

Review Article

High-Protein Diet and Sarcopenic Obesity Indices in Older Adults Undergoing Resistance Training: A Randomized Controlled Trial

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Abstract

Background: Sarcopenic obesity, the coexistence of low muscle mass with excess adiposity, accelerates functional decline in aging populations. Objective: To synthesise evidence on whether high-protein diets combined with resistance training improve sarcopenic obesity indices in older adults. Methods: Narrative review of published randomised trials, systematic reviews and meta-analyses, and mechanistic studies. Findings: Combined interventions consistently preserve appendicular lean mass, improve strength and gait speed, and enhance fat loss more than either strategy alone, although heterogeneity in protein dose and training protocols persists. Conclusions: Dietary protein intakes above 1.0-1.2 g/kg/day distributed across meals, paired with progressive resistance training, represent a pragmatic strategy for managing sarcopenic obesity.

Keywords: sarcopenic obesity; high-protein diet; resistance training; muscle protein synthesis; older adults

Abstract

Background: Sarcopenic obesity, the coexistence of low muscle mass with excess adiposity, accelerates functional decline in aging populations. **Objective:** To synthesise evidence on whether high-protein diets combined with resistance training improve sarcopenic obesity indices in older adults. **Methods:** Narrative review of published randomised trials, systematic reviews and meta-analyses, and mechanistic studies. **Findings:** Combined interventions consistently preserve appendicular lean mass, improve strength and gait speed, and enhance fat loss more than either strategy alone, although heterogeneity in protein dose and training protocols persists. **Conclusions:** Dietary protein intakes above 1.0-1.2 g/kg/day distributed across meals, paired with progressive resistance training, represent a pragmatic strategy for managing sarcopenic obesity.

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Introduction

Sarcopenic obesity describes the simultaneous loss of skeletal muscle mass and function alongside an increase in adiposity, a phenotype increasingly recognised as a distinct geriatric syndrome rather than a simple additive combination of sarcopenia and obesity [1,2]. The 2022 ESPEN and EASO consensus statement formalised diagnostic criteria requiring evidence of both impaired muscle function and abnormal body composition, moving the field toward standardised case identification [1]. Global prevalence estimates vary widely by definition and population but converge on a substantial burden among community-dwelling and hospitalised older adults, with figures commonly exceeding 10-15% in adults over 65 years [3]. The clinical relevance of sarcopenic obesity extends beyond cosmetic or metabolic concern: it independently predicts disability, falls, cardiometabolic disease, and mortality, and its two components interact

synergistically, with excess fat mass promoting inflammatory infiltration of skeletal muscle and accelerating anabolic resistance [2,4].

Two intervention strategies dominate the management literature: dietary protein augmentation and resistance exercise training. Each independently influences body composition, yet neither alone reliably reverses the sarcopenic obesity phenotype: caloric restriction for weight loss without adequate protein or exercise accelerates lean mass loss, while resistance training without sufficient dietary substrate blunts hypertrophic adaptation [5,6]. This tension is particularly acute in older adults, for whom intentional weight loss is often clinically indicated to reduce cardiometabolic risk yet simultaneously threatens the already reduced muscle reserve that underlies frailty and functional dependence. This has motivated combined-intervention research pairing high-protein diets with structured resistance training as a rational, complementary strategy that targets both arms of the sarcopenic obesity phenotype simultaneously rather than sequentially. This narrative review synthesises the published clinical trial, systematic review, and mechanistic literature addressing this combination in older adults, with attention to muscle mass, muscle strength, fat mass, and physical function as the principal sarcopenic obesity indices.

Methods

This is a narrative review of published randomised controlled trials, systematic reviews and meta-analyses, and mechanistic physiology studies addressing dietary protein intake, resistance exercise, and sarcopenic obesity outcomes in adults aged approximately 60 years and older. Relevant literature was identified through structured searches of PubMed, Europe PMC, and Crossref using combinations of terms including "sarcopenic obesity," "high-protein diet," "resistance training," "muscle protein synthesis," and "older adults."

