Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences
Tome 79, No 6, 2026

MEDICINE
Clinical medicine

STUDY ON THE DYNAMIC ASSOCIATION BETWEEN OPTIMIZED PROTEIN INTAKE STRATEGIES AND METABOLIC INFLAMMATORY MARKERS IN OLDER ADULTS WITH SARCOPENIC OBESITY

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Received on February 28, 2026
Presented by D. Damianov, Member of BAS, on April 28, 2026

Abstract

The aim of this study was to investigate the effects of optimized protein intake strategies on metabolic inflammatory markers in elderly patients with sarcopenic obesity. This prospective study enrolled 384 older adults with sarcopenic obesity, randomized into a control group (standard dietary intervention) and an observation group (standard diet plus optimized protein intake). Outcomes were assessed at baseline, 6, and 12 months, measuring metabolic-inflammatory markers (IL-6, TNF-α, CRP, irisin), muscle-related indices (SMI, HGS), obesity-related indices (BMI), nutritional parameters, and Sarcopenia Quality of Life (SarQoL) scores. At 6 and 12 months, inflammatory markers decreased significantly in both groups, with lower levels in the observation group ($P < 0.05$). Muscle mass and function improved significantly, while fat accumulation decreased, with superior results in the observation group. Nutritional indices and SarQoL scores also increased significantly, showing greater improvements in the observation group compared to controls ($P < 0.05$). Optimized protein intake strategies significantly ameliorate metabolic inflammatory status, reduce inflammatory markers, enhance muscle mass and function, decrease fat accumulation, and improve nutritional status and quality of life, warranting clinical promotion.

Key words: sarcopenic obesity, optimized protein intake strategy, metabolic inflammatory markers, dynamic association

The authors received funding from the Capital Health Development General Practice and Community Health Research Special Project under Grant No. SF2025-1Y-001.

https://doi.org/10.7546/CRABS.2026.06.12

Introduction. Sarcopenia is a common skeletal muscle disorder in older adults, characterized by reduced skeletal muscle mass, decreased muscle strength, and impaired physical function. Obesity, in contrast, involves excessive fat accumulation and abnormal fat distribution. The co-occurrence of these conditions is referred to as sarcopenic obesity [1]. The global prevalence of sarcopenic obesity among older adults is approximately 11%, and it may exceed 20% in those older than 75 years [2]. According to statistics [3], the prevalence of sarcopenic obesity among older adults in China is about 23.1% in men and 18.3% in women, and it increases with age. Patients with sarcopenic obesity frequently exhibit metabolic inflammation, primarily manifested by markedly elevated levels of inflammatory biomarkers. Metabolic inflammation is a chronic, low-grade inflammatory state that is closely associated with a range of chronic diseases [4]. Evidence suggests that dietary protein intake, particularly protein from plant sources, is negatively correlated with serum inflammatory markers such as interleukin-6 (IL-6) and C-reactive protein (CRP) [5]. In addition, protein intake exhibits a complex relationship with changes in body composition. For example, one study reported that for every 5% increase in the proportion of total energy derived from protein, the risk of sarcopenia decreased by 38% [6]. However, evidence regarding the effects of protein intake on metabolic-inflammatory biomarkers in older adults with sarcopenia complicated by obesity remains limited, and findings from some studies have yet to be adequately validated. Therefore, this study aimed to further investigate the impact of an optimized protein intake strategy on metabolic-inflammatory markers in older adults with sarcopenic obesity, in order to provide evidence for precise nutritional interventions and improved prognostic outcomes in this population. The findings are reported as follows.

Materials and methods. ***Study population.*** In this prospective clinical study, a total of 384 patients with sarcopenic obesity who attended our hospital between January 2023 and January 2025 were consecutively enrolled. Using a random-number table, participants were allocated to a control group ($n = 192$) or an observation group ($n = 192$); the control group received standard dietary intervention, whereas the observation group received a protein-optimized intake strategy in addition to the standard diet. Baseline demographic and clinical characteristics were comparable between the two groups, with no statistically significant differences ($P > 0.05$). The study protocol was approved by the hospital ethics committee prior to initiation. Inclusion criteria were: 1) Age ≥ 60 years; 2) Diagnosis of sarcopenic obesity according to the criteria described in Sarcopenic Obesity and Metabolic Syndrome [8]; 3) Ability to comply with dietary intervention, scheduled follow-up visits, and blood and other biological sample collection; and 4) Provision of written informed consent by the patient and their legal guardian. Exclusion criteria were: 1) Presence of severe dysfunction of vital organs, including the heart, liver, or kidneys; 2) Presence of chronic inflammatory diseases, active infections, or active malignancies; 3) Participation in other pharmacological

or nutritional intervention studies within the preceding 3 months; 4) Presence of short bowel syndrome, malabsorption disorders, or other gastrointestinal diseases; and 5) Uncontrolled metabolic disorders, such as thyroid dysfunction or diabetes mellitus.

