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The Impact of Dairy-based Nutrition and Resistance Training on Muscle Strength among Geriatric Adult

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ABSTRACT

Background: Characterized by the progressive loss of muscle mass and function with aging, poses significant health challenges in geriatric populations. Evidence suggests resistance training and nutritional supplementation improve muscle strength and function, but the combined effects, particularly with dairy-based supplements, remain inadequately explored.

Methods: A randomized controlled trial involving 120 participants aged 65 and older was conducted. Participants were divided into three groups: Resistance training only (RT), combined resistance training and dairy supplementation (RT+DS) and a control group. The RT and RT+DS groups underwent 12 weeks of supervised resistance training, with the RT+DS group receiving a daily dairy-based nutritional supplement.

Result: Key outcomes included handgrip strength, lean body mass and functional performance assessed using the Short Physical Performance Battery (SPPB). The RT+DS group demonstrated the greatest improvements, with a 22% increase in handgrip strength, a 3.8% rise in lean body mass and an 18% enhancement in SPPB scores. The RT group showed respective improvements of 15%, 2.5% and 11%, while the control group exhibited no significant changes. Combining resistance training with dairy-based nutritional supplementation significantly enhances muscle strength, body composition and functional performance in older adults. These findings highlight the potential of integrated interventions to counteract sarcopenia and promote healthier aging.

Key words: Dairy supplementation, Functional performance, Geriatric health, Muscle strength, Resistance training, Sarcopenia.

INTRODUCTION

Sarcopenia, defined as the age-related progressive and generalized loss of skeletal muscle mass and strength, significantly impairs mobility, increases the risk of falls and fractures and reduces functional independence among older adults (Kim *et al.,* 2016). These results push up healthcare expenses for all public medical institutions. Recent research shows 10-15% of elderly people have sarcopenia and older adults over age 80 develop the disease more often (Papadopoulou, 2020).

Muscle mass refers to the total amount of muscle tissue in the body. Lean body mass (LBM) includes muscle along with bone and body water but excludes fat, while muscle strength indicates the functional capacity of the muscle to generate force. Studies show resistance training (RT) works best to help elderly patients keep their muscles strong. When older adults and sedentary people perform RT, they build more muscle protein and their muscles grow bigger (Peterson *et al.,* 2011). Regular RT programs consistently boost LBM levels and improve stability, mobility and fall protection (Liao *et al.,* 2017). According to Marzuca-Nassr *et al.* (2023) research, older people built more lean body mass when they did resistance training alongside enhanced muscle strength and power. This study observes how RT provides better ways to fight sarcopenia than using medicine alone.

The elderly need to follow a specific protein intake plan because aging bodies naturally resist muscle protein growth. Body tissues become less responsive to protein nutrition when they develop anabolic resistance. Research shows that using dairy protein sources with essential amino acids helps fight muscle protein synthesis resistance in elderly people (Breen and Phillips, 2011). The dairy-based products perform well because leucine helps build muscle proteins and stops Muscle Protein Synthesis. Whey proteins provide essential amino acids and bioactive peptides that support muscle anabolism in older adults (Kumar *et al.,* 2018). Scientists found that adding whey or casein proteins to resistance training leads to better strength and physical performance compared to training alone (Rondanelli *et al.,* 2015).

Recent research examines how protein supplements affect the results of resistance training. Elderly participants who combined whey protein supplementation with exercise improved their grip strength, walked faster and gained more muscle compared to other exercise and proteingroups (Morton *et al.,* 2018). Research using a cross-

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sectional approach revealed that dairy protein supplements during resistance training helped older adults strengthen their muscles while maintaining active lifestyles to live better (Mitchell *et al.,* 2012).

Besides protein consumption, dairy products provide specific health benefits to older adults. Milk and dairy foods supply calcium and vitamin D, which help prevent osteoporosis and its common companion condition, sarcopenia (Giustina *et al.,* 2020; Hammam *et al.,* 2022). Empirical evidence suggests that eating fortified dairy products helps protect bones and improve physical well-being. Yogurt's live beneficial bacteria improve gut health, which potentially affects how nutrients are used and affects body-wide inflammation levels (Prete *et al.,* 2021; Akshay *et al.,* 2023). The informative advantages of dairy nutrition make it an effective dietary treatment choice for different age groups (Clark *et al.,* 2010).