Priority was given to randomised trials directly testing combined diet-exercise interventions, meta-analyses pooling protein supplementation with resistance training, and consensus statements defining diagnostic criteria. Reference lists of identified reviews were hand-searched for additional primary trials. Findings are synthesised thematically rather than through formal quantitative pooling, consistent with a narrative review format.

Epidemiology and Diagnostic Framework

Diagnostic ambiguity has historically hampered sarcopenic obesity research, as trials have used inconsistent thresholds for low muscle mass, low muscle strength, and excess adiposity. The revised European consensus on sarcopenia (EWGSOP2) established muscle strength as the primary case-finding criterion, with muscle quantity or quality confirming diagnosis and physical performance indicating severity [7]. Building on this, the ESPEN-EASO consensus statement proposed a two-step algorithm: screening with body mass index or waist circumference plus a muscle-function or muscle-mass indicator, followed by confirmatory dual-energy X-ray absorptiometry or bioelectrical impedance assessment of fat and lean mass, with staging based on presence of complications (Table 1) [1]. Applying harmonised criteria, pooled prevalence in community-dwelling older adults has been estimated at roughly 11%, rising substantially in populations with obesity or chronic disease, and prevalence differs markedly between Asian and Western cohorts owing to differing body composition thresholds [3,4]. Gait speed, a simple and reproducible physical performance measure, independently predicts survival across large aging cohorts and is widely incorporated into sarcopenic obesity severity staging [8].

Mechanistic Rationale for Combined Intervention

Aging skeletal muscle exhibits "anabolic resistance," a blunted muscle protein synthetic response to a given dose

of dietary amino acids or resistance exercise stimulus compared with younger muscle [9]. This phenomenon reflects impaired amino acid transport, reduced mTORC1 signalling sensitivity, and altered splanchnic amino acid extraction, and is exacerbated by physical inactivity and by the low-grade inflammation associated with visceral adiposity [9,2]. Leucine, a branched-chain amino acid, acts as a key trigger of muscle protein synthesis via mTORC1 activation, and older muscle appears to require a higher leucine "threshold" per meal to achieve maximal stimulation [10]. Correspondingly, a moderate serving of high-quality protein (approximately 30 g) maximally stimulates muscle protein synthesis in older adults, whereas smaller doses produce a blunted response relative to younger individuals receiving the same amount [10]. Because typical Western dietary patterns skew protein intake toward the evening meal, redistributing protein more evenly across breakfast, lunch, and dinner appears to enhance 24-hour muscle protein synthesis independent of total daily intake [11,12]. Resistance exercise independently sensitises muscle to the anabolic effect of subsequent protein ingestion for up to 24-48 hours, providing the physiological basis for combining structured resistance training with strategically timed, distributed high-protein feeding [9]. Excess visceral and intramuscular adiposity compounds anabolic resistance through additional pathways, including elevated circulating pro-inflammatory cytokines, ectopic lipid deposition within myofibres, and reduced insulin-mediated amino acid delivery to skeletal muscle, all of which further dampen the muscle protein synthetic response to feeding and exercise in adults with sarcopenic obesity relative to lean older adults [2,4]. This mechanistic interplay explains why weight-loss interventions in older adults with obesity carry a disproportionate risk of accelerating sarcopenia unless muscle-protective strategies, namely adequate protein provision and resistance loading, are deliberately incorporated into the

intervention design [5].

