Protein supplementation under resistance training conditions in elderly patients with sarcopenia: A meta-analysis of randomized controlled trials

Rui Cheng¹, Meng Xu¹, Xu-Jun Qin², Yi Wan³*, Xiao-Long Ye⁴*

¹ Xijing Hospital, Air Force Medical University, Xi’an, Shaanxi, 710032, China.

² School of Preventive Medicine, Air Force Medical University, Xi’an, Shaanxi, 710032, China.

³ Department of Health Services, Health Logistics Training Base, Air Force Medical University, Xi’an, Shaanxi, 710032, China.

⁴ Educational Testing and Evaluation Center, Air Force Medical University, Xi’an, Shaanxi, 710032, China.

* Correspondence: yxlong@fmmu.edu.cn; wanyi@fmmu.edu.cn

Abstract

Background: The efficacy of interventions for elderly patients with sarcopenia has received increasing attention. Exercise and nutrition have been recognized as effective treatments for sarcopenia in many studies. However, evidence-based support from relevant studies is still lacking.

Methods: The PubMed, Embase, Cochrane Library, VIP, CNKI, and SinoMed databases were searched. The basis for the diagnosis of sarcopenia, general condition of the subjects, duration and methods of exercise/nutritional therapy, outcome indicators, and quality of evidence were evaluated, and a meta-analysis of differences in treatment outcomes between the groups from baseline to the end of each study was
conducted.

**Results:** A total of 1860 papers were screened, including six randomized controlled trials, and the effects of protein intervention under exercise conditions on muscle mass, strength, and function in elderly patients with sarcopenia were investigated. The results showed that protein supplementation under resistance exercise conditions had the following effects on elderly patients with sarcopenia: there was a significant difference in knee flexion and extension strength ($p = 0.02$), grip strength ($p = 0.02$), fat mass ($p = 0.04$), and normal pace and pace ($p = 0.0008$ and $p = 0.0010$, respectively) between the intervention group and baseline data.

**Conclusion:** The meta-analysis revealed some positive effects of protein intervention treatment under exercise conditions on elderly patients with sarcopenia. However, the quality of evidence is low. High-quality randomized controlled trials should be conducted in the future to provide a better clinical basis.

**Keywords:** Sarcopenia, Exercise, Proteins

1. Introduction

Sarcopenia is a progressive disease associated with advancing age in which muscle mass and/or muscle strength or physiological function, is decreased[1]. Early symptoms of sarcopenia are not typical. However, this latent and easily overlooked disease frequently causes adverse outcomes such as fractures, disability, and loss of activity in the elderly, while it increases the risk of disability and seriously that affects the quality of life[2]. Therefore, reasonable interventions should be provided for elderly patients with sarcopenia based on early detection and diagnosis, which is
significant for improving the quality of life[3].

Currently, the primary treatment of sarcopenia includes drug treatment[4], nutritional intervention[5, 6], and exercise therapy[7, 8]. Elderly patients should consume 1.0-1.5 g/kg body weight of protein per day. Branched-chain amino acids are important amino acids that constitute muscle proteins. Whey protein is rich in branched-chain amino acids and can increase muscle mass and some muscle functions[9]. Studies have reported that exercise therapy is based primarily on resistance, rapid strength, and whole-body vibration training. Further studies have reported primary interventions such as tai chi and massage[10].

Although the clinical understanding of sarcopenia has improved, and exercise and nutrition have been found to be effective treatments for sarcopenia[11], research on the therapeutic effect of protein supplementation on senile sarcopenia patients under the condition of resistance training is lacking. This study used meta-analysis to investigate the effects of protein supplementation under resistance training conditions on the symptoms of sarcopenia in elderly patients under randomized controlled trial conditions, to provide reliable evidence-based support for the development of nutrition and exercise programs for elderly patients with sarcopenia.

