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Anti-Inflammatory Diet Combined with Exercise Improves Physical Function and Inflammatory Profiles in Older Adults with Sarcopenia: A Randomized Controlled Trial

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Abstract

Objective

Muscle loss frequently occurs in patients with cancer and age-related chronic degenerative diseases. Acute infection-induced inflammatory stress further worsens the prognosis for these individuals. Considering the uncertainty surrounding the effectiveness of exercise and anti-inflammatory diets, this study seeks to assess the impact of four distinct interventions on inflammatory status and sarcopenia-related indices in hospitalized older patients with sarcopenia who are experiencing acute infections.

Methods

A prospective, parallel-group randomized controlled trial was conducted involving 1,800 hospitalized patients with acute infections. Among these, 200 older sarcopenic patients were screened and subsequently randomized (1:1:1:1) into four groups for a 12-week intervention: Anti-inflammatory Diet (AID), Exercise (Ex), Exercise combined with Anti-inflammatory Diet (Ex + AID), and Exercise combined with High-Protein Diet (Ex + HPD). The primary outcomes included changes (Δ) from baseline to follow-up in inflammatory status, muscle mass, and muscle function, which was assessed through grip strength, gait speed, and the SARC-F score.

Results

A total of 193 patients completed the trial. Significant inter-group differences were noted in the changes (Δ) of seven indicators: monocyte percentage, monocyte count, eosinophil count, mean corpuscular volume (MCV), Platelet-to-Albumin Ratio (PAR), Monocyte-to-Albumin Ratio Index (MARI), and SARC-F score. Pairwise comparisons indicated that the Ex-group significantly surpassed the AID group in enhancing Δmonocytes and ΔMARI. The Ex + HPD group exhibited significant differences in Δeosinophil count when compared to the Ex-group. Furthermore, the Ex + AID group demonstrated greater improvement in ΔPAR relative to both the Ex + HPD and AID groups. In terms of the ΔSARC-F score, all three exercise-inclusive groups (Ex, Ex + AID, and Ex + HPD) significantly outperformed the AID group ($P < 0.001$).

Conclusion

Synergistic interventions that integrate diet and exercise demonstrate greater efficacy than monotherapy. Exercise functions as the primary intervention for modulating inflammation and reversing frailty linked to sarcopenia. This study offers essential evidence-based support for clinical interventions targeting older patients with sarcopenia.

1. Introduction

Skeletal muscle atrophy represents a critical and prevalent complication among the elderly, particularly in patients with age-related chronic degenerative diseases such as cancer, heart failure, chronic obstructive pulmonary disease (COPD), and neurodegenerative disorders[1, 2]. This progressive decline in muscle mass and function is often clinically observed as sarcopenia or cachexia, which significantly contributes to physical frailty and results in diminished quality of life, extended hospitalizations, and markedly increased mortality rates among patients[3]. In the context of these chronic diseases, the pathophysiological mechanisms driving muscle wasting are notably intricate, primarily influenced by persistent low-grade systemic inflammation, metabolic dysregulation, and decreased physical activity[4].

Chronic diseases establish a foundation for the decline in muscle function among older adults, while acute infections—common occurrences in this population—represent a significant exacerbating factor. The inflammatory stress caused by acute infections further deteriorates the prognosis for older individuals with already compromised physical function[5]. During episodes of acute infection, a sudden increase in pro-inflammatory cytokines, including interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and C-reactive protein (CRP), induces a hypermetabolic state that significantly accelerates muscle protein breakdown and inhibits protein synthesis [6]. For older adults, this inflammatory burden, resulting from chronic diseases and compounded by acute episodes, leads to a rapid and irreversible decline in functional independence, rendering acute hospitalization a critical juncture for the deterioration of long-term clinical outcomes [7].

At present, countering severe muscle degeneration remains a major clinical challenge. Although current clinical guidelines generally recommend exercise interventions including resistance training and nutritional support dominated by protein supplementation as the cornerstones of sarcopenia management, the practical effectiveness and feasibility of these conventional approaches are still considerably limited under acute clinical care conditions [8]. Nevertheless, there is considerable uncertainty regarding the actual effectiveness and feasibility of these conventional approaches in acute medical care settings. Hospitalized older adults facing acute infections are often bedridden for extended periods and experience severe fatigue, which impairs their bodies' ability to effectively utilize dietary protein [9, 10]. Consequently, optimal interventions to mitigate muscle loss during the hypercatabolic state associated with acute infection remain insufficiently explored in the existing literature.

Given the ambiguous efficacy of standard combined exercise and anti-inflammatory nutritional interventions during acute physiological stress, this study aims to evaluate the effects of four distinct interventions on inflammatory status and indicators related to sarcopenia, including muscle mass, handgrip strength, gait speed, and SARC-F score, in hospitalized older patients with sarcopenia and acute infection. By comparing various intervention strategies, this study seeks to provide evidence-based medical guidance for mitigating functional decline associated with acute hospitalization in this population.

2. Methods

2.1. Study design and setting

This study was a prospective randomized controlled trial (RCT) conducted in a hospital setting utilizing a balanced randomization scheme (1:1:1:1). Participants were recruited from the outpatient and inpatient departments of East China Hospital affiliated with Fudan University, as well as from the Shanghai Changning District Community Health Center, over a time frame from January 2024 to December 2025. The trial received approval from the hospital ethics committee (2025K313-F251) and

was registered with the Clinical Trial Registry Center (ChiCTR2600126078). The trial was registered on June 3, 2026. The first participant was enrolled on October 1, 2025. This is a retrospective registration of the clinical trial.All research methods complied with the ethical principles of human experimentation and the requirements of the 1975 Helsinki Declaration and its subsequent revisions. Prior to enrollment, all participants signed written informed consent forms. The study was managed by the Shanghai Geriatric Medical Center, recognized as an authoritative specialized center in geriatric medicine in Shanghai.