Intervention methods. *Control group: standard dietary intervention.* Total daily energy intake was determined based on each participant's basal metabolic rate and physical activity level. The dietary composition was as follows: 1) Carbohydrates: Whole grains, including whole wheat bread, brown rice, and oats, were selected as staple foods, with an intake of 100–150 g per meal. Daily vegetable intake was maintained at 500–600 g, with leafy green vegetables (e.g., spinach and bok choy) accounting for more than 50% to ensure adequate dietary fibre and vitamin intake. Fruit intake was limited to 200–300 g/day, preferentially selecting low-glycemic fruits such as apples and oranges. 2) Protein: Protein sources included lean meat (e.g., chicken breast, lean beef), fish (e.g., perch and cod), eggs, and legumes and their products (e.g., tofu and soy milk). Daily intake included 50–75 g of lean meat, 50–75 g of fish, 1–2 eggs, and 50–100 g of legumes or legume products. 3) Fat: Intake of saturated and trans fatty acids was strictly limited. Cooking oils rich in unsaturated fatty acids, such as olive oil and rapeseed oil, were recommended, with total daily oil intake restricted to 25–30 g. High-fat cooking methods (e.g., frying and deep-frying) were avoided, with preference given to steaming, boiling, stewing, and baking. Intake of nuts and seeds (e.g., almonds and walnuts) was limited to no more than 10–15 g/day.

Observation group: protein-optimized intake strategy. Total daily energy intake was maintained at 1800–2000 kcal/day, consistent with the control group, with macronutrient proportions adjusted to ensure isocaloric intake. The dietary protocol was: 1) Carbohydrates: Staple food intake was reduced to 80–120 g (dry weight) per meal. Vegetable intake followed the control protocol, while high-sugar fruits were limited to prevent glycemic fluctuations. 2) Protein: Intake was increased to 20–25% of total energy (approx. 90–125 g/day), emphasizing high-quality sources rich in essential amino acids. The regimen included daily supplementation with 20–30 g whey protein, 2–3 eggs (at least one whole), and increased lean meat and fish (75–100 g/day each). Protein was distributed evenly across meals to minimize potential renal burden. 3) Fat: Cooking oil was restricted to 20–25 g/day. High-fat meats were reduced, while unsaturated fatty acids from deep-sea fish ($\geq$ 2 servings/week) and olive oil were prioritized. Nut and seed intake was limited to $\leq$ 10 g/day. The intervention duration was 12 months for both groups.

Outcome measures. Outcome measures were assessed at baseline and at 6 and 12 months post-intervention.

Inflammatory biomarkers. Serum levels of IL-6 and CRP were measured using chemiluminescent immunoassays with an IMMULITE 1000 analyzer (Siemens Healthineers). TNF-α levels were determined using a time-resolved fluorescence

immunoassay with an HTRF® Human TNF-alpha Kit (Revvity). Irisin levels were quantified using a double-antibody sandwich enzyme-linked immunosorbent assay (ELISA) with a kit from Phoenix Pharmaceuticals.

Muscle-related indices. Body composition parameters, including percent body fat (PBF), visceral fat area (VFA), skeletal muscle mass index (SMI), and total lean mass (TLM), were assessed via bioelectrical impedance analysis using an InBody 770 device (Biospace, Korea). Handgrip strength (HGS) was measured using an electronic handgrip dynamometer (EH101; Hudong Xiangshan Weighing Apparatus Group, China).

Anthropometric measurements. Body mass index (BMI), mid-arm circumference (MAC), and maximum right calf circumference (CC) were recorded. Values for MAC and CC were calculated as the mean of three consecutive measurements.

Nutritional indicators. Serum albumin (ALB) was measured using the bromocresol green method, and transferrin (TRF) was determined by immunoturbidimetry using a BS-2000M analyzer (Mindray Bio-Medical Electronics, China). Hemoglobin (HGB) levels were assessed using a BM830 analyzer (Balingman Sunshine Technology, China) via the 546-nm colourimetric method. Prealbumin (PA) was measured by immunoturbidimetry on an AU5800 analyzer (Beckman Coulter, USA). Serum insulin-like growth factor-1 (IGF-1) was quantified using a chemiluminescent immunoassay with an iSYS IGF-1 analyzer (Immunodiagnostic Systems, UK).