2. Materials and methods

2.1 Search strategy

The PubMed, Embase, Cochrane Library, VIP, CNKI, and SinoMed databases were searched. Date limits were from database establishment to April 2019. The key words the literature retrieved included “sarcopenia”, “exercise”, “sports”, “physical
education”, “resistance exercise”, “resistance training”, “proteins”, “lactalbumin”,
“albumin”, “amino acids”, “peptides”, “milk proteins” and “dietary proteins”. Search
strategy: Sarcopenia AND (Exercise OR sports OR physical education OR resistance
exercise OR resistance training) AND (proteins OR lactalbumin OR albumins OR
amino acids OR peptides OR milk proteins OR dietary proteins).

2.2 Literature inclusion and exclusion criteria

The inclusion criteria were the following: (1) elderly people aged ≥60 years; (2)
participants diagnosed with sarcopenia based on the criteria established by the
European Working Group on Sarcopenia in Older People, Asia Working Group for
Sarcopenia, International Working Group on Sarcopenia, and Foundation for the
National Institutes of Health[12]; (3) randomized controlled trial study design; and (4)
the intervention was for protein supplementation under regular resistance training
conditions.

The exclusion criteria were the following: (1) repeated publications; (2)
diagnostic criteria for sarcopenia were experimental tools or scale assessment.

Primary outcome indices were muscle strength (including grip strength and knee
flexion and extension strength), pace (including normal and maximum pace), and
skeletal muscle mass.

Secondary outcome indices were limb muscle mass index, body weight, body
mass index, and fat mass.

2.3 Data extraction

Two researchers independently extracted the data before table extraction and
performed a crosscheck. Extracted information primarily included the author of the paper and year of publication, basis for sarcopenia diagnosis, basic characteristics of the research subjects, duration of the exercise/nutrition therapeutic intervention, details of the exercise/nutrition intervention, and outcome indices.

2.4 Literature screening and quality assessment

Two researchers independently assessed the included papers based on literature quality assessment standards in the *Cochrane Handbook* version 5.1.0[13], and disagreements were resolved through consensus or expert consultation.

2.5 Statistics

Data were quantitatively combined using RevMan version 5.3 software. If there was heterogeneity among the studies ($I^2 \geq 50\%$), a random-effects model was used for the meta-analysis, and if the heterogeneity among the studies was small ($I^2 < 50\%$), a fixed-effects model was used. Continuous variable data were expressed as weighted (WMD) or standardized (SMD) mean difference and 95% confidence intervals (95% CI). In this study, the final value after intervention was used as the main effect parameter. If the difference in baseline data between the intervention and control groups was too large, the difference between the baseline measurement and the final value after intervention was used as the effect parameter. The $p < 0.05$ standard was used for overall response, and Z-test was used for statistical analysis of the meta-analysis results. Publication bias was analyzed using Egger’s or Begg’s test, with $p > 0.10$ indicating no publication bias.
3. Results

3.1 Literature search results

In the initial screening, 1781 papers satisfying the search requirements were selected, of which six were finally included after layer-by-layer screening [14-19]. The process for paper inclusion is shown in Figure 1. Basic characteristics of the included papers are shown in Table 1.

![Fig. 1 Paper inclusion process](image-url)
Table 1 Basic characteristics FFM, fat-free mass; DEXA, dual-energy X-ray absorptiometry; PASE, Physical Activity Scale for the Elderly.