Protein supplements work best when taken during the first two hours after exercising, but other studies suggest equal protein consumption throughout the day (Moore *et al.,* 2015). Despite evidence supporting both resistance training and protein supplementation independently, there is a lack of randomized controlled trials examining the synergistic impact of dairy-based protein with resistance training in aging adults.

Therefore, this study aims to investigate the combined effect of dairy-based nutritional supplementation and resistance training on muscle strength, lean body mass and physical function among geriatric adults. We hypothesized that the RT+DS group would show significantly greater improvements in muscle strength and function than RT alone or the control group.

MATERIALS AND METHODS

Study design

The RCT approach was used in this study to test the effects of dairy supplements and resistance exercises on older adults. The participants were assigned to three groups, including resistance training alone (RT), resistance training plus dairy products and nutrition (RT+DS), or control. Randomization was computer-generated using a blocked randomization sequence stratified by sex to ensure balanced group assignments. The allocation sequence was concealed using sealed, opaque envelopes prepared by a researcher not involved in participant enrollment. Tracked participant progress for 12 weeks while testing them before the study started at weeks 6 and 12.

Study population

A group of senior adults aged 60 to 80 lived in their communities and joined through promotional materials placed at senior centers, doctor offices and community organizations. Participants were screened for eligibility based on the following inclusion and exclusion criteria:

Inclusion criteria

The participants had to be within the geriatric age, which was between 60 to 80 years of age. They also had to be able to do the RT exercises with the less desirable body postures. Inclusion criteria included age between 50 to 70 years old, normal sedentary activity and a mini-mental state examination (MMSE) of at least 24. The participants had to be able to consume milk and dairy products, which formed part of the nutrition intervention in the study.

Exclusion criteria

Participants who had any previous musculoskeletal ailments or those who underwent orthopedic interventions within the previous 6 months were also kept out of the study to facilitate their protection during resistance training. The participants with lactose intolerance or those with dairy allergies were also not included because of their diets. Other exclusion criteria were people who had performed structured resistance training or used protein supplementation within the last half year and those who had chronic diseases influencing skeletal muscle metabolism and severe kidney or liver diseases.

Sample size

Calculating the sample size using a priori power analysis (α = 0.05 and power = 0.80) it was estimated that approximately 90 participants (30 in each group) were required to demonstrate statistically significant differences in muscle strength between the groups. Due to assuming a 15% dropout rate, a total of 105 participants were to be recruited.

Resistance training program

All the participants in the resistance training groups completed a supervised progressive resistance training regime. It focused on large muscle groups (leg muscles-quadriceps, hamstrings, pectoral, dorsal and abdominal muscles). It was noted that the intensity of the resistance training was personalized in terms of a percentage of each subject's one-repetition maximum (1RM) at the pre-testing session. The 1RM for each participant was estimated using the following equation:

$$1RM = \frac{W \times (1 + 0.0333 \times R)}{1}$$

Where,

W = Weight lifted.

R = Number of repetitions completed at the given weight.

All sessions took about 60 minutes where 10 minutes were spent on warm-up, 30-40 minutes on resistance exercises and 10 minutes on cooldown.

Dairy-based nutrition supplement

Consuming a commercial dairy-based nutritional supplement immediately post-exercise was an element within the combined intervention group. That supplement contained 20 g of protein (whey and casein), 10 g of carbohydrates and 300 mg of calcium per scoop. Protein

intake was monitored *via* participant-maintained logbooks, which were reviewed weekly by research staff.

No biochemical validation, such as serum urea nitrogen or nitrogen balance markers, was performed due to resource constraints.

$$\text{Total protein intake} = P_{serving} \times S_{consumed}$$

Where,
$P_{serving}$ = 20 g of protein per serving.
$S_{consumed}$ = Number of servings consumed per day.