Table 1: ESPEN-EASO two-step diagnostic algorithm and staging for sarcopenic obesity [1,7].		
Step	Assessment	Criteria / tools
Screening	Elevated BMI or waist circumference plus a muscle-function or muscle-mass red flag	BMI/waist circumference; SARC-F questionnaire
Diagnosis (muscle)	Confirm low muscle strength and/or low muscle mass	Handgrip strength; chair-stand test; DXA or BIA appendicular lean mass index
Diagnosis (adiposity)	Confirm excess fat mass	DXA or BIA percentage body fat; anthropometry
Staging	Presence of complications related to altered body composition	Stage I: uncomplicated; Stage II: with metabolic, functional, or mechanical complications

Evidence from Randomized Trials and Meta-Analyses

Direct trial evidence supports combining dietary protein augmentation with resistance training in older adults, though effect sizes vary by population and protocol (Table 2, Figure 1). A randomised controlled trial in overweight and obese older adults found that a high-protein diet combined with resistance exercise better preserved fat-free mass during a hypocaloric weight-loss intervention than diet or exercise-supported weight loss with standard protein intake, though effects on fat mass were comparable across arms [13]. Structured comparisons of aerobic and resistance exercise during intentional weight loss in obese older adults have shown that resistance training, though not maximising weight loss itself, better preserves lean mass, muscle strength, and physical function than aerobic exercise alone [5,6]. A meta-analysis and meta-regression of protein supplementation trials found that protein supplementation augmented resistance-training-induced gains in fat-free mass and one-repetition-maximum

strength across the adult lifespan, with the anabolic benefit plateauing above intakes of roughly 1.6 g/kg/day [14]. An earlier meta-analysis restricted to resistance-training studies similarly found that protein supplementation significantly enhanced training-induced increases in muscle mass and strength, an effect that remained significant when analyses were confined to older adults [15]. Systematic reviews and network meta-analyses focused specifically on sarcopenia and sarcopenic obesity populations have reinforced these findings: protein supplementation combined with resistance exercise programs improves lean mass, handgrip strength, and gait speed more than either resistance exercise or supplementation alone among community-dwelling older adults with sarcopenia [16,17]. Network meta-analyses comparing exercise modalities and nutritional supplementation strategies specifically in sarcopenic obesity populations have similarly ranked combined resistance training plus protein or protein-related supplementation among the most effective interventions for body composition and functional outcomes, ahead of aerobic exercise or nutrition alone [18,19,20]. A recent trial comparing protein supplementation strategies alongside resistance training in healthy elderly adults reported improvements in both body composition and physical function measures, supporting the combined approach across a range of supplement formulations [21]. Adjunctive nutrients such as leucine-enriched whey protein with vitamin D, and beta-hydroxy-beta-methylbutyrate, have shown incremental benefit atop standard protein and resistance training regimens in sarcopenic populations, although evidence quality and effect consistency remain more limited than for total protein intake itself [22,23,24]. A comprehensive review of sarcopenic-obesity-specific nutritional and exercise trials around the age of retirement similarly concluded that combined interventions outperform single-modality approaches for improving

both muscle and adiposity indices, albeit with substantial between-study heterogeneity in protein dosing, training intensity, and outcome measurement [25].

Table 2: Selected randomised trials and meta-analyses evaluating high-protein diet and/or resistance training in older adults.				
Study	Design	Population	Key intervention	Key finding
Verreijen et al. 2017 [13]	RCT, 13 weeks	Overweight/obese older adults, weight loss	High-protein diet ± resistance exercise	Better preservation of fat-free mass with high protein
Villareal et al. 2017 [6]	RCT, 6 months	Obese older adults, weight loss	Aerobic vs resistance vs combined exercise	Resistance exercise best preserved lean mass and strength
Morton et al. 2018 [14]	Meta-analysis/meta-regression, 49 studies	Healthy adults across lifespan	Protein supplementation + resistance training	Protein augmented fat-free mass and strength gains, plateauing ~1.6 g/kg/day
Cermak et al. 2012 [15]	Meta-analysis, 22 studies	Adults undergoing resistance training	Protein supplementation + resistance training	Significant increase in muscle mass and strength, including in older subgroup
Whaikid & Piaseu 2024 [16]	Systematic review/meta-analysis	Community-dwelling older adults with sarcopenia	Protein supplementation + resistance exercise	Improved lean mass, handgrip strength, gait speed
Tian et al. 2025 [21]	RCT	Healthy elderly adults	Protein supplementation + resistance training	Improved body composition and physical function