| Author          | Date  | Diagnostic evidence                                                                 | Region | Age     | Sex | Total | Intervention group | Outcome variables                                                                 |
|-----------------|-------|-------------------------------------------------------------------------------------|--------|---------|-----|-------|-------------------|---------------------------------------------------------------------------------|
| Yun-Kyoung Kim  | 2002  | Physical constitution (summed heel height and ankle circumference)                   | South Korea | M/F    | 50 | 25 | Male/Caucasian | Intervention: 1. Fat mass; 2. Lean mass |
| Siihara         | 2013  | Anthropometric measurements (body weight, height, body fat, fat-free mass, muscle mass) | Malaysia | 50-70 | 18 | 30 | Female/Asian | Intervention: 1. Fat mass; 2. Lean mass | Intervention: 1. Fat mass; 2. Lean mass | Physical Activity Scale for the Elderly (PASE) | Body weight | Body mass index (BMI) | Energy intake | Energy expenditure (EE) |
| Deereb, Sethuraman | 2016  | Dual-energy X-ray absorptiometry (DEXA)                                              | India   | 60-70 | 60 | 15 | Exercise terrain | Intervention: 1. Fat mass; 2. Lean mass | Intervention: 1. Fat mass; 2. Lean mass | Physical Activity Scale for the Elderly (PASE) | Body weight | Body mass index (BMI) | Energy intake | Energy expenditure (EE) |
| Mathew, L.     | 2018  | Dual-energy X-ray absorptiometry (DEXA)                                              | Canada  | 60-70 | 180 | 30 | Exercise terrain | Intervention: 1. Fat mass; 2. Lean mass | Intervention: 1. Fat mass; 2. Lean mass | Physical Activity Scale for the Elderly (PASE) | Body weight | Body mass index (BMI) | Energy intake | Energy expenditure (EE) |
| Mathew, L.     | 2018  | Dual-energy X-ray absorptiometry (DEXA)                                              | Canada  | Elderly | 20 | 10 | Exercise terrain | Intervention: 1. Fat mass; 2. Lean mass | Intervention: 1. Fat mass; 2. Lean mass | Physical Activity Scale for the Elderly (PASE) | Body weight | Body mass index (BMI) | Energy intake | Energy expenditure (EE) |
| Shu Chen        | 2018  | Dual-energy X-ray absorptiometry (DEXA)                                              | China   | 50-90 | 40 | 20 | Exercise terrain | Intervention: 1. Fat mass; 2. Lean mass | Intervention: 1. Fat mass; 2. Lean mass | Physical Activity Scale for the Elderly (PASE) | Body weight | Body mass index (BMI) | Energy intake | Energy expenditure (EE) |

3.2 Methodological quality assessment of the included papers

Two researchers independently performed quality assessments of the included papers based on the literature quality assessment standards in the Cochrane Handbook version 5.1.0. The results showed that the quality of the six papers was grade B. The risk of bias for individual studies is shown in Figure 2, and the risk proportion for study inclusion is shown in Figure 3.
3.3 Meta-analysis results

The included papers had intervention durations ranging from 12 to 24 weeks. The six included papers all employed a matched randomized design, of which five employed a random number table for grouping and one did not report the method of randomization. Allocation concealment was used in two papers, and specific
allocation concealment was not reported or mentioned in four. A double-blind methodology was used in four papers, and two did not report the method of blinding. All data in the results of the included paper were complete, description of the selected reports was clear, and there were no other factors that led to bias in the implementation of the study.

This meta-analysis continued to analyze whether the difference between the intervention group and baseline data was significant when data between the control and experimental groups after intervention was not significant. If the difference between the intervention group and baseline data was not significant, the analysis would not be performed. The following are the significant different of the data between the control group and the experimental group and the significant differences between the intervention group and baseline data.

3.3.1 Effect of protein supplementation under resistance training conditions on knee flexion and extension strength in elderly patients with sarcopenia.

Two studies have analyzed the effect of protein supplementation under resistance training conditions on knee flexion and extension strength in elderly patients with sarcopenia. The heterogeneity among the studies was high ($p = 0.03, I^2 = 79\%$), and the random-effects model was used. The results revealed no significant difference in knee flexion and extension strength between the two groups [SMD = 0.44, 95% CI (-0.33, 1.22), $p = 0.26$] (Figure 4).
Fig. 4 Effect of protein supplementation under resistance training conditions on knee flexion and extension of elderly patients with sarcopenia: intervention vs. experimental group

The intervention group and baseline data were reanalyzed. The heterogeneity among the studies was low ($p = 0.38$, $I^2 = 0\%$), and the fixed-effects model was used. The results revealed a significant difference in knee flexion and extension strength between the two groups [$SMD = -0.41$, $95\% CI (-0.76, -0.06)$, $p = 0.02$] (Figure 5).