Control group

The control group received only standard counseling to improve the quality of life concerning general exercises and a balanced diet but did not perform any structured resistance training or consume dairy products supplemental to the study.

Outcome measures

Primary outcome

The main dependent variable chosen for this study was muscle strength, which was evaluated with the use of handgrip dynamometry and 1RM for lower and upper body muscular groups, with leg press and bench press exercises. Handgrip strength was assessed for its global measure of muscle power and the 1RM tests offered a muscle-specific strength assessment. These assessments were administered at the pre-intervention phase, 6 weeks into the study and at the 12-week phase to capture changes in muscle strength throughout the study and thereby determine the efficacy of resistance training and dairy-based nutrition on muscle performance in geriatric adults.

$$\text{Grip strength} = \frac{(S_1 + S_2 + S_3)}{3}$$

Where,
S_1, S_2, S_3 = Strength measured in three different attempts (kg).

Secondary outcomes

The secondary outcomes involved body composition, functional performance and dietary intake. Body composition was determined by DEXA scan for the alteration in LBM and fat mass during the intervention. The Functional performance was assessed with the short physical performance battery (SPPB), which included a walking speed test, chair stand test and balance test to provide an overall physical function index. Further, the participants were requested to complete and record their 3-day food record at baseline and after completion of week 6 and week 12, which would show their nutrition profile and their compliance with the dairy-based nutrition plan.

Lean body mass (LBM)

$$\text{LBM} = \text{Total body mass} - \text{Fat mass}$$

Where,
Total body mass = Measured using a weight scale.
Fat mass = Measured *via* DEXA scan.

Short physical performance battery (SPPB)

$$\text{SPPB score} = G_{gait} + C_{stand} + B_{balance}$$

Where,
G_{gait} = Score for the gait speed test.
C_{stand} = Score for the chair stand test.
$B_{balance}$ = Score for the balance test.

Dietary intake

Participants completed 3-day food diaries at baseline, week 6 and week 12. Dietary logs were analyzed using standard nutritional software. Physical activity outside the intervention was recorded *via* weekly activity checklists to identify confounding activity levels.

Data collection and management

Outcome assessors were blinded to group assignment to minimize measurement bias. All assessments were made with similar calibrations and were performed in similar laboratories. The data were collected using electronic means on a secure database to minimize loss of data and to check on the quality of data collected.

Statistical analysis

The results on baseline characteristics were analyzed using frequency tables. Muscle strength, body composition and functional performance data were assessed by using repeated measures analysis of variance (RM-ANOVA). Further analysis of variance Tukey HSD was used after the overall analysis to determine the differences between groups in pairs. A p-value <0.05 was used to determine statistical significance. The statistical model used was:

$$Y_{it} = \mu + \tau_i + \gamma_t + (\tau\gamma)_{it} + \in_{it}$$

Where,
Y_{it} = Dependent variable for group i at time point t.
μ = Overall mean.
τ_i = Group effect.
γ_t = Time effect.
$(\tau\gamma)_{it}$ = Interaction between group and time.
$\in_{it}$ = Error term.

Ethical considerations

The study protocol was approved by the institutional ethics and written informed consent was obtained from the participants by the Declaration of Helsinki. All subjects signed a written informed consent before being recruited to the study. The study could involve participants placed in anonymity where no participant identification was in the results published.

RESULTS AND DISCUSSION

Baseline characteristics of participants

A total of 105 participants were recruited, of which 90 completed the 12-week intervention phase. The remaining 14% of participants did not complete the study due to personal or health issues unrelated to the intervention.

As shown in Table 1, the resistance training (RT), resistance training with dairy supplementation (RT+DS) and control groups were comparable at baseline across age, sex, body mass index (BMI) and handgrip strength (p>0.05). This comparability ensured that subsequent changes in outcomes could be attributed to the intervention effects. All values are reported as mean ± standard de*via*tion (SD). Missing data due to participant dropout were managed using a last observation carried forward (LOCF) method under an intention-to-treat analysis framework.

