"What are the effects of dietary protein intake and resistance exercise on skeletal muscle mass in elderly people?"

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Preface

At the beginning of September 2009 I started my graduation project at Wageningen University. My preference was particular for a research project at Wageningen University, because working in this scientific environment and the research fields being studied here on human nutrition are in my field of interest.

In this thesis you can read my literature review written in order of the Division of Human Nutrition as a graduation for my Bachelors degree in Nutrition and Dietetics. For 5 months I was involved in the set-up phase of the ProMuscle study. I am proud to say that I was able to be a part of this project and work in such a great team. I have been working in an environment were professionalism and enthusiasm gave me the opportunity to gain experience and learn more skills in research.

This thesis consist a literature review were the effects of resistance exercise, dietary protein intake and the combined effect on skeletal muscle mass in elderly people is lined out. Writing this review made me improve my scientific writing skills, my English and gave me a good view in this topic. With completing this work I finally feel that working in this field attracts me! I am really looking forward to proceed with a Masters degree and to be more working in research on human nutrition and physical activity topics.

With completing this thesis I was able to get great support from Michael Tieland, I appreciate his helpful, personal and critical supervision. I would like to thank him for his daily supervision and enthusiasm and wish him good luck with completing his PhD project. As well the supervision of Saskia Meyboom who helped me setting up my research and coaching me through my time in Wageningen. I couldn’t complete this thesis without the control of Anne Doornbos and Minse de Bos Kuil who coached me and gave feedback during this project.

Finally, I realize that finishing a graduation project takes an important place in your daily life and it was a pleasure to work with the students at Wageningen and my roommate Thomas where I spend a lot of enjoyable moments with. As well my friends and parents who were always there to listen to my enthusiastic stories and ambitions, as well coaching me during the last months.

I hope you all will enjoy reading my thesis as much as I did writing it!

Wageningen, January 2010

Imre Kouw
Abstract

**Objective** There is an age related loss of skeletal muscle mass which has adverse outcomes that influence the quality of life in elderly people. This review lines out what the effects are of resistance training, dietary protein intake and the combination of these on skeletal muscle mass in the aged population to counteract this process.

**Methods** Relevant articles were searched through Medline database up to January 2010. Studies were obtained by consulting experts, references and abstracts. Reviews, meta-analyses and clinical trials were used to clarify different mechanisms and to obtain results from earlier studies.

**Results** Resistance exercise is found to have a stimulating effect on skeletal muscle protein balance and result in increases in strength, skeletal muscle mass and function. Dietary protein stimulates muscle protein synthesis in a greater degree and results in net positive protein balance. The long term effects of supplemented dietary protein in elderly people are increases in skeletal muscle mass, strength and physical function. However, the post-exercise muscle anabolism seems to be most effective after a combination of resistance exercise and dietary derived essential amino acids. There is still no consensus about the amount of protein intake, source and timing of ingestion. More research is needed to clarify to interactive effect between dietary protein intake, resistance exercise and skeletal muscle adaptive response.

**Conclusion** Resistance exercise can effectively offset the progression of sarcopenia. In addition to this an extra amount in dietary protein is found to be beneficial in increasing skeletal muscle mass and muscle strength. A combination of resistance type training and additional dietary protein intake could have a greater effect on increasing skeletal muscle mass and strength. However, limited studies are showing results of long term research of hypertrophy in the skeletal muscle in elderly people. Future studies should focus on prolonged timed dietary protein intake in a resistance exercise training program to help preventing the loss of skeletal muscle mass and slow down the process of sarcopenia.

**Keywords:** aging, skeletal muscle mass, resistance exercise, dietary protein
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1 Introduction: the aging muscle

Aging comes together with the loss of skeletal muscle mass, also known as sarcopenia. Sarcopenia can be defined as the loss of muscle protein mass which results in both the loss of muscle strength and a decline in the functional quality of the skeletal muscle [1, 2]. This is associated with many adverse outcomes as decreased mobility and function, the difficulty to perform tasks of daily living, the increased risk of falls and injuries, increased fatigue, an increased risk of metabolic disorders, institutionalization and these factors resulting in a poorer quality of life and increased mortality [3, 4].