Fig. 5 Effect of protein supplementation under resistance training conditions on knee flexion and extension of elderly patients with sarcopenia: intervention group vs. baseline data

3.3.2 Effect of protein supplementation under resistance training conditions on grip strength in elderly patients with sarcopenia

Two studies analyzed the effect of protein supplementation under resistance training conditions on grip strength in elderly patients with sarcopenia. The heterogeneity among the studies was low ($p = 0.42$, $I^2 = 0\%$), and the fixed-effects model was used. The results revealed a significant difference in grip strength between the two groups [$WMD = 2.27$, $95\% CI (0.39, 4.14)$, $p = 0.02$] (Figure 6).
3.3.3 Effect of protein supplementation under resistance training conditions on skeletal muscle mass in elderly patients with sarcopenia

Five studies analyzed the effect of protein supplementation under resistance training conditions on skeletal muscle mass in elderly patients with sarcopenia. The heterogeneity among the studies was low ($p = 0.40$, $I^2 = 2\%$), and the fixed-effects model was used. The results revealed no significant difference in skeletal muscle mass between the two groups [WMD = -0.24, 95% CI (-1.29, 0.82), $p = 0.66$] (Figure 7). A reanalysis of the intervention group with baseline data also revealed no significant difference in skeletal muscle mass between the two groups.

![Fig. 6 Effect of protein supplementation under resistance training conditions](image)

On grip strength in elderly patients with sarcopenia

3.3.4 Effect of protein supplementation under resistance training conditions on limb

![Fig. 7 Effect of protein supplementation under resistance training conditions](image)

On skeletal muscle mass in elderly patients with sarcopenia
muscle mass index in elderly patients with sarcopenia

Two studies have analyzed the effect of protein supplementation under resistance training conditions on limb muscle mass index in elderly patients with sarcopenia. The heterogeneity among the studies was low ($p = 0.24$, $I^2 = 28\%$), and the fixed-effects model was used. The results revealed no significant difference in limb muscle mass index between the two groups [WMD = -0.03, 95% CI (-0.71, 0.65), $p = 0.93$] (Figure 8). A reanalysis of the intervention group with baseline data also showed no significant difference in the limb muscle mass index between the two groups.

![Fig. 8 Effect of protein supplementation under resistance training conditions](image)

On limb muscle mass index in elderly patients with sarcopenia

3.3.5 Effect of protein supplementation under resistance training conditions on body weight of elderly patients with sarcopenia

Four studies have analyzed the effect of protein supplementation under resistance training conditions on the body weight of elderly patients with sarcopenia. The heterogeneity among the studies was low ($p = 0.75$, $I^2 = 0\%$), and the fixed-effects model was used. The results revealed no significant difference in knee flexion and extension strength between the two groups [WMD = 1.87, 95% CI (-2.72, 6.45), $p = 0.42$] (Figure 9). A reanalysis of the intervention group with baseline data also revealed no significant difference in body weight between the two groups.
3.3.6 Effect of protein supplementation under resistance training conditions on body mass index of elderly patients with sarcopenia

Four studies have analyzed the effect of protein supplementation under resistance training conditions on the body mass index of elderly patients with sarcopenia. The heterogeneity among the studies was low \( (p = 0.35, I^2 = 9\%) \), and the fixed-effects model was used. The results revealed no significant difference in body mass index between the two groups \([\text{WMD} = -0.42, 95\% \text{ CI} = (-1.27, 0.43), p = 0.33]\) (Figure 10).

A reanalysis of the intervention group with baseline data also revealed no significant difference in body mass index between the two groups.