2.2. Participants

We employed a systematic recruitment strategy to enroll elderly individuals, utilizing methods such as posting posters, distributing leaflets, and conducting health lectures in hospitals. Eligible participants were identified based on the following inclusion criteria [11] : (1) local Shanghai residents aged ≥ 60 years; (2) completion of the standard sarcopenia screening process[12]; (3) acute hospital admission with elevated inflammatory markers; (4) agreement to biological sample collection; and (5) willingness to participate in the prescribed clinical interventions and follow-ups. The exclusion criteria included: (1) inability to communicate; (2) refusal of regular follow-ups; (3) severe systemic diseases; (4) progressive malignancies; and (5) current use of medications that affect musculoskeletal metabolism.

2.3. Sample size calculation

The required sample size was determined using the statistical software PASS v11.0 (NCSS, Caseville, Utah, USA). Drawing from existing literature[13, 14], researchers estimated that the participation rate in the dietary and/or exercise groups during the reversal of sarcopenia would be approximately 30%. To ensure the detection of at least one statistically significant difference in primary outcome measures between groups, a sample size of 45 patients with sarcopenia was necessary. Utilizing a two-tailed Fisher's exact test and accounting for an anticipated dropout rate of 10%, the trial required a minimum of 200 participants (50 per group) to achieve a 95% confidence level at a significance threshold of 0.05 (two-tailed test, statistical power = 1-β), thereby enabling the effective detection of statistical differences.

2.4. Randomization and blinding

Participants were randomized into groups according to a randomized grouping protocol, with subjects assigned to the intervention group in a 1:1:1:1 ratio. The procedure involved statistical personnel, who

were unaware of the grouping information, generating a random number sequence using Research Randomizer software (http://www.randomizer.org/). A non-participating staff member subsequently sealed the randomization results in opaque envelopes. This same staff member later opened the envelopes to reveal each participant's specific group assignment. All pre-analysis data had identifiable information removed. Details of the allocation were disclosed only after the completion of all data analyses by personnel not directly involved in the trial.

2.5. Study intervention

In this study, the intervention program comprised two primary components: nutrition and exercise. The intervention lasted for 12 weeks. The four groups were organized as follows: Group 1 (Anti-inflammatory Diet + Exercise): Participants received targeted anti-inflammatory dietary guidance in conjunction with an exercise regimen. Group 2 (High-Protein Diet + Exercise): Participants followed a protein-enriched dietary plan alongside an exercise program. Group 3 (Exercise Only): Participants maintained a standard diet while adhering to the exercise regimen. Group 4 (Anti-inflammatory Diet Only): Participants followed the anti-inflammatory diet without any prescribed exercise modifications.

Dietary Guidance: Detailed menus were formulated based on recommendations[15]from clinical nutritionists. Compliance was monitored through weekly digital logs using a WeChat mini-program and regular telephone follow-ups.

Exercise Guidance: The intervention's core consisted of resistance training combined with aerobic and balance exercises[16].Resistance training, which targeted large muscle groups using body weight or resistance bands, was conducted 2–3 times per week, progressively increasing from low loads to 8–12 repetitions per set. Aerobic exercise, such as brisk walking or swimming, was recommended 3–5 times per week for 20–30 minutes, while balance training occurred 2–3 times per week[17, 18].

Throughout the intervention, healthcare professionals provided remote monitoring and guidance to participants via an online portal. Supplementary documents included guidelines for dietary nutrition and exercise interventions, as well as standardized operating procedures for practical applications. Follow-ups were conducted uniformly, featuring telephone assessments at weeks 2, 4, and 6 to ensure compliance and address any execution barriers, along with outpatient visits during other weeks. The primary endpoints were evaluated at the 12-week outpatient visit.

2.6. Outcome measures

To systematically examine the effects of nutritional and exercise interventions on inflammatory levels and somatic function in elderly patients with sarcopenia, we conducted assessments at baseline and immediately following the 12-week intervention period. The primary outcome measures included sarcopenia-related biomarkers assessed 12 weeks post-intervention, which encompassed bioelectrical impedance analysis (BIA) of muscle mass, SARC-F scale scores, grip strength measurements, and walking speed assessments. Secondary outcomes included a complete blood count analysis and 15 comprehensive inflammatory markers, such as the neutrophil-to-lymphocyte ratio (NLR), platelet-to-

lymphocyte ratio (PLR), and CALLY index. Detailed information regarding the 15 comprehensive inflammatory indicators, calculated from peripheral blood counts and related parameters, is available in the Supplementary Materials.

2.7. Statistical analysis

Data were analyzed using SPSS version 29.0. Continuous variables that followed a normal distribution were reported as mean ± standard deviation and compared using Analysis of Variance (ANOVA). For non-normally distributed data, results were expressed as median [Q1, Q3] and compared using the Kruskal-Wallis H test. Categorical data were assessed using either the Chi-square test or Fisher's exact test. Differences in the magnitude of change (Δ = baseline - post-intervention) among the four groups were evaluated using ANOVA or the Kruskal-Wallis H test, followed by the Nemenyi-corrected Mann-Whitney U test for pairwise comparisons. A two-sided P value < 0.05 was deemed statistically significant.