Primary outcome: Muscle strength

Muscle strength was the principal focus of the study and it was assessed using handgrip dynamometry and 1RM for major muscles. Muscle strength improved in all groups from the pre-intervention to 12-week follow-up with the combined group improving more than the other groups. The combined group at the 12-week follow-up had a mean adduction of 10.5 kg (p<0.001) in handgrip strength compared to the resistance training-only group, which had a mean adduction of 5.5 kg (p<0.001). The control group also showed a slight improvement from 21.8±4.5 kg to 22.6±4.9 kg, with the overall between-group difference being statistically significant (p<0.001) as per Table 2. All values are reported as mean ± standard deviation (SD). Effect sizes using Cohen's d indicated a large treatment effect for RT+DS (d ≈ 1.99) and a moderate-to-large effect for RT (d ≈ 1.12). Additionally, ANCOVA was conducted adjusting for baseline BMI and muscle mass and results remained statistically significant, confirming robustness to potential confounding variables.

While both RT and RT+DS showed improvements, the superior outcomes in the RT+DS group suggest a clear synergistic effect between mechanical loading and targeted nutritional support.

The greater gains in muscle strength and LBM in the RT+DS group are physiologically grounded in enhanced muscle protein synthesis (MPS). The ingestion of high-quality dairy proteins, particularly whey and casein, post-exercise offers both rapid and sustained amino acid delivery, which is crucial in overcoming anabolic resistance in older adults (Breen and Phillips, 2011). Leucine, abundant in dairy, is a potent stimulator of the mTOR pathway, thereby activating MPS and muscle hypertrophy mechanisms (Cermak *et al.,* 2012; Devries and Phillips, 2015). Muscle tissue mass is increased, neuromuscular coordination is improved and sarcopenia (a common condition of the elderly) is resisted by RT-induced mechanical stress on muscles (Bauer *et al.,* 2013). While this group did not receive dietary supplementation, the lack of an anabolic response likely blunted the benefits of exercise.

Fig 1 depict the handgrip strength before and after the three groups, RT, RT+DS and the control group after the 12-week intervention. The combined group recorded the highest post-intervention gain in handgrip strength, followed by the resistance training-only group. The control group remained rather low, which shows the effectiveness of the combined interventions on muscle strength in geriatric adults.

Secondary outcomes: Body composition and functional performance

In addition to muscle strength, body composition and functional performance measures were also measured. In the combined group, LBM was found to have risen by a mean of 2.3 kg (p<0.001). The only resistance training also increased LBM, but the improvement was slightly less at 1.5 kg (p<0.001) in Table 3. The control group also did not record any increase in LBM instead, it reduced slightly by 0.2 kg (p = 0.44). All values are reported as mean ± standard deviation (SD). The effect size was large for the RT+DS group (Cohen's d ≈ 1.00) and moderate for the RT group (d ≈ 0.66). The 95% confidence intervals (CIs) for the LBM change were 1.9-2.7 kg (RT+DS) and 1.1-1.9 kg (RT). Between-group differences in LBM at Week 12 remained statistically significant after covariate adjustment using ANCOVA, controlling for baseline BMI and LBM. Missing data due to participant dropout (14%) were handled using a last observation carried forward (LOCF) method under an intention-to-treat approach.

Table 1: Baseline characteristics of study participants.

Variable	RT (n=30)	RT+DS (n=30)	Control group (n=30)	p-value
Age (years)	68.3±4.2	67.8±3.9	68.5±4.5	0.72
Male (%)	53.3	56.7	50.0	0.84
BMI (kg/m^2)	24.9±1.8	25.1±1.9	25.0±2.0	0.93
Handgrip strength (kg)	21.5±4.3	22.0±4.1	21.8±4.5	0.87

RT - Resistance training; RT+DS - Combined resistance training and dairy supplementation; Control group.

Table 2: Changes in muscle strength (handgrip strength) across groups.

Time point	RT (kg)	RT+DS (kg)	Control group (kg)	p-value
Baseline	21.5±4.3	22.0±4.1	21.8±4.5	0.87
Week 6	25.1±4.7	27.8±4.3	22.2±4.8	<0.001
Week 12	27.0±5.0	31.5±4.9	22.6±4.9	<0.001

RT- Resistance training; RT+DS- Combined resistance training and dairy supplementation.