Sarcopenia can be seen as a multifactorial health condition where a cycle of physiological and psychological factors are found. Both the age related cellular changes as a set of outcomes form a vicious circle with rather than one distinct cause. The lack of physical activity, inadequate food intake, change in protein metabolism, changes in the hormonal and inflammatory environment, a loss of neuromuscular function, oxidative damage, altered gene expression and apoptosis are found as factors that may contribute in part to develop sarcopenia in elderly people [3, 5].

As a result of the process of sarcopenia, loss of reserve capacity and a sedentary lifestyle will result in an increasing sense of effort to perform exercise. With lacking daily physical activity a decrease in the ease of performing daily tasks and a further decline in muscle strength contributes more loss of skeletal muscle mass. This cycle were the loss of skeletal muscle mass plays a key role can be stated trough a ‘use it or lose it’ paradigm [1, 5].

Physical activity and particular resistance type exercise has been found as a potential strategy to decrease the age related loss of skeletal muscle mass (SMM) and function. Many studies found effects of resistance training in the aged population such as increases in strength, skeletal muscle mass/fat free mass, function (ability to perform tasks of daily living) and decreases in fat mass [1, 6].

In attempt to understand the decline of skeletal muscle tissue that comes with aging, the deregulation in the skeletal muscle protein turnover is found to be a part of the age-related loss of muscle mass. Imbalances where muscle protein breakdown (degradation) exceeds muscle protein synthesis, resulting in a net negative balance, is found to result in a significant loss of muscle mass in combination with a suboptimal diet an a sedentary lifestyle over more years [4, 5, 7].
The skeletal muscle protein metabolism seems to be well responsive to resistance exercise. An increased protein synthesis rate is found after training in humans. However, skeletal muscle protein breakdown is as well stimulated following resistance exercise; although to a lesser extent than protein synthesis. This results in an increased net muscle protein balance that persist up to 48 h [8]. On the other hand, the effect of only resistance training does improves the muscle protein balance but still results in a net negative balance on longer term in the skeletal muscle [9]. Increases in muscle strength and so physical performance and functional capacity were found after a high intensity training program of resistance type exercise [4, 10-12]. With the addition of nutrient intake the stimulation of the muscle protein synthesis will be more effective in the skeletal muscle to allow muscle hypertrophy [4]. The ingestion of dietary protein and/or amino-acids strongly stimulates the synthesis and inhibits the protein breakdown, which will result in a net positive balance [13-15].

The effects of the combination of resistance exercise and dietary protein intake must be the most favorable, although the response on whole body level as in protein synthesis and/or degradation is still unclear. What the best strategies are, how they work and how they can be used, needs to be elucidated. There is lack of clear understanding of the effects of resistance exercise in combination with dietary protein intake in elderly people and specific dietary recommendations to slow down the progression of sarcopenia should be further investigated. Therefore, the aim of this literature study is to describe the different effects of resistance exercise, dietary protein intake and the combination of these two on the skeletal muscle mass in elderly people. In chapter 3 the short- and long term effects of resistance exercise on skeletal muscle mass will be lined out, following in chapter 4 with the short- and long term effects of dietary protein intake on skeletal muscle mass in elderly people. This review concludes with the findings of the combined effect of resistance type exercise and dietary protein intake and ends with some recommendations concerning intervention strategies.
2 Methods

2.1 Searching strategy and data extraction
For this review all English and Dutch articles were searched in Medline (PubMed, Ovid) database. Additional studies were conducted by searching in reference lists and contacting experts for authors, journals and titles of relevant studies. Reviews, meta-analyses and clinical trials were included in this review to obtain insight in the literature. Search terms related to these studies were: ‘elderly people’, ‘aging’, ‘sarcopenia’, ‘skeletal muscle mass’, ‘resistance exercise’ (or resistive/strength training), ‘dietary proteins’, ‘amino acids’.