3. Results

3.1. Participants' characteristics

From January 2024 to December 2025, this study recruited 1,800 elderly patients from hospitalized participants in a prospective cohort study. Following screening, 128 subjects were excluded based on predefined inclusion and exclusion criteria, and an additional 12 participants chose to withdraw. Ultimately, 200 eligible elderly patients with sarcopenia were selected from 399 qualified participants and enrolled in the intervention trial, where they were subsequently randomized into four intervention groups. During the intervention period, seven subjects withdrew or were excluded from the intervention groups, resulting in a final sample size of 193 participants. The participant enrollment process, including enrollment, randomization, and intervention procedures, is illustrated in Fig. 1.

The dropout group and the completion group exhibited similarities in demographic characteristics and medical conditions. Among the 193 patients included in the analysis and who completed the follow-up, baseline data across all groups demonstrated excellent comparability regarding demographic characteristics, comorbidities, inflammatory markers, and sarcopenia-related clinical parameters, with no statistically significant differences observed between groups (P > 0.05). The subjects were aged between 60 and 95, with an average age of 80.52.The detailed baseline characteristics of the subjects are presented in **Table. 1.**

Table 1
Baseline characteristics of subjects before intervention

Metric	Intervention				P[d]
	Anti-inflammatory diet combined with exercise group(n = 47)	High-protein diet combined with exercise group(n = 49)	Exercise group(n = 49)	Anti-inflammatory diet group(n = 48)	
Age	81.38 ± 9.30[a]	80.77 ± 9.16	80.41 ± 8.92	79.85 ± 9.01	0.062
Sex (Male)	23(48.94)[b]	25(51.02)	25(51.02)	24(50.00)	0.864
BMI	24.10 ± 3.75	24.53 ± 3.87	24.24 ± 3.79	24.32 ± 3.84	0.338
Smoke(%)	4(8.51)	3(6.12)	3(6.12)	3(6.25)	0.117
Drink(%)	5(10.64)	4(8.16)	4(8.16)	5(10.42)	0.593
Diabetes mellitu(%)	2(4.26)	2(4.08	2(4.08)	2(4.17)	0.954
Hypertension (%)	7(14.89)	6(12.24)	6(12.24)	7(14.58)	0.348
CVDs (%)	18(38.30)	18(36.73)	16(32.65)	17(35.42)	0.872
Pulmonary disease(%)	3(6.38)	4(8.16)	3(6.12)	3(6.25)	0.663
Digestive system diseases (%)	3(6.38)	3(6.12)	3(6.12)	3(6.25)	0.232
Urinary system diseases (%)	2(4.26)	2(4.08)	1(2.04)	2(4.17)	0.089
IADL	1.0(0.0,2.0)[c]	1.0(0.0,2.0)	1.0(0.0,2.0)	1.0(0.0,2.0)	0.697
ADL	1.0(1.0,3.0)	1.0(1.0,3.0)	1.0(1.0,3.0)	1.0(1.0,3.0)	0.116
MNA	25.5(25.0,27.5)	26.0(25.0,27.0)	26.0(25.0,27.0)	26.5(25.0,27.0)	0.564
SOFA	13.0(10.0,14.0)	13.0(11.0,15.0)	13.0(10.0,14.0)	13.0(11.0,15.0)	0.169
Charlson index	7.0(5.0,9.0)	7.0(5.0,9.0)	7.0(5.0,9.0)	7.0(5.0,9.0)	0.393
aCCI	3.0(2.0,4.0)	3.0(2.0,4.0)	3.0(2.0,4.0)	3.0(2.0,4.0)	0.313
Length of hospital stay (months)	3.0(1.0,10.0)	2.5(1.0,10.3)	2.5(1.0,10.0)	2.5(1.0,8.0)	0.712

Metric	Intervention				P[d]
	Anti-inflammatory diet combined with exercise group(n = 47)	High-protein diet combined with exercise group(n = 49)	Exercise group(n = 49)	Anti-inflammatory diet group(n = 48)	
Number of anti-inflammatory drugs	1.0(1.0,2.0)	1.0(1.0,2.0)	1.0(1.0,2.0)	1.0(1.0,2.0)	0.144
SARC-F	7.06 ± 1.58	7.06 ± 1.61	6.86 ± 1.67	6.85 ± 1.62	0.207
Gripping power(kg)	18.02 ± 5.37	18.86 ± 4.68	16.72 ± 4.25	17.83 ± 4.59	0.881
Speed(m/s)	0.52 ± 0.35	0.57 ± 0.37	0.52 ± 0.30	0.54 ± 0.35	0.951
Muscle mass (kg/m²)	5.54 ± 0.77	5.36 ± 0.88	5.51 ± 0.86	5.60 ± 0.77	0.971

Note: The total study sample consisted of n = 193 participants, categorized into four groups based on different intervention methods. The following abbreviations are used in both Chinese and English: Body Mass Index (BMI), Age-Adjusted Charlson Comorbidity Index (aCCI), Cardiovascular and Cerebrovascular Diseases (CVDs), Instrumental Activities of Daily Living (IADL) score, Activities of Daily Living (ADL) score, Sequential Organ Failure Assessment (SOFA) score,Charlson Comorbidity Index(CCI), Mini-Nutrition Assessment Scale (MNA). [a]Average ± standard deviation.[b] n (%).[c] Median [Q1, Q3] .[d]*P* values for group comparisons using Kruskal–Wallis test for continuous variables and chi-square test for categorical variables.

3.2. Primary outcome

From the baseline period to the 12-week follow-up, intergroup analysis demonstrated significant differences in SARC-F scores among all intervention groups (P < 0.001, **Table. 2**). Additionally, notable intergroup differences were observed in lymphocyte count, lymphocyte percentage, eosinophil count, mean corpuscular volume (MCV), PAR, and MARI across all groups (all comparison P-values < 0.05, **Table. 2**).