3.3.7 Effect of protein supplementation under resistance training conditions on fat
mass in elderly patients with sarcopenia

Three studies have analyzed the effect of protein supplementation under resistance training conditions on fat mass in elderly patients with sarcopenia. The heterogeneity among the studies was low \( p = 0.16, I^2 = 46\% \), and the fixed-effects model was used. The results revealed a significant difference in fat mass between the two groups \([\text{WMD} = -0.41, 95\% \text{ CI} (-0.80, -0.02), p = 0.04]\) (Figure 11).

![Fig. 11 Effect of protein supplementation under resistance training conditions on fat mass in elderly patients with sarcopenia](image)

3.3.8 Effect of protein supplementation under resistance training conditions on normal pace in elderly patients with sarcopenia

Two studies have analyzed the effect of protein supplementation under resistance training conditions on normal pace in elderly patients with sarcopenia. The heterogeneity among the studies was low \( p = 0.37, I^2 = 0\% \), and the fixed-effects model was used. The results showed that for exercise and nutritional model training, the difference in normal pace between the two groups was statistically significant \([\text{WMD} = -0.72, 95\% \text{ CI} (-1.14, -0.30), p = 0.0008]\) (Figure 12).
3.3.9 Effect of protein supplementation under resistance training conditions on maximum pace in elderly patients with sarcopenia

Two studies have analyzed the effect of protein supplementation under resistance training conditions on maximum pace in elderly patients with sarcopenia. The heterogeneity among the studies was low ($p = 0.39, I^2 = 0\%$), and the fixed-effects model was used. The results revealed a significant difference in maximum pace between the two groups [WMD = -0.71, 95% CI (-1.13, -0.29), $p = 0.0010$] (Figure 13).

3.4 Publication bias analysis

Egger’s test reported no significant publication bias existed for the included
studies ($p > 0.10$).

4. Discussion

4.1 Methodological quality assessment of included studies

Our meta-analysis, which aimed to evaluate the effect of protein supplementation under resistance exercise conditions in elderly patients with sarcopenia, demonstrated a significant effect of protein supplementation on increasing muscle strength and pace in these patients.

4.2 Effect of protein supplementation under resistance training conditions on increasing muscle strength in elderly patients with sarcopenia compared to conventional therapy

With respect to different muscle sites, knee flexion and extension strength, grip strength, and peak inspiratory flow rate are usually used as evaluation methods[20]. Knee flexion and extension strength forest plot results showed that exercise and nutritional therapy could improve knee flexion and extension strength in elderly patients with sarcopenia. Grip strength forest plot results showed that protein supplementation under resistance exercise conditions could improve grip strength in elderly patients with sarcopenia. Muscle strength refers to “the ability of the human nerve-muscle system to overcome or oppose resistance while working.” Based on this definition, strength does not only involve muscle but is also closely associated with nerves; on the one hand, increased muscle cross section, i.e., muscle hypertrophy, is involved, and on the other hand, the improvement of motor unit recruitment ability is involved[21]. Protein intake is positively correlated with muscle mass and strength.
Protein inherently promotes the synthesis of muscle proteins[22], especially of whey protein that is rich in branched-chain amino acids, which prevents muscle breakdown and promotes muscle synthesis[23]. A number of meta-analyses and systematic retrospective studies[24-32] have concluded that active strength training, including progressive resistance training, can significantly increase muscle strength in the elderly or patients with chronic ill. A systematic review[7] showed that comprehensive exercise for 3-18 months increased muscle strength and improved physical function but had no significant effect on muscle mass, which is consistent with the findings of the meta-analysis in the present study. This may be related to nerve recruitment ability[33]. As the number of motor units activated during muscle contraction reflects the state of muscle recruitment, the greater the number of motor units involved in contraction, the greater is the muscle strength. Regular, long-term exercise training continuously strengthened certain muscles in the subjects, resulting in a large enhancement in muscle recruitment and thereby an increase in muscle strength.