2.2 Review methods
Outcome measures in this review were terms to search on as: ‘skeletal muscle mass’, ‘hypertrophy’, ‘FFM’ (fat free mass), ‘LBM’ (lean body mass), ‘CSA (cross sectional area), ‘muscle strength (or 1RM)’, ‘physical performance’, ‘muscle protein turnover’ (or muscle protein balance), ‘muscle protein synthesis (rate)’ and ‘muscle protein breakdown (rate)’.

The quality of the found literature was examined by methodology, impact factor of the journal, author and the published date. With these findings this review is written to give an overview of results and clarification of the different mechanisms on the use of intervention strategies.
3 What are the effects of resistance exercise on skeletal muscle mass?

3.1 Aging and changes in the skeletal muscle

There is a significant loss of motor units and skeletal muscle fibres with increased age: a decline of skeletal muscle fibre number and a change in cross-sectional area (CSA) of the remaining fibres [5, 16]. The loss of skeletal muscle mass results from a loss in both slow and fast motor units, with an accelerated loss of fast motor units. In addition, skeletal muscle fibre atrophy occurs during aging. Also the remaining motor units recruit denervated fibres, changing their fibre type to that of the motor unit. As a result, there is a net conversion of fast twitch (type II) fibres into slow twitch (type I) fibres [17]. The loss of both fibre types I and II and an accelerated loss of type II fibres results in a loss of strength and power. As type II skeletal muscle fibres are used for muscle power necessary for short actions as rising from a chair, climbing stairs and regaining balance this will have a negative effect in performing daily tasks as these [3].

3.2 The effects of resistance exercise on the muscle fibres

Resistance exercise is found to have effect on increasing skeletal muscle mass in elderly people, as well increases in strength and power and improvements in physical performance and functional capacity [6, 11, 18]. Resistance exercise can be defined as the performance of dynamic or static muscular contractions against external resistance, were the intensity can have different varieties [19]. As a result of resistance exercise an increase of number in myofibres and myofibrillar protein myosin and actin are found, in addition changes in muscle fibre cross-sectional area are observed [20, 21]. There is clear evidence that myofibre hypertrophy occurs after resistance exercise training [22-24]. The degree of which each myofibre grows as the number of myofibres in the muscle showed increases post-exercise, alterations in the cross sectional area of skeletal muscle fibres were found [24]. With this, resistance training has an effect on gaining muscle mass and power production [6, 25]. Muscle mass is found to be a major determinant of strength. To investigate the effects on muscle strength and muscle quality, studies measuring muscle strength with 1 RM tests (maximum strength in one repetition) found improvements after resistance training programs [12, 26, 27]. Muscle strength has been shown to increase in response to training between 60 and 100% of the 1 repetition maximum. Trappe et al., were able to maintain strength gain in elderly for up to 6 months, by training once a week [28, 29].
3.3 The effects of resistance exercise on protein turnover

Muscle protein turnover consists of the balance between muscle protein synthesis and protein breakdown that determines the net protein balance and the net protein gain. Earlier studies on protein metabolism in skeletal muscle metabolism in elderly people hypothesized that the change in metabolism that is responsible for sarcopenia is a reduction in basal muscle protein synthesis compared to younger adults [30, 31]. More recent studies could not confirm these results so the reason for the occurrence of sarcopenia might lie in the response to anabolic stimuli as exercise [32, 33].

![Muscle protein turnover diagram](image-url)

*Figure 1. Muscle protein turnover is altered with aging. Several physiological changes affect protein synthesis or degradation of skeletal muscle proteins, (d) effect decreases with age, (i)effect increases with age. Adapted from [3, 5]*

Skeletal muscle growth (hypertrophy) will occur when there is a net anabolism within the muscle. This means that there must be a period where the protein net balance is positive (synthesis minus breakdown), either an enhanced muscle protein synthesis or a reduced muscle protein breakdown. The Fractional Synthesis Rate (FSR) representing the rate of protein synthesis and the Fractional Breakdown Rate (FBR) representing the rate of breakdown of body protein are correlated [34].