Quality of life assessment. Quality of life was evaluated using the Sarcopenia Quality of Life (SarQoL) questionnaire, which covers seven domains including physical and mental health, mobility, and activities of daily living. Scores range from 0 to 100, with higher scores indicating a better quality of life and lower sarcopenia severity.

Statistical analysis. All statistical analyses were performed using SPSS version 25.0. Continuous variables are expressed as mean ± standard deviation (SD). Between-group comparisons were conducted using independent-samples t-tests, and within-group comparisons were performed using paired t-tests. Categorical variables are presented as number (percentage) and were compared using the χ^2 test. A two-sided P value < 0.05 was considered statistically significant.

Results. ***Comparison of inflammatory biomarker levels between the two groups.*** At 6 and 12 months after intervention, serum levels of IL-6, TNF-α, CRP, and irisin decreased significantly in both groups ($P < 0.05$). Moreover, levels of IL-6, TNF-α, CRP, and irisin were significantly lower in the observation group than in the control group at both follow-up time points ($P < 0.05$), as shown in Table 1.

Comparison of muscle-related indices between the two groups. At 6 and 12 months after intervention, levels of SMI, TLM, and HGS increased significantly, while levels of PBF and VFA decreased significantly in both groups ($P < 0.05$). Furthermore, at both follow-up time points, the observation group

Table 1

Comparison of serum IL-6, TNF-α, CRP, and irisin levels between the two groups (mean ± SD)

IL-6 and TNF-α

Group	n	IL-6 (pg/mL)			TNF-α (pg/mL)		
		Baseline	6 months	12 months	Baseline	6 months	12 months
Control	192	6.78 ± 1.25	$4.97 \pm 0.88^{*}$	$2.14 \pm 0.15^{*a}$	8.25 ± 1.29	$6.33 \pm 1.22^{*}$	$4.57 \pm 0.74^{*a}$
Observation	192	6.74 ± 1.31	$3.05 \pm 0.21^{*}$	$0.98 \pm 0.30^{*a}$	8.27 ± 1.16	$5.15 \pm 0.83^{*}$	$2.96 \pm 0.11^{*a}$
t value		0.306	29.406	47.922	0.160	11.081	29.819
P value		0.760	< 0.01	< 0.01	0.873	< 0.01	< 0.01

CRP and Irisin

Group	n	CRP (mg/L)			Irisin (ng/mL)		
		Baseline	6 months	12 months	Baseline	6 months	12 months
Control	192	5.88 ± 0.69	$3.92 \pm 0.14^{*}$	$2.11 \pm 0.36^{*}$	8.37 ± 1.96	$6.25 \pm 1.43^{*}$	$4.66 \pm 0.78^{*a}$
Observation	192	5.89 ± 0.57	$2.14 \pm 0.58^{*}$	$0.93 \pm 0.15^{*}$	8.33 ± 1.87	$4.39 \pm 0.25^{*}$	$2.17 \pm 0.36^{*a}$
t value		0.155	41.338	41.925	0.205	17.754	0.163
P value		0.877	< 0.01	< 0.01	0.838	< 0.01	< 0.01

Note: Compared with baseline (pre-intervention), $^{*}P < 0.05$; compared with the 6-month post-intervention assessment, $^{a}P < 0.05$.

exhibited significantly higher SMI, TLM, and HGS levels and significantly lower PBF and VFA levels compared with the control group ($P < 0.05$), as shown in Fig. 1.

Comparison of anthropometric measurements between the two groups. At 6 and 12 months after intervention, BMI, MAC, and CC increased significantly in both groups ($P < 0.05$). Moreover, at both follow-up time points, BMI, MAC, and CC were significantly higher in the observation group than in the control group ($P < 0.05$), as shown in Fig. 2.

Comparison of nutritional indicators between the two groups. At 6 and 12 months after intervention, levels of ALB, HGB, PA, TRF, and IGF-1 increased significantly in both groups ($P < 0.05$). In addition, the observation group exhibited significantly higher levels of ALB, HGB, PA, TRF, and IGF-1 than the control group at both follow-up time points ($P < 0.05$), as shown in Fig. 3.

Comparison of quality of life between the two groups. SarQoL domain scores increased significantly in both groups at 6 and 12 months after intervention ($P < 0.05$). Furthermore, all SarQoL domain scores were significantly higher in the observation group than in the control group at both follow-up time points ($P < 0.05$).