Table 2
Analysis of Variance in Index Changes Between Interventions Before and After

Variable	Mean difference (CI)				*P*
	Anti-inflammatory diet combined with exercise group(n = 47)	High-protein diet combined with exercise group(n = 49)	Exercise group(n = 49)	Anti-inflammatory diet group(n = 48)	
ΔWhite blood cell count (1000 cells/uL)	-4.56 (-5.09, -4.03)	-4.68 (-5.20, -4.16)	-4.42 (-4.95, -3.89)	-4.39 (-4.97, -3.81)	0.432
ΔLymphocytes (%)	-5.20 -9.92,0.49)	-7.10 (-10.38, -3.82)	-6.33 (-9.53, -3.13)	-5.69 (-8.71, -2.66)	0.025
ΔMonocytes (%)	1.39 (-0.03, 2.81)	-0.65 (-1.69, 0.39)	1.91 (0.74, 3.08)	1.27 (0.01, 2.53)	0.581
ΔNeutrophils (%)	-7.71 (-12.89, -2.53)	-8.77 (-12.18, -5.36)	-8.07 (-11.41, -4.73)	-7.86 (-11.38, -4.34)	0.424
ΔEosinophils (%)	0.50 (-0.36, 1.36)	0.77 (-0.26, 1.80)	0.02 (-0.85, 0.89)	1.04 (0.10, 1.98)	0.056
ΔBasophils (%)	0.15 (-0.01, 0.31)	0.22 (0.08, 0.36)	0.04 (-0.11, 0.19)	0.02 (-0.08, 0.12)	0.187
ΔLymphocytes (1000 cells/uL)	1.08 (0.62, 1.53)	1.00 (0.70, 1.25)	0.93 (0.64, 1.21)	0.99 (0.70, 1.28)	0.004
ΔMonocyte count (1000 cells/uL)	0.28 (-0.18, 0.74)	-0.25 (-0.60, 0.10)	0.58 (0.21, 0.95)	0.25 (-0.19, 0.69)	0.254
ΔNeutrophils (1000 cells/uL)	-3.17 (-3.74, -2.60)	-3.26 (-3.69, -2.83)	-3.09 (-3.53, -2.65)	-3.07 (-3.58, -2.56)	0.865
ΔEosinophil count (1000 cells/uL)	-0.16 (-0.34, 0.03)	-0.07 (-0.09, 0.22)	-0.24 (-0.40, -0.07)	-0.22 (-0.38, -0.07)	0.025
ΔBasophil count (1000 cells/uL)	-0.03 (-0.05, -0.01)	-0.04 (-0.06, -0.02)	-0.05 (-0.07, -0.03)	-0.05 (-0.07, -0.03)	0.932
ΔRed blood cell count (million cells/uL)	-0.09 (-0.16, -0.02)	-0.09 (-0.17, -0.01)	-0.12 (-0.20, -0.04)	-0.06 (-0.13, 0.01)	0.071
ΔHemoglobin (g/dL)	-0.23 (-0.30, -0.16)	-0.31 (-0.38, -0.24)	-0.24 (-0.31, -0.17)	-0.26 (-0.33, -0.19)	0.396

Variable	Mean difference (CI)				*P*
	Anti-inflammatory diet combined with exercise group(n = 47)	High-protein diet combined with exercise group(n = 49)	Exercise group(n = 49)	Anti-inflammatory diet group(n = 48)	
ΔHematocrit (%)	1.87 (0.93, 2.81)	1.14 (0.25, 2.03)	1.68 (0.85, 2.51)	1.11 (0.23, 1.99)	0.446
ΔMCV (fl)	-2.06 (-3.61, -0.51)	0.26(-1.20, 1.71)	0.56 (-0.81, 1.93)	-0.90(-0.57, 2.36)	0.043
ΔMCH (pg)	-0.33 (-0.92, 0.26)	-0.09 (-0.65, 0.47)	-0.28 (-0.77, 0.21)	-0.81 (-1.32, -0.30)	0.159
ΔMCHC (g/dL)	-0.45 (-0.76, -0.14)	-0.11 (-0.45, 0.23)	-0.13 (-0.41, 0.15)	-0.40 (-0.70, -0.10)	0.262
ΔRDW (%)	0.32 (-0.23, 0.87)	0.21 (-0.18, 0.60)	-0.20 (-0.62, 0.22)	0.04 (-0.28, 0.36)	0.918
ΔPlatelet count (1000 cells/uL)	-48.38 (-71.83, -24.93)	-30.12 (-52.02, -8.22)	-38.27 (-54.53, -22.01)	-48.96 (-70.78, -27.14)	0.233
ΔMean Platelet Volume (fl)	0.00 (-0.39, 0.39)	-0.02 (-0.40, 0.36)	0.26 (-0.15, 0.67)	0.16 (-0.18, 0.50)	0.446
ΔAlbumin (g/L)	-0.47 (-1.97, 1.03)	1.06 (-0.56, 2.68)	-1.24 (-2.52, 0.04)	-0.29 (-1.77, 1.19)	0.479
ΔCRP (mg/dL)	-0.80 (-1.10, -0.50)	-0.81 (-1.08, -0.54)	-0.74 (-0.93, -0.55)	-0.83 (-1.20, -0.46)	0.598
ΔNLR	-0.91 (-1.68, -0.14)	-0.71 (-1.09, -0.33)	-0.70 (-1.13, -0.27)	-0.68 (-1.07, -0.29)	0.335
ΔPLR	19.37 (-2.39, 41.13)	37.94 (22.58, 53.30)	33.04 (14.82, 51.26)	16.05 (1.22, 30.88)	0.429
ΔLMR	3.76 (3.35, 4.17)	4.19 (3.69, 4.69)	3.77 (3.31, 4.23)	4.07 (3.59, 4.55)	0.242
ΔSII	-320.88 (-472.59, -169.17)	-223.50 (-319.10, -127.90)	-242.33 (-360.34, -124.32)	-264.99 (-371.00, -158.98)	0.536