4.3 Effect of protein supplementation under resistance training conditions on fat mass in elderly patients with sarcopenia compared to conventional therapy

The forest plot results showed that protein supplementation under resistance exercise conditions can increase fat mass in elderly patients with sarcopenia. All subjects were aged ≥60 years and diagnosed with sarcopenia. They have lower protein absorption capacity and protein conversion rate than normal elderly individuals. When compared at the same basal metabolic rate, increased moderate exercise
combined with complete diet structure in addition to sufficient daily protein intake may cause excessive protein intake, resulting in a surplus of calories and an increase in fat mass.

4.4 Effect of protein supplementation under resistance training conditions on pace in elderly patients with sarcopenia compared to conventional therapy

The results of both normal and maximum pace forest plots showed that exercise and nutritional therapy can improve the pace of elderly patients with sarcopenia. The pace of all subjects increased through exercise and nutrition, and with adequate nutrition, their ability to perform continuous muscle work also increased. Studies have shown significant improvements in the lung capacity, minute ventilation, cardiac output, and ejection fraction of elderly subjects after long-term resistance training[34]. We believe that resistance training continuously improved lung and heart function, which in turn increased the exercise ability of the subjects, resulting in increased pace.

However, the study also had some limitations, such as the inclusion of only a few studies due to language restrictions, inconsistent quality of research methods, possibility of publication bias, small sample size, and short exercise duration. Discovering the effects of other outcome indices, such as muscle mass, may be difficult.

5. Conclusions

Protein supplementation under resistance training conditions has a positive effect on the treatment of elderly patients with sarcopenia. However, more high-quality, large-sample, multicenter randomized controlled trial studies are needed to further
evaluate the therapeutic effects. The 6 articles included in this study all adopted intervention measures of nutrition and exercise, but the article did not mention whether an informed agreement was signed with the observation group before the intervention.

**Data Availability**

The data sets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

**Conflicts of Interest**

The authors declare no conflicts of interest.

**Funding Statement**

This work was supported by the Funding of the First Affiliated Hospital of the Air Force Medical University.

**Acknowledgments**

The authors would like to thank participants for their time and commitment to the study.

**Ethics approval and consent to participate**

All subjects have provided their written informed consent prior to enrolment, and the Local Ethics Committee has approved the study protocol.
References

1. R. A. Fielding, B. Vellas, W. J. Evans et al., "Sarcopenia: An Undiagnosed Condition in Older Adults. Current Consensus Definition: Prevalence, Etiology, and Consequences. International Working Group on Sarcopenia," *Journal of the American Medical Directors Association*, vol. 12, no. 4, 2011.

2. L. Koeun, S. Yongbin, H. Jimi et al., "Recent Issues on Body Composition Imaging for Sarcopenia Evaluation.," *KOREAN JOURNAL OF RADIOLOGY*, vol. 20, no. 2, 2019.

3. E. Freiberger, C. Bollheimer, S. Goisser et al., "Sarcopenic obesity and complex interventions with nutrition and exercise in community-dwelling older persons – a narrative review," *Clinical Interventions in Aging*, vol. 2015, no. default, 2015.

4. R. Yves, O. Graziano, M. J. E, G. Sophie, A. van Kan Gabor, V. Bruno, "Current and future pharmacologic treatment of sarcopenia.," *CLINICS IN GERIATRIC MEDICINE*, vol. 27, no. 3, 2011.

5. J. J. H. Morante, C. G. Martinez, J. M. Morillas-Ruiz, "Dietary Factors Associated with Frailty in Old Adults: A Review of Nutritional Interventions to Prevent Frailty Development," *Nutrients*, vol. 11, no. 1, 2019.

6. N. Anders, H. Kim, K. M. A, C. Claus, "Musculoskeletal ageing and primary prevention.," *Best practice & research. Clinical obstetrics & gynaecology*, vol. 27, no. 5, 2013.

7. C. A. J, L. Francesco, S. S. M et al., "Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS).," *AGE AND AGEING*, vol. 43, no. 6, 2014.

8. X. Michail, "The role of exercise in prevention of sarcopenia and frailty of elderly," *Annals of*
Physical and Rehabilitation Medicine, vol. 57, no. 2014.