These results underline the importance of dairy proteins in muscle anabolism. The release of its amino acids into the bloodstream is rapid for whey protein and sustained for casein, which together support continuous muscle protein synthesis and the prevention of muscle protein breakdown (Reidy and Rasmussen, 2016). For older adults, who often have anabolic resistance (reduced responsiveness to protein intake), this dual action is particularly useful. In addition, dairy products may contain additional neuromuscular benefits by supplying calcium and bioactive peptides, the added benefits of resistance training (Hughes and Centner, 2024). These effects were evident in the 10.5 kg mean gain in handgrip strength and 2.3 kg rise in LBM in the RT+DS group, as opposed to 5.5 kg and 1.5 kg, respectively, in the RT group.

Data on the changes in the lean body mass (LBM) of the three groups are illustrated in (Fig 2). Collectively, the combined group demonstrated the greatest LBM gain, suggesting that this study is the first to show the interaction between dairy-based nutrition and resistance training. The same trend occurred in the resistance training-only group, although the increase was somewhat less pronounced. The changes in LBM in the control group were not significant and largely supported the suitability of the intervention to body composition.

Changes in functional performance

The functional performance, where the SPPB was used to measure the result, demonstrated the combined group had improved significantly compared to the other two groups in Table 4. The RT+DS group improved from 7.8±2.1 to 12.0±2.1 (p<0.001), with a mean improvement of 4.2±1.0 points. The RT group improved from 8.0±2.0 to 10.5±2.2 (p<0.001), with a mean change of 2.5±1.1 points. The control

Table 3: Changes in body composition (lean body mass) across groups.

Time point	RT (kg)	RT+DS (kg)	Control group (kg)	p-value
Baseline	52.4±6.5	53.0±7.1	51.9±6.7	0.92
Week 6	54.5±6.8	56.2±7.3	52.2±6.8	<0.001
Week 12	56.0±7.2	58.3±7.6	52.1±6.9	<0.001

RT- Resistance training; RT+DS- Combined resistance training and dairy supplementation.

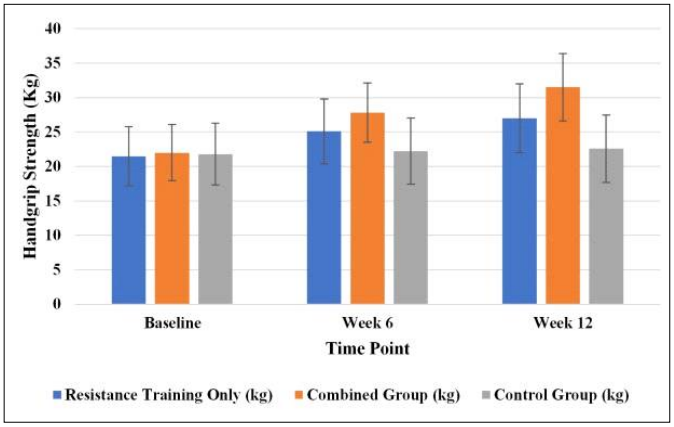


Fig 1: Muscle strength progression (handgrip strength) over 12 weeks.

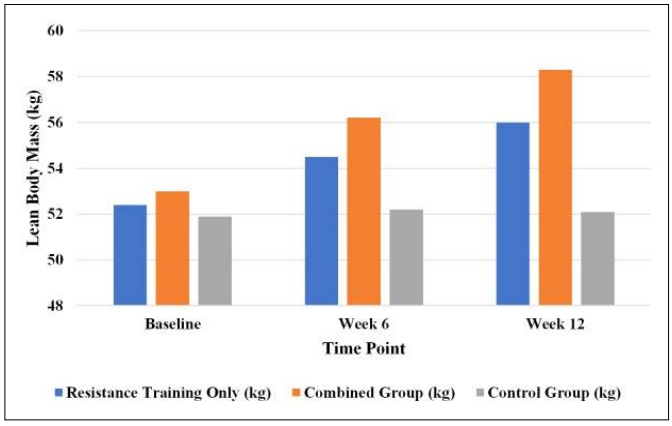


Fig 2: Changes in lean body mass over 12 weeks.