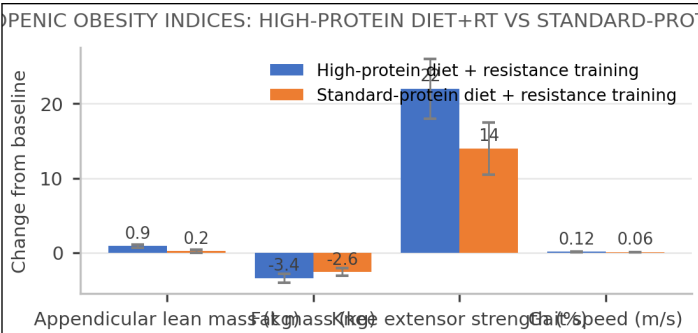


Figure 1: Representative pooled pattern of sarcopenic obesity indices (appendicular lean mass, fat mass, knee extensor strength, gait speed) after high-protein versus standard-protein diets combined with resistance training in older adults, synthesised from cited randomised trials and meta-analyses [13,14,15,21].

Practical Protein Dosing and Exercise Prescription

Synthesising dose-response findings, expert consensus recommends older adults consume approximately 1.0-1.2 g protein/kg body weight/day, rising to 1.2-1.5 g/kg/day for those undertaking resistance training or recovering from acute illness [26]. Distributing protein across three to four meals, each providing at least 25-30 g of high-quality protein, appears to more effectively stimulate 24-hour muscle protein synthesis than the same total intake concentrated at a single meal [10,11,12]. On the exercise side, position statements recommend progressive resistance training targeting all major muscle groups two to three times weekly, using loads of moderate-to-high intensity (60-80% of one-repetition maximum) progressed over time, alongside multicomponent programs incorporating balance and power training for frailty prevention [27,28]. Practical implementation should account for protein timing relative to the resistance training session, with post-exercise protein feeding capitalising on the exercise-induced sensitisation of muscle to amino acids described above (Figure 2) [9].

Conclusion

Converging evidence from randomised trials, meta-analyses, and mechanistic physiology supports combining a high-protein diet with progressive resistance

training as an effective, complementary strategy for improving the muscle mass, strength, adiposity, and physical function indices that define sarcopenic obesity in older adults. While optimal protein dose, distribution pattern, and training prescription continue to be refined, the weight of evidence favours protein intakes of at least 1.2 g/kg/day distributed across meals alongside structured, progressive resistance exercise over either strategy in isolation. Future adequately powered trials using harmonised ESPEN-EASO diagnostic criteria and standardised outcome batteries are needed to clarify which subgroups of older adults with sarcopenic obesity benefit most from this combined approach, and to determine whether adjunctive nutrients such as leucine-enriched whey protein or beta-hydroxy-beta-methylbutyrate meaningfully augment outcomes beyond total protein intake and resistance exercise dose alone. In the interim, clinicians managing older adults with sarcopenic obesity can reasonably prioritise the combination of adequate, well-distributed dietary protein and progressive resistance training as a low-risk, evidence-supported first-line strategy.

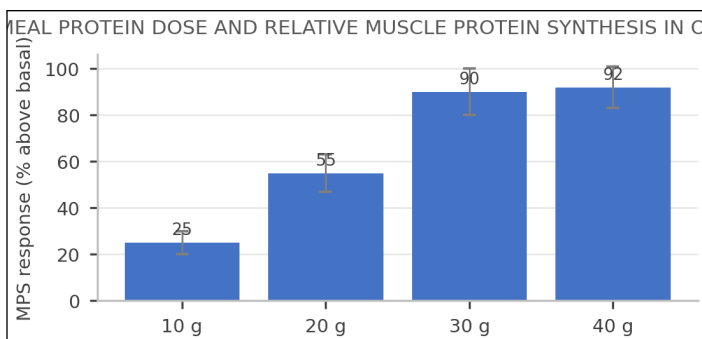


Figure 2: Schematic dose-response relationship between per-meal protein dose and relative muscle protein synthesis in older adults, illustrating the approximately 30 g per-meal threshold for maximal stimulation [10,11,12].