9 N. M. Cermak, "Perspective: Protein Supplementation During Prolonged Resistance Type Exercise Training Augments Skeletal Muscle Mass and Strength Gains," Journal of the American Medical Directors Association, vol. 14, no. 1, 2013.

10 F. Hita-Contreras, A. Martínez-Amat, D. Cruz-Díaz, F. R. Pérez-López, "Osteosarcopenic obesity and fall prevention strategies," MATURITAS, vol. 80, no. 2, 2015.

11 C. Liao, H. Chen, S. Huang, T. Liou, "The Role of Muscle Mass Gain Following Protein Supplementation Plus Exercise Therapy in Older Adults with Sarcopenia and Frailty Risks: A Systematic Review and Meta-Regression Analysis of Randomized Trials," Nutrients, vol. 11, no. 8, pp. 1713, 2019.

12 Y. Zeng, X. Hu, L. Xie, Z. Han, Y. Zuo, M. Yang, "The Prevalence of Sarcopenia in Chinese Elderly Nursing Home Residents: A Comparison of 4 Diagnostic Criteria," Journal of the American Medical Directors Association, vol. 19, no. 8, 2018.

13 J. SJ, "Review: Cochrane handbook for systematic reviews for interventions, Version 5.1.0, published 3/2011. Julian P.T. Higgins and Sally Green, Editors," Research Synthesis Methods, vol. 2, no. 6, 2011.

14 H. K. K. PhD, T. S. MD, PhD et al., "Effects of Exercise and Amino Acid Supplementation on Body Composition and Physical Function in Community-Dwelling Elderly Japanese Sarcopenic Women: A Randomized Controlled Trial," JOURNAL OF THE AMERICAN GERIATRICS SOCIETY, vol. 60, no. 1, 2012.
15 M. L. Maltais, J. P. Ladouceur, I. J. Dionne, "The Effect of Resistance Training and Different Sources of Postexercise Protein Supplementation on Muscle Mass and Physical Capacity in Sarcopenic Elderly Men," JOURNAL OF STRENGTH AND CONDITIONING RESEARCH, vol. 30, no. 6, 2016.

16 M. L. Maltais, K. Perreault, A. Courchesne-Loyer, J. Lagacé, R. Barsalani, I. J. Dionne, "Effect of Resistance Training and Various Sources of Protein Supplementation on Body Fat Mass and Metabolic Profile in Sarcopenic Overweight Older Adult Men: A Pilot Study," INTERNATIONAL JOURNAL OF SPORT NUTRITION AND EXERCISE METABOLISM, vol. 26, no. 1, 2016.

17 S. Shahar, Noor, M. Badrasawi et al., "Effectiveness of exercise and protein supplementation intervention on body composition, functional fitness, and oxidative stress among elderly Malays with sarcopenia," Clinical Interventions in Aging, vol. 2013, no. 2013.

18 Shu C, Yunlu S, Ting Q, Xiaomei S, Xiaowei J, "Effects of fortifies nutrition combining with resistance exercise on physical function and activity of daily living for elderly patients with sarcopenia," Journal of Nursing Science, vol. 32, no. 21, pp. 8-10, 2017.

19 D. Zdzieblik, S. Oesser, M. W. Baumstark, A. Gollhofer, D. König, "Collagen peptide supplementation in combination with resistance training improves body composition and increases muscle strength in elderly sarcopenic men: a randomised controlled trial," BRITISH JOURNAL OF NUTRITION, vol. 114, no. 8, 2015.

20 B. A. E, H. Nilay, K. Samantha, M. Matthew, "Sarcopenia and frailty in chronic respiratory disease.," Chronic Respiratory Disease, vol. 14, no. 1, 2017.

21 E. R. M, D. Jacques, "Rate Coding and the Control of Muscle Force.," Cold Spring Harbor Perspectives in Medicine, vol. 7, no. 10, 2017.
22 P. Lopez, R. S. Pinto, R. Radaelli et al., "Benefits of resistance training in physically frail elderly: a systematic review," AGING CLINICAL AND EXPERIMENTAL RESEARCH, vol. 30, no. 8, 2018.

