Study Protocol

Scientific title	Effects of precision nutrition combined with structured resistance training on muscle mass and function in older adults at risk of sarcopenia: a randomized controlled trial
Public title	Can personalized nutrition plus resistance training improve muscle mass and function in older adults at risk of sarcopenia?
Short title	Precision nutrition and resistance training in sarcopenia
Protocol version/date	Version 1.0 - 10 January 2026
Principal investigator	Yan Shi, Associate Professor
Coordinating institution	School of Physical Education, University of Sanya
Ethics committee	Ethics Committee of University of Sanya
Ethics reference	IRB-2026-001
Study design	Assessor-blinded, two-arm parallel randomized controlled trial
Sample	147 randomized participants (74 PRIME; 73 control)
Intervention period	12 weeks

1. Background and rationale

Sarcopenia is characterized by age-related loss of muscle strength and muscle mass and is associated with impaired mobility, falls and disability. Progressive resistance training is an established strategy for improving muscle function, but older muscle may exhibit anabolic resistance, so dietary protein quantity and distribution may influence the magnitude of adaptation. PRIME is a rule-based precision-nutrition strategy that combines body-mass-adjusted protein targets, meal distribution, post-exercise timing, scheduled diet review and escalation when targets are not achieved. The trial isolates the added value of nutrition personalization by holding the structured resistance-training programme constant in both groups.

2. Objectives and hypotheses

The co-primary objectives are to compare 12-week change in skeletal muscle mass index and handgrip strength between PRIME plus structured resistance training and structured resistance training plus standard non-personalized nutrition guidance. Secondary objectives are to compare gait speed, five-times sit-to-stand, Timed Up-and-Go and SPPB, quantify nutrition and training adherence, monitor adverse events, and examine prespecified response moderators. The primary hypothesis is supported only if both co-primary outcomes show a statistically significant group-by-time effect favoring PRIME at two-sided alpha 0.05. Secondary and moderator analyses are supportive.

3. Study design and setting

This is a parallel, assessor-blinded randomized controlled trial coordinated by School of Physical Education, University of Sanya, No. 191 Xueyuan Road, Jiyang District, Sanya, Hainan 572022, China.

Community and primary-care partners support recruitment and intervention delivery. Participants are followed for 12 weeks after randomization. Recruitment began 1 February 2026; final enrolment occurred 31 May 2026; study completion was 31 August 2026.

4. Ethics and governance

Ethical approval was granted by the Ethics Committee of University of Sanya on 15 January 2026, reference IRB-2026-001. Written informed consent is obtained before any study-specific procedure. Participant confidentiality, secure data handling and voluntary withdrawal are maintained throughout the study. Ethics/research-governance contact: University Research Office, University of Sanya, No. 191 Xueyuan Road, Jiyang District, Sanya, Hainan 572022, China; telephone +86 898 88386011; email research@sanyau.edu.cn.

5. Participants

5.1 Recruitment

Potential participants are recruited through primary-care referrals, senior centres, community groups and public flyers. Telephone prescreening is followed by an in-person eligibility visit. SARC-F (score >=4) is used to prioritize objective screening, but final eligibility is based on the criteria below.

5.2 Inclusion criteria

1. Age 65 years or older.
2. Community dwelling and able to ambulate independently with or without a usual aid.
3. At risk of or with probable sarcopenia defined by handgrip strength <27 kg in men or <16 kg in women and/or five-times sit-to-stand >15 seconds.
4. Willing to complete dietary records and supervised training.
5. Low physical activity (<150 min/week of moderate-to-vigorous activity) and/or habitual protein intake <1.0 g/kg/day used as risk-enrichment criteria.

5.3 Exclusion criteria

6. Structured resistance training more than once weekly within the previous 12 weeks.
7. Unstable cardiometabolic or musculoskeletal condition that contraindicates resistance exercise.
8. Severe cognitive impairment preventing protocol adherence (Mini-Cog <3).
9. eGFR <45 mL/min/1.73 m².

6. Sample size and enrolment

An a priori G*Power analysis used two-sided alpha 0.05 and 80% power, with a clinically meaningful gait-speed difference used as a conservative functional benchmark for recruitment planning. Recruitment was increased to accommodate screening exclusions and attrition. Of 220 adults approached, 198 completed prescreening, 162 attended the eligibility visit, 15 declined or withdrew before baseline testing, and 147 participants were randomized (74 PRIME; 73 control).

7. Randomization, allocation concealment and blinding

Randomization is stratified by sex and baseline protein-intake category (<1.0 versus >=1.0 g/kg/day) using fixed blocks within strata. Allocation is concealed until baseline assessment is complete. Outcome assessors are blinded to group assignment. Participants, exercise professionals and dietitians cannot be blinded because the nutrition intervention is behaviorally apparent.

8. Interventions

8.1 Structured resistance training in both groups

Training is delivered for 12 weeks, three sessions per week, approximately 60 minutes per session. Sessions include a 5-minute warm-up, 40-45 minutes of resistance work and a 5-minute cool-down. Exercises include leg press, knee extension, hamstring curl, calf raise, chest press, seated row, overhead press and loaded sit-to-stand. Initial loads are approximately 50%-60% of estimated 1RM for 2 sets of 12-15 repetitions in weeks 1-2, 60%-70% 1RM for 2-3 sets of 8-12 repetitions in weeks 3-8, and 70%-80% 1RM for 3 sets of 6-10 repetitions in weeks 9-12. RPE and repetitions-in-reserve guide progression. If the upper repetition bound is achieved with at least two repetitions in reserve, the next-session load is increased by approximately 2.5%-5%.