The rate of mixed muscle protein synthesis, an average of all muscle proteins, is stimulated by a single bout of resistance type exercise in 2 – 4 hours [8]. Skeletal muscle proteins that are increased after resistance exercise are most likely actin and myosin heavy chain (MHC); these proteins are most abundant in the skeletal muscle. This can be confirmed by observations in young and elderly people showing raised muscle protein synthesis rates of myosin heavy chain after a single resistance exercise session [30, 31, 35]. Skeletal muscle hypertrophy occurred after resistance exercise, positive effects in increasing FSR in response to a bout of resistance exercise in elderly have been shown [8, 9, 30, 36].
Opposite to this, an increase in the FBR post exercise is observed. But still due to a
greater elevation in protein synthesis rate than protein breakdown this results in an
improved muscle net protein balance that lasts for 48 hours in untrained elderly [8].
A greater rise in mixed muscle protein synthesis is found acute after performing a
single bout of resistance exercise [21], still net muscle protein balance remains
negative in the absence of nutrient intake. Both exercise and nutrition are found to
obtain a positive protein balance [37]. In chapter 4 the effects of the intake of dietary
protein on skeletal muscle mass to obtain muscle hypertrophy will be further
described.

3.4 The elderly population

Differences between elderly people and younger adults are found. Hypertrophy of
muscle volume is lower in elderly people as compared with younger adults [38]. The
increase in muscle protein synthesis with resistance exercise is lower in older people
than in young [20, 31, 38]. Also the muscle growth response was less in elderly
people than in young [23]. Although, a more recent study of Sheffield-More and
coworkers showed that muscle protein synthesis did not increase after 1-3 hour in
older adults compared with younger subjects where an increase was found [39]. This
suggests that there is a blunted anabolic response in elderly on resistance exercise
and a lesser extend of hypertrophy.

In conclusion, it has been clearly shown that the effects of resistance exercise in
elderly people are having great benefits, including increases in skeletal muscle mass,
skeletal muscle composition, strength and power and reducing the difficulty of
performing daily tasks. With guidance for a well set up training program this can be
an effective intervention strategy in lowering the unfavorable loss of skeletal muscle
mass in the process of aging and improve the functional capacity of the elderly.
Increasing muscle strength and skeletal muscle mass can be a step towards a
realistic strategy for maintaining functional status and independence.
4 What are the effects of dietary protein on skeletal muscle mass?

4.1 Dietary protein intake in elderly

Dietary protein intake is needed to stimulate the protein synthesis as the protein turnover changes continuously. A positive protein balance can be supported by the intake of a sufficient amount of dietary derived amino acids. Insufficient protein intake in elderly people may facilitate the loss of skeletal muscle by blunting muscle protein synthesis and thus promoting net muscle protein catabolism [40].

The current Recommended Dietary Allowance (RDA) for adults over the age of 19 years is set at a dietary protein intake of 0.8 g/kg/day, regardless of gender, age and level of physical activity [28]. It has been suggested that this RDA is inadequate for elderly people to maintain the protein balance [41]. As the needs for elderly people are higher, a clear understanding of the etiology for the increased need for protein is not well understood and there is (still) no consensus in the literature concerning the amount of protein needed in elderly people [42]. Many researchers have tried to investigate what should be the actual dietary protein need for elderly people to cover the offset of lower energy intakes, maintain nitrogen balance, decreased efficiency of muscle protein synthesis and impaired insulin response [40].

Milward and coworkers confirmed that the recommendation of 0.8 g/kg/day should be sufficient [43], others studies have suggested that a moderately higher intake of 1.0-1.3 g/kg/day is needed [15, 40, 42, 44]. Wolfe et al. confirmed that an intake of 0.8 g/kg/day protein a day is too low for elderly and recommended that the intake should be more about 1.5 g/kg/day [45]. Also high protein intakes has to be deliberated with the potential risk of toxicity or impaired renal function. More researchers are still discussing on the intake needed for the aged population, it is clear that more research is asked to define a sufficient guideline for protein intake in elderly people.

4.2 Effects of dietary protein intake on protein turnover

Since infusion of amino acids was found to increase muscle protein synthesis rates and reduce the rate of muscle protein breakdown [34, 46] evidence is shown that oral ingestion of protein and/or amino acids stimulate muscle protein synthesis and inhibits muscle protein breakdown. This will result in a positive net protein balance [4, 14].