Variable	Mean difference (CI)				*P*
	Anti-inflammatory diet combined with exercise group(n = 47)	**High-protein diet combined with exercise group(n = 49)**	**Exercise group(n = 49)**	**Anti-inflammatory diet group(n = 48)**	
ΔNPR	13.26 (11.15, 15.37)	11.71 (10.52, 12.90)	12.29 (11.08, 13.50)	13.14 (11.84, 14.44)	0.945
ΔPAR	0.30 (-0.26, 0.86)	0.34 (-0.22, 0.89)	0.42 (-0.10, 0.94)	1.30 (0.80, 1.79)	**0.010**
ΔCAR	-0.02 (-0.03, -0.01)	-0.02 (-0.03, -0.01)	-0.02 (-0.03, -0.01)	-0.02 (-0.03, -0.01)	0.662
ΔCLR	-0.31 (-0.45, -0.17)	-0.28 (-0.36, -0.20)	-0.26 (-0.33, -0.19)	-0.27 (-0.34, -0.20)	0.655
ΔSIRI	-1.07 (-1.69, -0.45)	-1.02 (-1.35, -0.69)	-0.82 (-1.13, -0.51)	-0.87 (-1.16, -0.58)	0.354
ΔCALLY	369.53 (290.73, 448.33)	436.48 (343.61, 529.35)	378.22 (290.33, 466.11)	411.88 (323.38, 500.38)	0.572
ΔHALP	-1.60 (-2.93, -0.27)	-1.71 (-2.47, -0.95)	-1.55 (-2.33, -0.77)	-0.98 (-1.87, -0.09)	0.646
ΔMARI	0.006 (0.004, 0.007)	0.008(0.006, 0.010)	0.005 (0.003, 0.007)	0.007 (0.005,0.008)	**0.011**
ΔNPAR	-0.22 (-0.33, -0.11)	-0.18 (-0.28, -0.08)	-0.11 (-0.22, 0.00)	-0.18 (-0.29, -0.07)	0.457
ΔAISI	-332.14 (-487.81, -176.47)	-282.00 (-369.98, -194.02)	-245.35 (-329.28, -161.42)	-267.66 (-339.21, -196.11)	0.547
ΔPPN	-988.24 (-1159.42, -817.06)	-943.91 (-1134.71, -753.11)	-922.87 (-1074.69, -771.05)	-971.88 (-1168.80, -774.96)	0.989
ΔSARC-F	0.51 (0.12, 0.90)	0.92 (0.59, 1.25)	1.06 (0.69, 1.44)	1.83 (1.50, 2.17)	**< 0.001**
Δ Gripping	0.03 (-1.58, 1.64)	0.91 (-1.08, 2.90)	-0.30 (-2.12, 1.52)	0.12 (-1.82, 2.06)	0.646

Variable	Mean difference (CI)				*P*
	Anti-inflammatory diet combined with exercise group(n = 47)	High-protein diet combined with exercise group(n = 49)	Exercise group(n = 49)	Anti-inflammatory diet group(n = 48)	
Δ Speed	0.06 (-0.09, 0.17)	0.01 (-0.12, 0.14)	0.06 (-0.07, 0.19)	0.08 (-0.04, 0.20)	0.205
Δ Muscle mass	0.80 (0.64, ,0.96)	0.72 (0.55, 0.89)	0.75 (0.61, 0.89)	0.70 (0.54, 0.86)	0.806

Note: Abbreviations in Chinese and English: Mean Red Cell Volume(MCV),Mean Corpuscular Hemoglobin(MCH),Mean Red Blood Cell Hemoglobin Concentration(MCHC),Red Blood Cell Distribution Width(RDW), Neutrophil/Lymphocyte Ratio (NLR), Platelet/Lymphocyte Ratio (PLR), Monocyte/Lymphocyte Ratio (MLR), Systemic Inflammatory Index (SII), Neutrophil/Platelet Ratio (NPR), Platelet/Albumin Ratio (PAR), C-reactive Protein/Albumin Ratio (CAR), C-reactive Protein/Lymphocyte Ratio (CLR), Systemic Inflammatory Response Index (SIRI), CALLY Index, Monocyte/Albumin Ratio (MAR), Hemoglobin-Albumin-Lymphocyte-Platelet (HALP) Score, Neutrophil Percentage/Albumin Ratio (NPAR), Systemic Inflammatory Syndrome Index (AISI), Platelet*Neutrophil Count (PPN); Δ = Baseline Value-Last Follow-up Value; Discrepancies between groups were determined employing the χ^2 test.

3.3. Secondary outcome

For indicators demonstrating significant overall variance, this study utilized the Nemenyi-corrected method for pairwise comparisons among groups. The analysis revealed that, regarding the mitigation of sarcopenia-related frailty, the improvement in SARC-F scores for all intervention groups that included exercise (e.g., Ex, Ex + AID, and Ex + HPD) was significantly greater than that of the anti-inflammatory diet alone group ($P < 0.001$). Detailed pairwise comparisons of the magnitude of change between groups are presented in **Supplementar Material**. To visually represent these differences, Fig. 2 displays box plots illustrating the specific distribution of improvement magnitudes across various intervention regimens for key clinical indicators.