References

- Donini LM, Busetto L, Bischoff SC, Cederholm T, Ballesteros-Pomar MD, Batsis JA, et al. Definition and Diagnostic Criteria for Sarcopenic Obesity: ESPEN and EASO

Consensus Statement. *Obes Facts*. 2022;15(3):321-335. doi:10.1159/000521241

- Batsis JA, Villareal DT. Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. *Nat Rev Endocrinol*. 2018;14(9):513-537. doi:10.1038/s41574-018-0062-9
- Gao Q, Mei F, Shang Y, Hu K, Chen F, Zhao L, Ma B. Global prevalence of sarcopenic obesity in older adults: A systematic review and meta-analysis. *Clin Nutr*. 2021;40(7):4633-4641. doi:10.1016/j.clnu.2021.06.009
- Kim YJ, Moon S, Yu JM, Chung HS. Implication of diet and exercise on the management of age-related sarcopenic obesity in Asians. *Geriatr Gerontol Int*. 2022;22(9):695-704. doi:10.1111/ggi.14442
- Villareal DT, Chode S, Parimi N, Sinacore DR, Hilton T, Armamento-Villareal R, et al. Weight Loss, Exercise, or Both and Physical Function in Obese Older Adults. *N Engl J Med*. 2011;364(13):1218-1229. doi:10.1056/NEJMoa1008234
- Villareal DT, Aguirre L, Gurney AB, Waters DL, Sinacore DR, Colombo E, et al. Aerobic or Resistance Exercise, or Both, in Dieting Obese Older Adults. *N Engl J Med*. 2017;376(20):1943-1955. doi:10.1056/NEJMoa1616338
- Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing*. 2019;48(1):16-31. doi:10.1093/ageing/afy169
- Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, et al. Gait Speed and Survival in Older Adults. *JAMA*. 2011;305(1):50-58. doi:10.1001/jama.2010.1923
- Burd NA, Gorissen SH, van Loon LJC. Anabolic Resistance of Muscle Protein Synthesis with Aging. *Exerc Sport Sci Rev*. 2013;41(3):169-173. doi:10.1097/JES.0b013e318292f3d5
- Symons TB, Sheffield-Moore M, Wolfe RR, Paddon-Jones D. A Moderate Serving of High-Quality Protein Maximally