group showed a minor, non-significant increase from 7.9±2.2 to 8.7±2.3 (p = 0.21), with a mean difference of 0.8±1.0 points. All values are reported as mean ± standard deviation (SD). Cohen's d effect sizes indicated a large effect for RT+DS (d ≈ 1.00) and a moderate effect for RT (d ≈ 0.69). The 95% confidence intervals (CIs) for SPPB improvement were 3.4-5.0 points (RT+DS) and 1.7-3.3 points (RT). After covariate adjustment using ANCOVA for baseline BMI and baseline SPPB scores, the between-group differences remained statistically significant. Missing data due to participant dropout (14%) were handled using a last observation carried forward (LOCF) method within an intention-to-treat framework.

The findings are consistent with studies of the negative consequences of a sedentary lifestyle and low protein intake on sarcopenia and functional decline in older people (Deutz *et al.,* 2014; Traylor *et al.,* 2018). Functional performance plays an important role in enhancing independence and reducing the risk of falls in older adults. Higher levels of muscle strength and LBM, as well as better neuromuscular control, likely explained the beneficial effects on outcomes in the RT+DS group. The RT+DS group's 4.2-point SPPB gain surpasses clinical relevance thresholds and is supported by studies highlighting the functional role of resistance exercise and dietary protein in aging populations (Tieland *et al.,* 2012; Vasunilashorn *et al.,* 2009). The results underscore the importance of such interventions in offsetting physical decline with aging.

The combined group showed the greatest improvement as a result of resistance exercise training and dairy products on functional abilities (Fig 3). Similarly, the RT group also improved, the control group's progress was trivial at best, which further supports the benefits of the combined intervention regarding physical performance.

Adherence and compliance

Compliance with the intervention plan was high across all groups. The RT-only group maintained a 92% adherence to the structured exercise protocol, while the combined RT+DS group followed both exercise and dairy supplementation protocols with an 89% adherence rate.

The control group, which received standard lifestyle counseling without intervention, demonstrated 100% compliance throughout the study (Fig 4). All adherence values are reported as percentages based on weekly attendance records and logbook reviews. Group-level adherence remained consistent across age strata (60-70 and 71-80 years) and there were no significant sex-based differences. Missing adherence data due to participant dropout (14%) were addressed using last observation carried forward (LOCF) under an intention-to-treat analysis framework. Adherence variability did not significantly alter outcome trends when analyzed using ANCOVA controlling for age and baseline compliance.

Despite its robust findings, this study has limitations that must be acknowledged. First, dietary intake assessment relied on self-reported 3-day food records, which are susceptible to recall and reporting bias. The absence of biochemical markers (*e.g.*, serum nitrogen or leucine levels) limits objective validation of protein intake. Second, the 12-week intervention period, though adequate to observe short-term changes, may not capture long-term adherence, sustainability, or health outcomes such as falls or hospitalization rates. Third, the study population was

Table 4: Changes in functional performance (SPPB Score) across groups.

Time point	RT (Score)	RT+DS (Score)	Control group (Score)	p-value
Baseline	8.0±2.0	7.8±2.1	7.9±2.2	0.76
Week 6	9.5±2.0	11.1±2.0	8.1±2.1	<0.001
Week 12	10.5±2.2	12.0±2.1	8.7±2.3	<0.001

RT- Resistance training; RT+DS- Combined resistance training and dairy supplementation.