8.2 PRIME nutrition

The PRIME arm receives individualized dietitian-led protein prescription. The baseline target is approximately 1.2 g/kg/day, with escalation up to 1.5 g/kg/day when tolerance and adherence support it. Participants are advised to distribute protein across three main meals, aiming for >=0.4 g/kg per meal, and to consume approximately 0.3 g/kg within 2 hours after training. Three-day food records are collected every 2 weeks. If target attainment is <90% for two consecutive review windows, counselling increases from every 2 weeks to weekly. If under-attainment persists after one intensified cycle, a food-first top-up equivalent to approximately 20 g/day is assigned to the lowest-protein meal.

8.3 Control nutrition condition

The control arm receives general healthy-eating, hydration and non-tailored protein education on the same contact schedule as PRIME. No individualized g/kg/day target, meal-distribution score or escalation rule is used. The same 3-day food records are collected for measurement purposes.

9. Outcomes

9.1 Co-primary outcomes

Outcome name	Metric or method of measurement	Timepoint(s)
Skeletal muscle mass index (SMMI)	Skeletal muscle mass (kg) estimated from multi-frequency bioelectrical impedance analysis (InBody 770) and indexed to height squared (kg/m²). Two consecutive fasting morning scans are averaged; skeletal muscle mass is derived using the prespecified Janssen equation.	Baseline (week 0) and post-intervention (week 12).
Handgrip strength	Maximum handgrip strength (kg) measured using a calibrated Jamar Smart Digital Hand Dynamometer. Three trials are performed per hand with 60-second rest intervals; the maximum recorded value is used.	Baseline (week 0) and post-intervention (week 12).

9.2 Secondary and implementation outcomes

Outcome name	Metric or method of measurement	Timepoint(s)
Gait speed	Usual-pace 4-m gait speed (m/s), measured on a marked walkway; two	Baseline (week 0) and week 12.

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Five-times sit-to-stand performance	Time (seconds) to complete five chair rises from a standardized 43-cm chair with arms crossed, after one familiarization trial.	Baseline (week 0) and week 12.
Timed Up-and-Go performance	Time (seconds) to stand from a chair, walk 3 m, turn, return and sit; two trials are performed and the faster trial is used.	Baseline (week 0) and week 12.
Short Physical Performance Battery (SPPB)	Total SPPB score (0-12 points) calculated from balance, gait-speed and chair-stand components using the standard scoring rubric.	Baseline (week 0) and week 12.
Protein intake	Mean daily protein intake (g/kg/day) calculated from 3-day food records (two weekdays and one weekend day) using nutrient-composition data.	Baseline and every 2 weeks during the 12-week intervention (weeks 2, 4, 6, 8, 10 and 12).
Protein target attainment	Ratio of achieved protein intake to the prespecified protein benchmark/prescription; values are derived from the 3-day food records.	Baseline and every 2 weeks during the intervention, with the principal post-intervention comparison at week 12.
Meal protein distribution	Proportion of main meals meeting the prespecified per-meal protein threshold (meal distribution score, 0-1).	Baseline and every 2 weeks during the intervention, with the principal post-intervention comparison at week 12.
Training session completion	Proportion of scheduled resistance-training sessions attended, calculated from supervised session logs.	Recorded at every session across 36 planned sessions over 12 weeks and summarized at week 12.
Training progression fidelity	Achieved weekly resistance-training volume load divided by prescribed weekly volume load, calculated from training logs.	Calculated weekly throughout the 12-week intervention and summarized at week 12.
Intervention-related adverse events	Musculoskeletal symptoms, dizziness, falls, exercise-related symptoms, gastrointestinal intolerance and other adverse events recorded by exercise professionals, dietitians and study staff, including action taken and relationship to the intervention.	Monitored continuously from randomization to completion of the 12-week intervention.

10. Safety monitoring

Medical and exercise contraindications are reviewed before enrolment. Participants with eGFR <45 mL/min/1.73 m² are excluded. Exercise professionals monitor pain, dizziness, falls, cardiorespiratory symptoms and musculoskeletal events at each session. Dietitians monitor tolerance of increased protein intake. Adverse events are recorded with onset, severity, action taken, outcome and relationship to the intervention. Concerning symptoms trigger exercise cessation and medical referral or emergency evaluation as appropriate.

11. Statistical analysis

Analyses follow the intention-to-treat principle. Linear mixed-effects models with participant random intercepts estimate group, time and group-by-time effects for skeletal muscle mass index and handgrip strength, adjusting for age, sex and baseline protein intake. The primary hypothesis requires significance of both co-primary group-by-time effects at two-sided alpha=0.05. Secondary physical-performance outcomes use corresponding mixed-effects models and are interpreted supportively using effect estimates, 95% confidence intervals and nominal p values. Nutrition exposure, session completion and progression fidelity are summarized longitudinally. Prespecified moderator models test interactions with sex and baseline protein-intake category. Per-protocol analyses are sensitivity analyses. Model assumptions, residual distributions and influential observations are checked before inference.

12. Data management and confidentiality

Participants are assigned study identifiers. Identifying information and analysis datasets are stored separately where practicable, with access restricted to authorized study personnel. Published and registry outputs use grouped or de-identified information. Study records are retained securely in accordance with University of Sanya research-governance requirements and applicable law.

13. Consent and withdrawal

Written informed consent is obtained before baseline study procedures. Participation is voluntary. Participants may withdraw from further intervention or assessment without affecting their usual care or services. Data already collected may be retained in de-identified form where permitted by the ethics-approved procedures and applicable requirements.

14. Funding, conflicts and dissemination

Funding: None. Conflict of interest: None. Results are intended for peer-reviewed publication, conference dissemination and public trial-registry reporting. De-identified data may be shared by the corresponding author on reasonable request, subject to ethics, confidentiality and institutional governance.