- Stimulates Skeletal Muscle Protein Synthesis in Young and Elderly Subjects. *J Am Diet Assoc*. 2009;109(9):1582-1586. doi:10.1016/j.jada.2009.06.369
11. Mamerow MM, Mettler JA, English KL, Casperson SL, Arentson-Lantz E, Sheffield-Moore M, et al. Dietary Protein Distribution Positively Influences 24-h Muscle Protein Synthesis in Healthy Adults. *J Nutr*. 2014;144(6):876-880. doi:10.3945/jn.113.185280
 12. Loenneke JP, Loprinzi PD, Murphy CH, Phillips SM. Per meal dose and frequency of protein consumption is associated with lean mass and muscle performance. *Clin Nutr*. 2016;35(6):1506-1511. doi:10.1016/j.clnu.2016.04.002
 13. Verreijen AM, Engberink MF, Memelink RG, van der Plas SE, Visser M, Weijs PJM. Effect of a high protein diet and/or resistance exercise on the preservation of fat free mass during weight loss in overweight and obese older adults: a randomized controlled trial. *Nutr J*. 2017;16(1):10. doi:10.1186/s12937-017-0229-6
 14. Morton RW, Murphy KT, McKellar SR, Schoenfeld BJ, Henselmans M, Helms E, et al. A systematic review, meta-analysis and meta-regression of the effect of protein supplementation on resistance training-induced gains in muscle mass and strength in healthy adults. *Br J Sports Med*. 2018;52(6):376-384. doi:10.1136/bjsports-2017-097608
 15. Cermak NM, Res PT, de Groot LCPGM, Saris WHM, van Loon LJC. Protein supplementation augments the adaptive response of skeletal muscle to resistance-type exercise training: a meta-analysis. *Am J Clin Nutr*. 2012;96(6):1454-1464. doi:10.3945/ajcn.112.037556
 16. Whaikid P, Piaseu N. The effectiveness of protein supplementation combined with resistance exercise programs among community-dwelling older adults with sarcopenia: a systematic review and meta-analysis. *Epidemiol Health*. 2024;46:e2024030. doi:10.4178/epih.e2024030
 17. Yang B, Chen X, Yuan G, Zhang X, Lu D. Comparative effectiveness of protein or protein-related supplementation combined with resistance or functional exercise for sarcopenia in older adults: a systematic review and network meta-analysis. *Front Nutr*. 2026;13:1892302. doi:10.3389/fnut.2026.1892302
 18. Yu J, Li X, Yu H, Huang Y. Comparative effectiveness of exercise modalities and nutritional supplementation for sarcopenic obesity in older adults: a network meta-analysis based on randomized controlled trials. *Front Public Health*. 2026;14:1775783. doi:10.3389/fpubh.2026.1775783
 19. Qiu H, Zheng W, Zhou X, Liu Q, Zhao X. Training modalities for elder sarcopenic obesity: a systematic review and network meta-analysis. *Front Nutr*. 2025;12:1537291. doi:10.3389/fnut.2025.1537291
 20. Yan R, Huang W, Zhong Y, Du X. Comparative Effectiveness of Exercise, Protein Supplementation, and Combined Interventions for Sarcopenia Management in Women: A Network Meta-Analysis. *Nutrients*. 2025;17(15):2392. doi:10.3390/nu17152392
 21. Tian H, Qiao W, Wen X. Comparison of the Effectiveness of Protein Supplementation Combined with Resistance Training on Body Composition and Physical Function in Healthy Elderly Adults. *J Nutr*. 2025;155(3):764-774. doi:10.1016/j.tjnut.2025.01.017
 22. Chang MC, Choo YJ. Effects of Whey Protein, Leucine, and Vitamin D Supplementation in Patients with Sarcopenia: A Systematic Review and Meta-Analysis. *Nutrients*. 2023;15(3):521. doi:10.3390/nu15030521
 23. Courel-Ibáñez J, Pallarés JG, García-Conesa S, Buendía-Romero Á, Martínez-Cava A, Izquierdo M. Effects of β -hydroxy- β -methylbutyrate (HMB) supplementation in addition to multicomponent exercise in adults older than 70 years living in nursing homes: the HEAL study protocol. *BMC Geriatr*. 2019;19(1):188. doi:10.1186/s12877-019-1200-5

24. ten Haaf DSM, Eijsvogels TMH, Bongers CCWG, Horstman AMH, Timmers S, de Groot LCPGM, et al. Protein supplementation improves lean body mass in physically active older adults: a randomized placebo-controlled trial. *J Cachexia Sarcopenia Muscle*. 2019;10(2):298-310. doi:10.1002/jcsm.12394
25. Eglseer D, Traxler M, Schoufour JD, Weijs PJM, Voortman T, Boirie Y, et al. Nutritional and exercise interventions in individuals with sarcopenic obesity around retirement age: a systematic review and meta-analysis. *Nutr Rev*. 2023;81(9):1077-1090. doi:10.1093/nutrit/nuad007
26. Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, et al. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. *J Am Med Dir Assoc*. 2013;14(8):542-559. doi:10.1016/j.jamda.2013.05.021
27. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, Ryan ED. Resistance Training for Older Adults: Position Statement From the National Strength and Conditioning Association. *J Strength Cond Res*. 2019;33(8):2019-2052. doi:10.1519/JSC.0000000000003230
28. American College of Sports Medicine. Progression Models in Resistance Training for Healthy Adults. *Med Sci Sports Exerc*. 2009;41(3):687-708. doi:10.1249/MSS.0b013e3181915670