Discussion. Sarcopenic obesity significantly impairs physical function and quality of life in older adults [7, 8]. While protein intake is crucial for maintain-

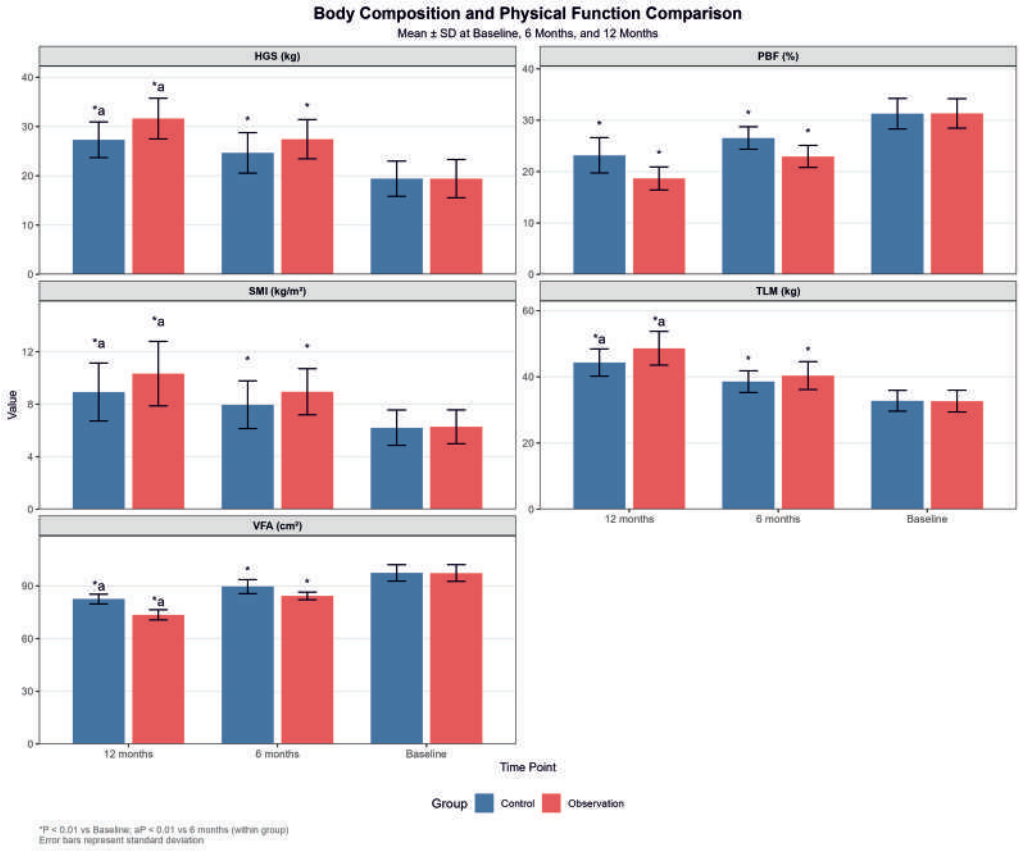


Fig. 1. Comparison of muscle-related indices between the two groups. Compared with baseline (pre-intervention), $^{*}P < 0.05$; compared with the 6-month post-intervention assessment, $^{a}P < 0.05$

ing muscle mass, the optimal strategy for this population remains unclear. This study investigated the effects of an optimized protein intake strategy on metabolic-inflammatory biomarkers and clinical outcomes. The optimized strategy, rich in high-quality proteins such as whey and eggs, significantly reduced serum levels of IL-6, TNF-α, CRP, and irisin. These reductions indicate effective alleviation of chronic low-grade inflammation, thereby mitigating its adverse effects on muscle and lipid metabolism.

Furthermore, the strategy improved body composition by promoting protein synthesis and regulating lipid metabolism. The intervention group exhibited significant increases in skeletal muscle mass index (SMI), total lean mass (TLM), and handgrip strength (HGS), alongside reductions in body fat percentage (PBF) and visceral fat area (VFA). Concurrent increases in BMI, mid-arm circumference (MAC), and calf circumference (CC) further support improvements in muscle mass and nutritional status. Nutritional and metabolic markers also improved,