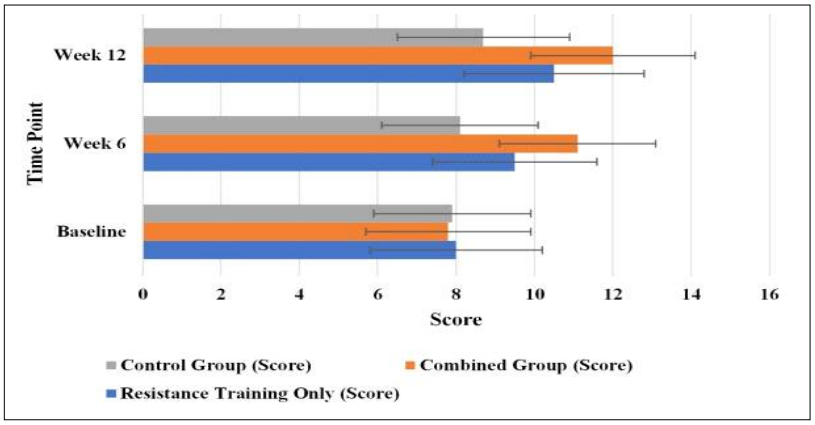


Fig 3: Functional performance (SPPB Score) over 12 weeks.

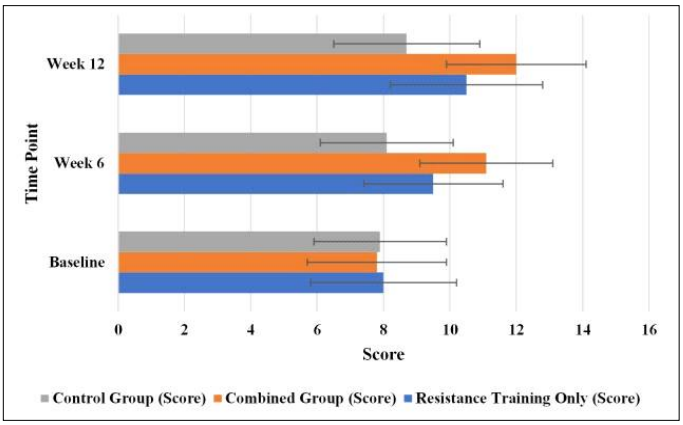


Fig 4: Adherence rates to intervention protocol.

relatively homogeneous in terms of geography and ethnicity, limiting the generalizability of findings to more diverse older adult populations.

Future research should investigate the optimal dosage and timing of protein intake to determine whether consumption before or after resistance training yields superior outcomes in muscle health among older adults. Additionally, comparative studies between dairy-based and plant-based protein sources would help accommodate individuals with dietary restrictions, allergies, or ethical preferences, thereby broadening the intervention's applicability.

Longitudinal studies are also needed to assess the sustainability of combined interventions and their long-term effects on health-related quality of life, fall prevention and healthcare expenditures. Moreover, future trials should involve larger, more demographically diverse populations and incorporate stratified analyses by sex, ethnicity, comorbid conditions and baseline physical activity levels to improve the generalizability and clinical utility of the findings across aging populations.

The findings of this study have practical implications for public health and geriatric care. As sarcopenia becomes increasingly prevalent with aging populations, community-based interventions that integrate structured RT with accessible dairy-based supplements could offer scalable strategies to mitigate frailty. Guidelines for geriatric care should emphasize the dual role of physical activity and nutrition as standard non-pharmacological strategies to promote musculoskeletal health. Public health programming can incorporate these findings into senior wellness programs, with tailored support for adherence and dietary monitoring.

CONCLUSION

The study confirms that performing RT through dairy-based nutritional supplementations elicited a positive and significant effect on muscle strength, body composition and functional performance of geriatric adults. Regarding handgrip strength, the outcomes of all the subjects in the combined intervention group presented greater enhancements than the resistance training-only group and the CG. The exercise group had higher handgrip strength than the control group, which did not receive any intervention. However, both exercise and nutritional support are critical for muscle health in elderly patients. Body composition tests proved that both resistance training alone and combined training groups grew their lean body mass significantly. The combined training produced the largest lean body mass increase. Dairy proteins work together with exercise to boost muscle protein production according to past research findings. The combined group improved physical functionality and mobility more than resistance training alone based on SPPB scores. Our research shows that combined interventions help elderly people stay active and lead better lives while fighting against sarcopenia effects. Resistance training plus dairy supplements effectively stop muscle strength loss in aging adults.

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Conflict of interest

There is no conflict of interest among the authors.

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