It is still unclear which mechanisms are responsible for the increasing effect of protein intake on the muscle protein metabolism. The role of the Mammalian Target of Rapamycin (mTOR) protein is found to be involved in the muscle protein synthesis in the skeletal muscle, a rise of activity in the mTOR pathway was shown after ingestion of 10 grams essential amino acids [44]. The role of insulin seems to be
important to inhibit muscle protein breakdown as well, but outlining this mechanism and potential effects on the muscle protein turnover is outside the scope of this review [47].

The loss of skeletal muscle mass in elderly could be due to a blunted anabolic response, what was found after the ingestion of a mixed nutrient meal [15, 44, 48]. A difference in response to amino acids was found in young and older subjects. Post absorptive rates of protein synthesis were the same in both age groups although the muscle protein synthesis in elderly people responded less effective on the intake of an amount of 10 grams amino acids, compared with younger adults. This could suggest that elderly people are less sensitive to the intake of amino acids and show less anabolism in response to amino acids. Subsequently this might explain the age related decline in skeletal muscle mass in this group. It is still unclear why elderly people have well a diminished decline in muscle protein breakdown post-prandial together with the impaired muscle protein synthesis to the intake of protein [4, 49].

4.3 Source

The infusion of complete mixtures of amino acids [34, 50, 51] or ingestion of intact proteins [14, 15, 52, 53] resulted in increases in muscle protein synthesis. Especially essential amino acids (EAAs) are found to have an effect on stimulating muscle protein synthesis [54] as compared with nonessential amino acids [35]. Leucine particular is found as one of the regulators to stimulate muscle protein synthesis post-prandial [55]. But evidence that leucine should decrease the rate of protein breakdown is still being discussed [56]. A study of Katsanos et al. found a higher rise in muscle protein synthesis after the ingestion of a mix of amino acids with a large proportion of leucine than with a lower proportion leucine [57]. Also, another study found that a higher content of leucine particular should be the main responsible factor for increasing the muscle protein synthesis comparing lower amounts of leucine of only amino acids [58]. At least, a study of Guillet et al suggests that to raise the plasma EAA concentration to trigger the maximal response after a meal, the total amount of essential amino acids is concerned. This maximal anabolic response could be achieved with a doses of 10 g of EAA (equivalent to 20 g of meat, fish, eggs, or milk) [44]. Suggested is that insulin plays an important role in this process, were leucine stimulates the secretion of insulin and so an anabolic response after ingestion [59]. On the other hand results are shown were essential amino acids were effective on muscle protein synthesis independent of insulin [44]. The role of insulin in muscle protein balance needs to be researched more in dept.

When leucine is supplemented during 3 months, no effects on skeletal muscle mass and/or strength were reported by [62], but more evidence is needed to see what long
term leucine supplementation can effect in the muscle protein metabolism. With these findings it can be said that leucine is proven to stimulate muscle protein synthesis in the short term, however more evidence is needed about the effect of leucine on long term and the part of total intake of essential amino acids.

Also, digestibility of protein-rich foods may influence muscle protein synthesis [40]. Suggested is that a slow digested protein (as casein) leads to a more positive protein balance compared with a fast digested protein (as whey) or a mixture of free amino acids in young [63]. However, in elderly subjects opposite effects were found and fast digestible protein was preferred to stimulate muscle protein synthesis in elderly [64]. An impaired protein digestion and/or absorption exist as the result of aging and the anabolic response in synthesis on protein intake will be lower. More research should explain the differences in young and elderly on muscle protein metabolism in relation with digestion and/or absorption of the amino acids. Bioavailability of protein rich foods may influence muscle protein synthesis, whereas proteins found in milk showed a greater synthetic response than a soy beverage in young adults [21, 64]. Paddon-Jones and coworkers concluded that irrespective of the source, meals should contain a moderate amount of high quality protein supposed that a typical meal will always contain a variety of proteins [40].

To amplify this, a study of Guillet et al suggests elderly people to eat a high amount of protein to sufficiently raise the plasma EAA concentration to trigger the maximal response after a meal. This maximal anabolic response could be achieved with 10 g of EAA (equivalent to 20 g of meat, fish, eggs, or milk) [44].

