 1150–1160. https://doi.org/10.1007/s00535-020-01693-6
26. Reinders, I., Murphy, R. A., Brouwer, I. A., Visser, M., Launer, L. J., Siggeirsdottir, K., Harris, T. B. (2015). Muscle quality and myosteatosis: Novel associations with mortality risk. *American Journal of Epidemiology*, 183(1), 53–60. https://doi.org/10.1093/aje/kwv153
27. Shen, W., Punyanitya, M., Wang, Z., Gallagher, D., St-Onge, M. P., Albu, J., … Heymsfield, S. B. (2018). Total body skeletal muscle and adipose tissue volumes: Estimation from a single abdominal cross-sectional image. *Journal of Applied Physiology*, 97(6), 2333–2338. https://doi.org/10.1152/japplphysiol.00744.2004
28. Thompson, B. J. (2019). Skeletal muscle ultrasound: Image-based assessment of muscle mass and quality. *Journal of the American College of Nutrition*, 38(3), 167– 176. https://doi.org/10.1080/07315724.2018.1486336
29. van der Werf, A., Langius, J. A. E., de van der Schueren, M. A. E., Nurmohamed, S. A., & Wierdsma, N. J. (2018). Percentiles for skeletal muscle index, area, and attenuation on CT. *European Journal of Clinical Nutrition*, 72, 288–296. https://doi.org/10.1038/s41430-017-0028-4
30. Zhang, X., Xie, X., Dou, Q., Liu, C., Zhang, W., Yang, Y., Chen, K. (2020). Association of sarcopenic obesity with metabolic syndrome. *Diabetes, Metabolic Syndrome and Obesity*, 13, 381–388. https://doi.org/10.2147/DMSO.S238190

List of Abbreviations

- **AMC** – Adverse Muscle Composition
- **ASM** – Appendicular Skeletal Muscle
- **AUC** – Area Under the Curve
- **BMI** – Body Mass Index
- **CSA** – Cross-Sectional Area
- **CT** – Computed Tomography
- **DXA** – Dual-Energy X-ray Absorptiometry
- **HbA1c** – Glycated Hemoglobin
- **HU** – Hounsfield Units
- **IR** – Insulin Resistance
- **MASLD** – Metabolic Dysfunction–Associated Steatotic Liver Disease
- **MEI** – Muscle Echo-Intensity
- **MetS** – Metabolic Syndrome
- **MRI** – Magnetic Resonance Imaging
- **MTH** – Muscle Thickness
- **NAFLD** – Non-Alcoholic Fatty Liver Disease
- **NOS** – Newcastle–Ottawa Scale
- **OR** – Odds Ratio
- **PDFF** – Proton Density Fat Fraction
- **PICOS** – Population, Intervention, Comparison, Outcomes, Study design

- **T2DM** – Type 2 Diabetes Mellitus
- **US** – Ultrasound
- **VAT** – Visceral Adipose Tissue