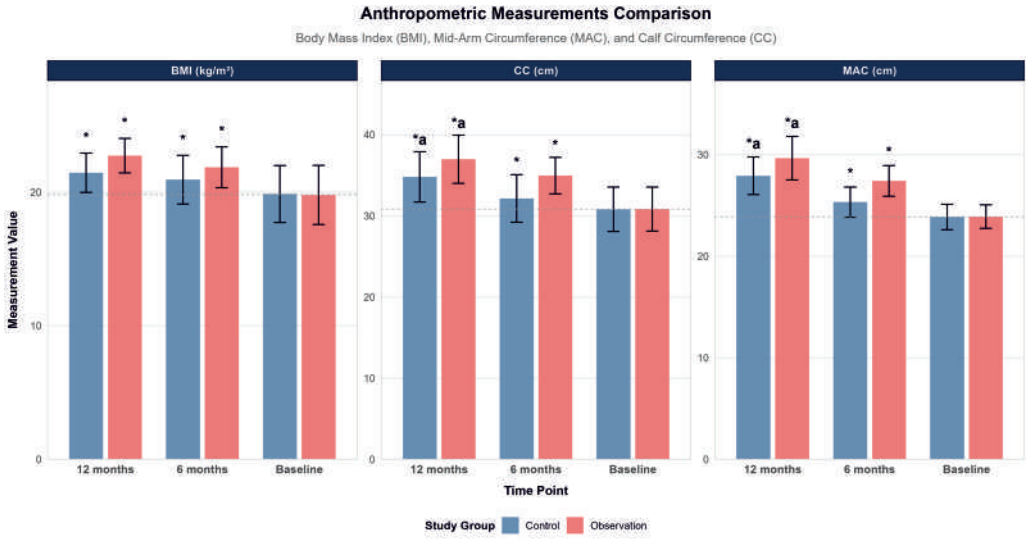


Fig. 2. Comparison of BMI, MAC, and CC between the two groups. Compared with baseline (pre-intervention), $^{*}P < 0.05$; compared with the 6-month post-intervention assessment, $^{a}P < 0.05$

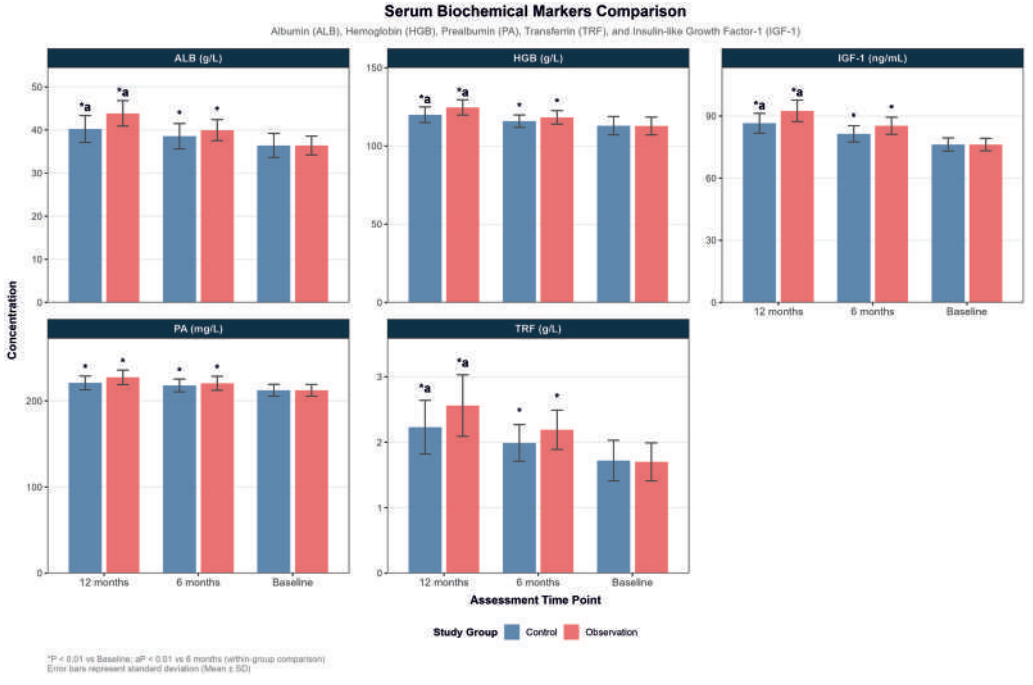


Fig. 3. Comparison of ALB, HGB, PA, TRF, and IGF-1 levels between the two groups. Compared with baseline (pre-intervention), $^{*}P < 0.05$; compared with the 6-month post-intervention assessment, $^{a}P < 0.05$

evidenced by elevated levels of albumin (ALB), hemoglobin (HGB), prealbumin (PA), transferrin (TRF), and insulin-like growth factor-1 (IGF-1). Collectively, these enhancements in muscle function and nutritional status contributed to a significant improvement in quality of life.

The study has limitations, including its single-centre design and relatively short follow-up period, which may restrict generalizability. Future multicentre studies with extended follow-up are warranted. In conclusion, an optimized protein intake strategy effectively reduces inflammation, improves muscle mass and function, decreases fat accumulation, and enhances nutritional status and quality of life in older adults with sarcopenic obesity.

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