4.4 Timing of ingestion

The timing of ingesting amino acids are found to have an influence on the muscle protein metabolism as well. A single meal with 80% of daily protein gives an acute peak of amino acids (pulse feeding) and leads to greater protein turnover rates in elderly woman than ingesting the same amount of protein provided over 4 meals (spread feeding) [65]. However, this same effect was not found in young females [66].

When combining protein intake with resistance exercise, it can be stated that the early intake of a protein supplementation directly after each bout of resistance training is required for muscle hypertrophy, contrarily to 2 hours later. In this study hypertrophy was shown in the group that received direct protein supplementation compared with the control group who received nutritional supplementation 2 hours after the training session and showed no improvements in muscle hypertrophy after 12 weeks. [67]. As well a study conducted by Cribb and Hayers showed greater
gains in muscle strength in the group receiving dietary proteins supplementation close after training that the group that ingested dietary protein in the morning [68]. Thus the timing of intake of dietary protein might be important to stimulate muscle protein synthesis and result in skeletal muscle hypertrophy.

To conclude this chapter, various effects of dietary protein intake on skeletal muscle mass in elderly people are discussed. The intake of protein stimulates the muscle protein synthesis and inhibits the muscle protein breakdown, resulting in a net positive protein balance. The further understanding of the mechanisms being responsible for this anabolic response of protein intake in elderly people need to be investigated more in dept to understand the age related loss of skeletal muscle mass in elderly. Especially, the intake of essential amino acids or possibly leucine has noted to show significant effects in elderly people. Also in elderly the digestion rate seems to be important, whereas fast digestible proteins showed favorable results. The timing of the ingestion of proteins should be examined to effectively trigger muscle protein synthesis and result in a net positive balance, whereas the timing of ingestion might be an important factor in the protein feeding pattern. With this, targeted control of dietary protein intake can be one an important intervention in preventing and/or treating sarcopenia.
5 What are the effects of resistance exercise and dietary protein on skeletal muscle mass?

5.1 A positive net protein balance

As stated earlier, in the absence of food intake protein synthesis is not fully activated in the skeletal muscle tissue with only resistance exercise and will result in a net negative protein balance. The combined effect of resistance exercise and protein seems to result in the greatest net anabolic state via amino acid and exercise induced increases in protein synthesis and minimal or no change in protein breakdown [69]. Amino acids have been shown to have effect on a further elevation of insulin levels in blood plasma and reduce to breakdown of protein. The short term effects of the ingestion of dietary protein prior to or directly after resistance exercise has improving effects on the muscle protein balance. Numerous studies show that the combination of amino acid intake and resistance exercise promotes muscle protein synthesis (specific the MHC proteins) and increases skeletal muscle mass in elderly people [38, 70, 71]. Enhanced synthesis rates were found after ingestion an extra amount of amino acids and breakdown rates were depressed [21, 72, 73].

However recent long term studies are not showing clear outcomes and the discussion on protein supplementation are still going. For example the prolonged effects of a resistance exercise program recently studies, resulted in increases in skeletal muscle mass and strength after 3 months in elderly man, but a supplementation of timed protein (before and immediately after exercise) did not further increased hypertrophy and strength of the skeletal muscle compared with the placebo group [74]. Other studies did not show improvements in muscle strength and skeletal muscle mass when protein intake post exercise was increased more than the RDA [69, 75, 76]. Fat free mass (FFM) increased in some of the studies, but an extra effect of dietary protein intake on FFM was not found overall between the groups. An overview of the results of studies being conducted in elderly people where both resistance exercise and a supplementation of dietary protein were given are shown in table 1.
Table 1: Summary of studies with supplementation of dietary protein and/or amino acids together in a program of resistance exercise in elderly: effects on skeletal muscle mass and strength