Note

(a)Monocytes (%) ;(b) Monocyte count; (c)Eosinophil count ;(d) Mean red blood cell volume;(e) PAR;(f) MARI;(g) SARC-F; *P*-values were corrected for multiple comparisons using false discovery rate (FDR) control. An FDR-adjusted $P < 0.05$ was considered significant.

4. Discussion

This study rigorously compared the clinical efficacy of multimodal nutritional interventions, including anti-inflammatory and high-protein diets, alongside exercise interventions[19, 20], in alleviating systemic inflammation and reversing physical decline in elderly patients with sarcopenia[21, 22]. Our findings

confirm that the combination of targeted diets and exercise not only promotes structural muscle recovery but also significantly downregulates systemic chronic inflammation, which serves as a fundamental catalyst for the progression of sarcopenia. This discovery provides robust clinical data that support the increasingly recognized "Immunonutrition" therapeutic strategy for sarcopenia on an international scale.

Consistent with previous literature, all four intervention regimens significantly reduced critical inflammatory markers while simultaneously enhancing red blood cell parameters. In the context of global aging research, "inflammaging" is widely acknowledged as a primary contributor to muscle loss[23, 24]. Chronic, low-grade systemic inflammation persistently activates the ubiquitin-proteasome system [25], inhibits the proliferation of muscle satellite cells, and hinders iron utilization, ultimately resulting in anemia of chronic disease[26, 27]. In the present study, significant differences between groups were noted in the platelet-to-albumin ratio (PAR) and monocyte-to-albumin ratio (MARI) following the intervention ($P < 0.05$). Moreover, the Ex + AID group demonstrated a statistically significant advantage over the isolated anti-inflammatory diet group in reducing PAR ($P = 0.035$). These findings suggest that an anti-inflammatory intervention enriched with polyphenols and omega-3 fatty acids, when coupled with exercise, not only suppresses the release of pro-inflammatory cytokines but also restores a favorable physiological environment for hematopoiesis and oxygen transport by enhancing microcirculation and mitigating platelet over-activation[28–30].

All intervention groups exhibited significant improvements in overall muscle mass and SARC-F scores ($P < 0.001$); however, the specific functional enhancements revealed distinct intervention characteristics. According to the consensus of international expert groups such as PROT-AGE, older adults frequently encounter "anabolic resistance," which is characterized by diminished muscle sensitivity to low doses of amino acids[31, 32]. Our findings further support the prevailing international perspective: to optimize the mechanical load (resistance exercise)-induced activation of the mTORC1 pathway and muscle hypertrophy signaling, it is essential to provide adequate high-quality protein substrates, such as a leucine-rich diet[33]. Only then can the anabolic threshold be effectively surpassed, resulting in improvements in absolute muscle strength, specifically grip strength.

The recovery of somatic function reflects a comprehensive manifestation of neuromuscular coordination, mitochondrial function, and overall metabolic status. Recent international research[34]on the "Gut-Muscle Axis" indicates that anti-inflammatory dietary patterns [35], such as the Mediterranean diet, can reshape gut microbiota and increase the production of short-chain fatty acids (SCFAs). This process enhances mitochondrial biogenesis and reduces oxidative stress at neuromuscular junctions [36].The specific improvement in gait speed observed in this study suggests that an anti-inflammatory diet may provide significant clinical value in enhancing overall mobility in older adults by alleviating systemic metabolic stress and optimizing neuromuscular conduction[37].

Regarding the improvement of physical frailty, as measured by changes in SARC-F scores, between-group comparisons indicated that all combined intervention groups that included exercise were

significantly more effective than the isolated anti-inflammatory diet group ($P < 0.001$). This finding reaffirms a fundamental principle of international clinical guidelines for sarcopenia: physical stimulus, specifically exercise, remains an indispensable cornerstone of sarcopenia management [17]. Contemporary exercise physiology suggests that skeletal muscle functions as a substantial endocrine organ; during exercise, it releases "myokines," such as IL-6 and irisin, which exert significant systemic anti-inflammatory effects [38]. The synergistic amplification effect observed with the combination of exercise and an anti-inflammatory diet on immunonutritional indices, such as PAR, supports the notion that "multimodal interventions" are superior to "unidimensional interventions." This provides a compelling rationale for personalized treatment strategies in future sarcopenia management[39].

4.1. Study limitations

Our study has several limitations. The 3-month intervention period, although standard, may be insufficient to detect significant changes in slow-to-adapt functional metrics, such as grip strength, across all groups. Additionally, this was a single-center study, which may introduce selection bias. Furthermore, the exclusive reliance on end-point biomarker measurements may obscure early intervention dynamics; thus, future trials should incorporate serial biomarker tracking (e.g., at months 1, 2, and 3) to capture acute metabolic shifts.

4.2. Implications of the study findings

This study compared the intervention effects of four approaches on elderly patients with sarcopenia who were hospitalized due to acute infection, yielding significant theoretical and clinical implications for the prevention and treatment of sarcopenia in this population. The findings indicated that all four intervention protocols effectively improved patients' complete blood counts, inflammatory markers, and core indicators of sarcopenia, thereby providing reliable evidence for routine clinical interventions in this vulnerable group. Furthermore, the study addressed a gap in research regarding sarcopenia interventions for elderly patients with acute infections and presented a personalized intervention protocol that demonstrated both compliance and feasibility. It also identified the specific advantages of different intervention approaches, offering concrete guidance for the clinical development of individualized nutritional and exercise prescriptions. The results confirmed that exercise is central to enhancing sarcopenic frailty status, and that combined nutritional and exercise interventions surpassed the efficacy of single anti-inflammatory diets, thereby establishing key principles for the design of clinical interventions. Additionally, through correlation analysis of various indicators, the study enriched the evidence regarding inflammation-mediated mechanisms underlying the pathogenesis of sarcopenia, thereby laying experimental foundations for future exploration of molecular mechanisms. The scientifically rigorous study design also provided methodological references for similar research, while the identified limitations offered clear entry points for future investigations.