23 R. Mariangela, K. Catherine, T. Gilles et al., "Whey protein, amino acids, and vitamin D supplementation with physical activity increases fat-free mass and strength, functionality, and quality of life and decreases inflammation in sarcopenic elderly.," The American journal of clinical nutrition, vol. 103, no. 3, 2016.

24 H. T. C. PhD, Y. C. C. PhD, Y. J. C. MD, PhD, S. Y. H. PhD, H. J. W. PhD, "Effects of Different Types of Exercise on Body Composition, Muscle Strength, and IGF-1 in the Elderly with Sarcopenic Obesity," JOURNAL OF THE AMERICAN GERIATRICS SOCIETY, vol. 65, no. 4, 2017.

25 A. B. Gadelha, F. M. L. Paiva, R. Gauche, R. J. de Oliveira, R. M. Lima, "Effects of resistance training on sarcopenic obesity index in older women: A randomized controlled trial," ARCHIVES OF GERONTOLOGY AND GERIATRICS, vol. 65, no. 2016.

26 G. Francesco, C. Antonio, S. N. Andrew, V. Carlo, "Resistance training and sarcopenia.," Monaldi archives for chest disease = Archivio Monaldi per le malattie del torace, vol. 84, no. 1-2, 2016.

27 H. Shih-Wei, K. Jan-Wen, L. Li-Fong, L. Chun-De, C. Lin-Chuan, L. Tsan-Hon, "Body composition influenced by progressive elastic band resistance exercise of sarcopenic obesity elderly women: a pilot randomized controlled trial.," European Journal of Physical and Rehabilitation Medicine, vol. 53, no. 4, 2017.

28 W. Kemmler, M. Teschner, A. Weissenfels et al., "Whole-body electromyostimulation to fight sarcopenic obesity in community-dwelling older women at risk. Resultsof the randomized controlled FORMOsA-sarcopenic obesity study," OSTEOPOROSIS INTERNATIONAL, vol. 27, no. 11, 2016.
29 M. Kohei, A. Yasuyoshi, I. Hideaki, F. Hiroaki, A. Tomoyuki, Y. Haruyasu, "Effect of a simple and adherent home exercise program on the physical function of community dwelling adults sixty years of age and older with pre-sarcopenia or sarcopenia.," Journal of physical therapy science, vol. 28, no. 11, 2016.

30 M. Emanuele, C. Riccardo, T. Matteo et al., "Physical activity and exercise as countermeasures to physical frailty and sarcopenia.," AGING CLINICAL AND EXPERIMENTAL RESEARCH, vol. 29, no. 1, 2017.

31 F. Santin-Medeiros, J. P. Rey-López, A. Santos-Lozano, C. S. Cristi-Montero, N. G. Vallejo, "Effects of Eight Months of Whole-Body Vibration Training on the Muscle Mass and Functional Capacity of Elderly Women," JOURNAL OF STRENGTH AND CONDITIONING RESEARCH, vol. 29, no. 7, 2015.

32 T. C. S. MS, M. S. F. PhD, J. R. S. PhD et al., "Muscle architecture and strength: Adaptations to short-term resistance training in older adults," Muscle & Nerve, vol. 49, no. 4, 2014.

33 H. E, S. G, C. D. O, "FUNCTIONAL SIGNIFICANCE OF CELL SIZE IN SPINAL MOTONEURONS.," JOURNAL OF NEUROPHYSIOLOGY, vol. 28, no. 1965.

34 M. P. D. C. de Rezende Barbosa, V. C. Oliveira, A. K. F. D. Silva, A. R. P. Riera, L. C. Vanderlei, "Effectiveness of functional training on cardiopulmonary parameters: a systematic review and meta-analysis of randomized controlled trials," CLINICAL PHYSIOLOGY AND FUNCTIONAL IMAGING, vol. 38, no. 4, 2018.