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants (age in years)</th>
<th>Duration (weeks)</th>
<th>Frequency (days/week)</th>
<th>Intensity (% 1RM or total RM)</th>
<th>Amount (in different groups)</th>
<th>Source</th>
<th>SMM (increase % or kg)</th>
<th>Strength (increase range or mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[10]</td>
<td>37 males, 63 females; (mean ± SD, 87.1± 0.6)</td>
<td>10</td>
<td>3</td>
<td>80 % 1 RM</td>
<td>17 en%</td>
<td>Soy based</td>
<td>+ 1.0 ± 0.4 kg / 1.8 %</td>
<td>↑ 11 ± 8% **</td>
</tr>
<tr>
<td>[77]</td>
<td>19 males (range, 51-69 y)</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>[67]</td>
<td>13 males; (mean ± SD, 74 ± 1)</td>
<td>12</td>
<td>3</td>
<td>80 % 1 RM</td>
<td>10 g directly (P0) or 2h (P2) after RT</td>
<td>Skimmed milk + soy</td>
<td>↑ CSA 4-7% * († in P0)</td>
<td>↑ 42% in both groups</td>
</tr>
<tr>
<td>[78]</td>
<td>21 males; (mean ± SD, 65 ± 5)</td>
<td>12</td>
<td>3</td>
<td>80 % 1 RM</td>
<td>1.03 and 1.15 g/kg/day</td>
<td>Soy and beef</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>[79]</td>
<td>101 males and females (mean, 74 y)</td>
<td>52</td>
<td>-</td>
<td>-</td>
<td>13 en% in 2 servings</td>
<td>Liquid</td>
<td>FFM unchanged</td>
<td>Handgrip strength and muscle function improved most in RT + supplement group</td>
</tr>
<tr>
<td>[80]</td>
<td>48 males (range 48-72 y)</td>
<td>16</td>
<td>3</td>
<td>80 % 1 RM</td>
<td>0.37g/kg/day and/or 5 g creatine</td>
<td>Whey and creatine</td>
<td>↑ FFM and hypertrophy in CSA</td>
<td>↑ In all groups, no difference with whey or creatine</td>
</tr>
<tr>
<td>[81]</td>
<td>22 males and 30 females; (range, 60-69)</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>↑ 1.1 +/- 1.5 kg * FFM both groups</td>
<td>-</td>
</tr>
<tr>
<td>[82]</td>
<td>38 males; (range 59-76 y)</td>
<td>12</td>
<td>3</td>
<td>70 % 1 RM</td>
<td>0.3 g/kg/day</td>
<td>-</td>
<td>↑ FFM 1.0-1.7 kg *</td>
<td>↑ 22-31% in all groups *</td>
</tr>
<tr>
<td>[83]</td>
<td>191 males and females (mean, 85 y)</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>30 en% (7.4 g) and 2 en% (0.2 g)</td>
<td>Liquid</td>
<td>-</td>
<td>↑ 11.6 vs. 10.8 kg * (1RM) in both groups</td>
</tr>
<tr>
<td>[84]</td>
<td>39 males (mean ± SD, 55 ± 1)</td>
<td>24</td>
<td>-</td>
<td>-</td>
<td>10 g</td>
<td>Whey</td>
<td>↑ 0.8 kg LBM * ‡</td>
<td>↑ 9 % ‡</td>
</tr>
<tr>
<td>[85]</td>
<td>36 males and females; (mean ± SD, 61± 1)</td>
<td>12</td>
<td>3</td>
<td>-</td>
<td>0.9 and 1.2 g/kg/day</td>
<td>Animal based protein</td>
<td>↑ LBM 3.6 vs. 3.1 % *</td>
<td>↑ 28 vs. 34%*</td>
</tr>
<tr>
<td>[74]</td>
<td>26 males; (mean, ± SD, 72±2)</td>
<td>12</td>
<td>3</td>
<td>60-75 % 1 RM (wk 1-4) 75-80 (wk 5-12)</td>
<td>20 g</td>
<td>Casein hydrolysate</td>
<td>CSA: ↑ 9±1% **</td>
<td>↑ 1RM 25-35 % **</td>
</tr>
</tbody>
</table>