5. Conclusion

This study demonstrates that structured 12-week multimodal interventions—specifically the combination of anti-inflammatory or high-protein diets with exercise—effectively reduce systemic inflammation, enhance hematopoietic markers, and improve physical function in elderly patients with sarcopenia. Although dietary modifications successfully modulate the inflammatory microenvironment, mechanical exercise remains the cornerstone of functional recovery. The integration of routine immunonutritional assessments with tailored multimodal therapies represents a highly promising approach for the clinical management of sarcopenia.

Abbreviations

MCV
Mean Red Cell Volume
MCH
Mean Corpuscular Hemoglobin
MCHC
Mean Red Blood Cell Hemoglobin Concentration
RDW
Red Blood Cell Distribution Width
NLR
Neutrophil/Lymphocyte Ratio
PLR
Platelet/Lymphocyte Ratio
MLR
Monocyte/Lymphocyte Ratio
SII
Systemic Inflammatory Index
NPR
Neutrophil/Platelet Ratio
PAR
Platelet/Albumin Ratio
CAR
C-reactive Protein/Albumin Ratio
CLR
C-reactive Protein/Lymphocyte Ratio
SIRI
Systemic Inflammatory Response Index
CALLY
C-reactive Protein–Albumin–Lymphocyte Index
MAR
Monocyte/Albumin Ratio

HALP
Hemoglobin-Albumin-Lymphocyte-Platelet Score
NPAR
Neutrophil Percentage/Albumin Ratio
AISI
Systemic Inflammatory Syndrome Index
PPN
Platelet*Neutrophil Count

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of Huadong Hospital, Fudan University (Approval No.: 20250125, Date of approval: September 30, 2025). All participants provided written informed consent. All experimental procedures were strictly performed in accordance with relevant guidelines and regulations, with no deviations from the research protocol approved by the Institutional Review Board of Huadong Hospital, Fudan University.

Competing interests

The authors (Chaonan Li, Jiaofeng Wang, Chaobao Zhang, Zhijun Bao) declare no competing interests.

Consent for publication

Not applicable.

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Author Contribution

Conception and design: Chaonan Li and Zhijun Bao, Administrative support: Zhijun Bao; Provision of study materials and clinical serum sample: Zhijun Bao and Jiaofeng Wang; Data analysis and interpretation: Chaonan Li and Chaobao Zhang; Manuscript writing: Chaonan Li and Chaobao Zhang;

Final approval of manuscript: All authors.The authors (Chaonan Li, Jiaofeng Wang , Chaobao Zhang, Zhijun Bao) declare no competing interests.

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Data Availability

All data supporting the findings of this study are available within the paper and its Supplementary Information.