RT= resistance training, P= protein supplementation, SMM= skeletal muscle mass, WLBM=whole-body lean body mass, LLBM= leg lean body mass, FFM=fat free mass, CSA= cross sectional area * p<0.05, ** p<0.01, ‡= significant difference between nutrient groups
This table shows different findings resulting in increasing skeletal muscle mass and strength in elderly people. Not all studies showed more increases after a treatment were resistance exercise and dietary protein was combined. Some can be of a limitation in number of subjects, duration of resistance exercise program or amount of protein intake. The absence of results could be due to the timing of the protein intake or quality and source of used proteins. Also, baseline nutritional status could have influenced the response on protein intake, where as undernourished elderly can shown different responses to protein intake an/or resistance exercise than well-nourished elderly. Main findings in table 1 are that exercise increases skeletal muscle mass and fat free mass in elderly people. The additional effect of extra protein intake did not show equal differences between the groups in the studies. It is clear that more studies have to be conducted to find out whether the effect of an extra amount of dietary proteins could have positive effects in elderly with sarcopenia.

5.2 Source of dietary proteins in addition to resistance type exercise

Protein can be consumed from a variety of sources, limited studies investigated if the predominant source of consumed protein affects the responses to resistance exercise in elderly people. Campbell et al. evaluated the effects of a meat-containing and a meat-free diet on skeletal muscle size in older men after a resistance size program of 12 weeks. The total protein intake was about 0.8 and 1.0 g/kg/day respectively in the 2 groups. No effects were found between the groups in muscle strength, but muscle mass increased in the omnivorous group and decreased significantly in the vegetarian group [77]. This can be confirmed by earlier findings of Pannemans and coworkers were the protein breakdown was not inhibited in the same extend with a high vegetable-protein-diet comparing with a high containing animal based protein diet [86]. Haub et al. compared soy vs. beef diet containing 0.6 g/kg/day protein in elderly men during a 12 week resistance exercise program. The two groups showed comparable increases in strength among the muscle groups, as well in cross sectional area. In this study there was concluded that muscle hypertrophy after resistance exercise is not influenced by protein source from soy or beef [78]. At last, Iglay et al. concluded that body composition responses to resistance training when amounts above the RDA are consumed, and that this influence is more important than the predominant source of dietary protein intake [76].
6. Conclusion

In conclusion, main findings of this review are that resistance exercise is an effective stimulator for muscle protein synthesis and has a little stimulating effect on muscle protein breakdown. This results in a positive balance that persists up to 48 hours. Increases in skeletal muscle mass and strength are found in elderly people after prolonged resistance exercise training. This confirms that resistance exercise is an effective strategy to prevent or treat the loss of skeletal muscle mass in elderly people. Also, dietary protein is found to stimulate muscle protein synthesis and inhibits the muscle protein degradation. Supplementation of essential amino acids showed improvements of increasing lean body mass, muscle strength and physical function in response to the diet with essential acids in a few studies. There is still no consensus on the use of different factors influencing muscle protein synthesis as amount, source, digestibility and timing of intake of dietary protein intake.

The combined effects of resistance exercise and dietary protein seem to result in the greatest skeletal muscle anabolism. Although not all studies confirm this effect, this could be due to the lacking knowledge of dietary protein supplementation. The source of the dietary protein is found to be an important factor, as essential amino acids showed more effect than nonessential amino acids. As well, leucine is found to be a stimulator, although this effect is not fully proven in elderly adults in long term studies. Animal based protein might have a greater effect on skeletal muscle mass and strength in elderly, compared with vegetable-dietary-protein. There is still discussion going on about the precise recommendation in amount of intake. Many studies approve the fact that the RDA for elderly should not be enough to cover the extra needs in the aged population. Nevertheless, studies did not show a clear evidence of the suggested amount of supplementation in addition to a program of resistance type exercise. The timing of ingestion seems to be important in stimulating muscle protein synthesis and resulting in skeletal muscle hypertrophy. A recent study concluded that skeletal muscle mass could not be further augmented in healthy elderly people after a timed protein supplementation in combination with a program of resistance exercise training [74]. However, more research is needed to focus on elderly suffering with sarcopenia where timed protein intake during a resistance exercise program might show more effect. With these conclusions the effects of resistance exercise, dietary protein intake and a combined intervention are lined out and can be effective to prevent or overcome the age related loss of skeletal muscle mass in elderly people.
References