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Figures

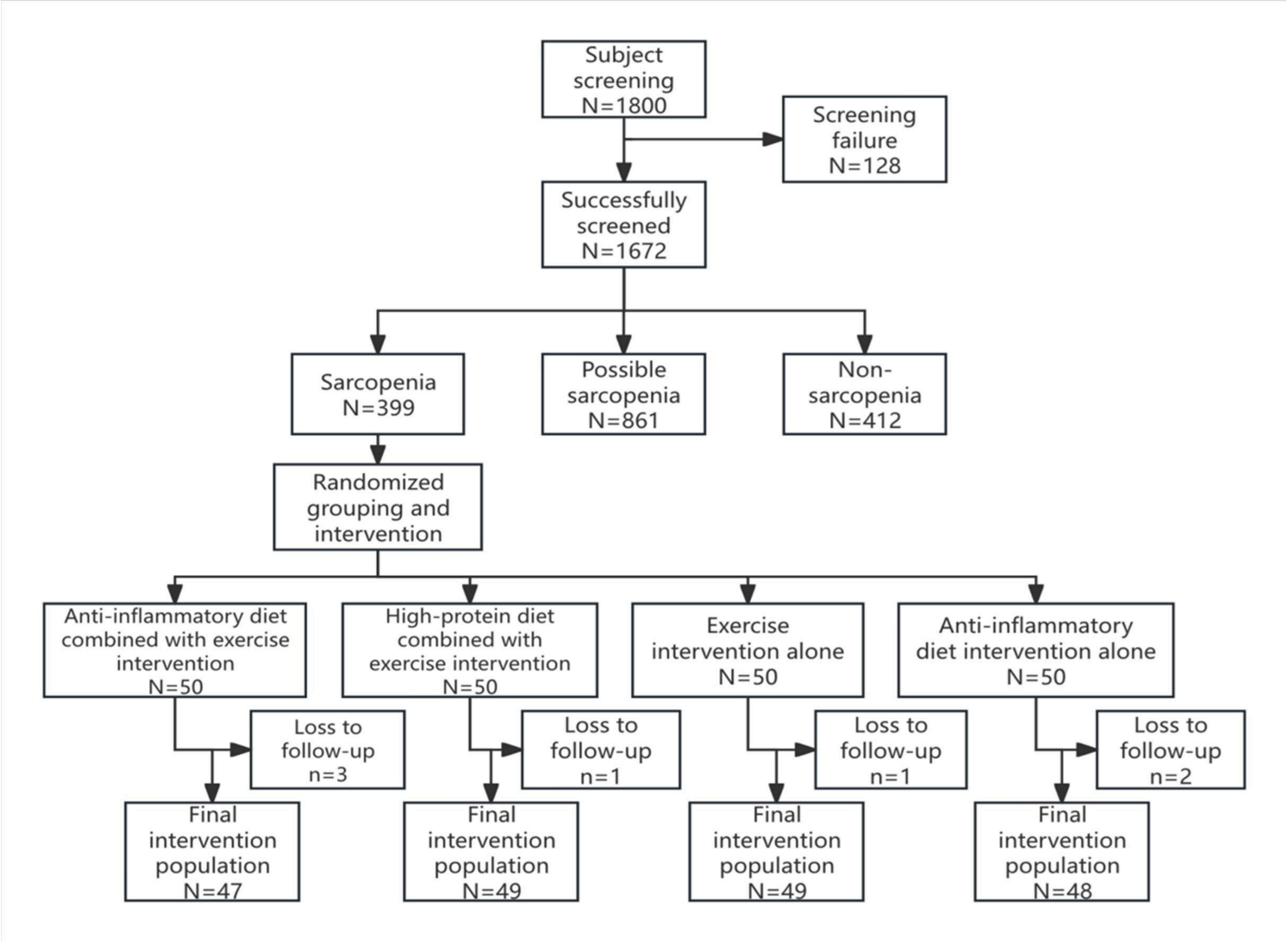


Figure 1

Flowchart of Subject Grouping Configuration

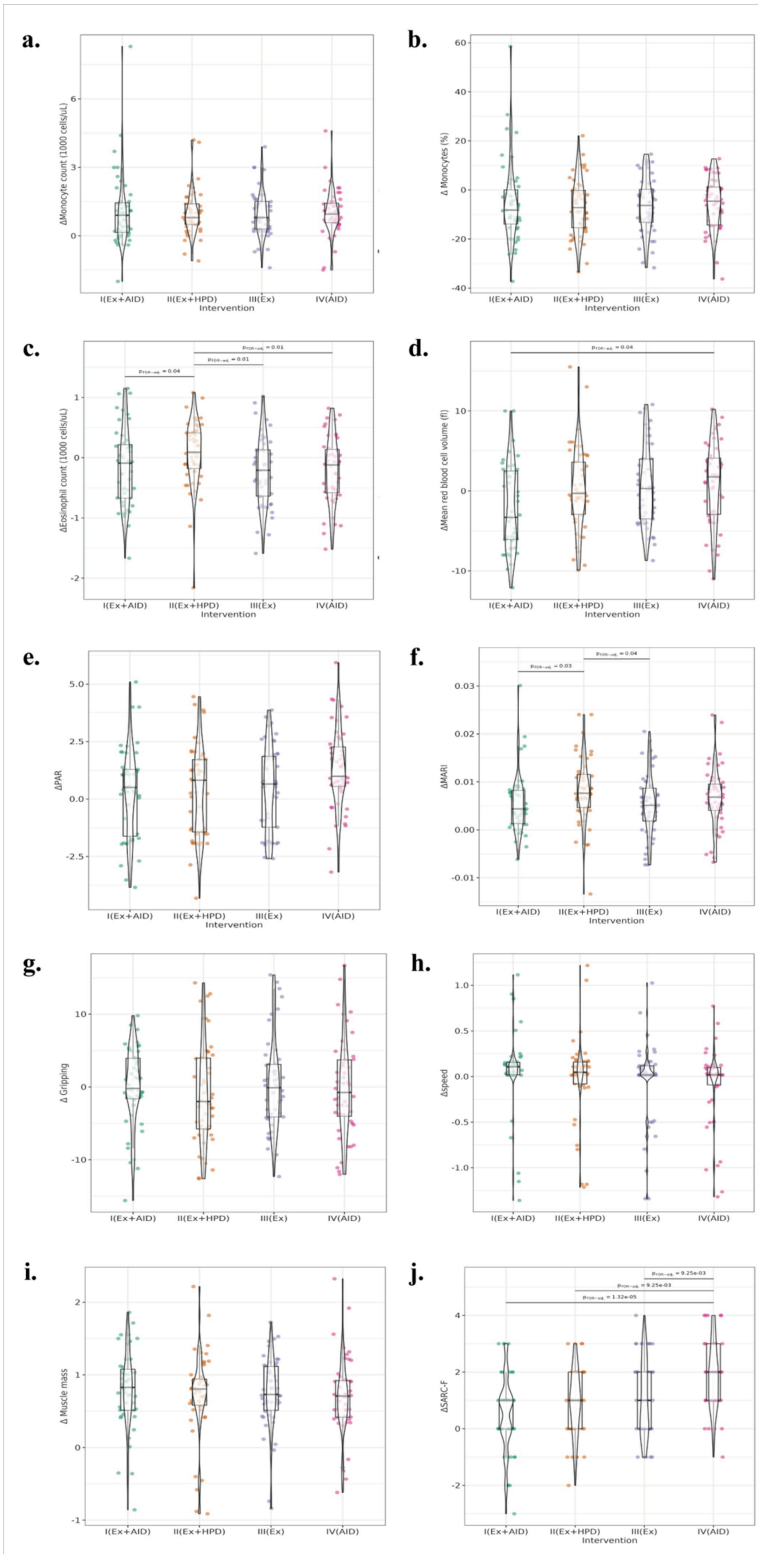


Figure 2

Differences in index change values between groups before and after intervention

Note：(a)Monocytes (%) ;(b) Monocyte count; (c)Eosinophil count ;(d) Mean red blood cell volume;(e) PAR;(f) MARI;(g) SARC-F; *P*-values were corrected for multiple comparisons using false discovery rate (FDR) control. An FDR-adjusted *P*<0.05 was considered significant.

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