Minerals and Healthy Ageing: a systematic review

The effect of calcium, iron, magnesium, phosphorus, potassium, selenium, and sodium on muscle mass, muscle strength, and physical performance in the elderly

Maya Abdelrazek and Aafke van Velzen

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Preface

You are about to start reading our thesis: Minerals and Healthy Ageing. We would like to introduce ourselves beforehand, and explain about the origin of this review. We are two students, with a great interest in health and nutrition, and are currently in the process of completing our bachelor in Nutrition and Dietetics at the Amsterdam University of Applied Sciences. Nutrition for the elderly became a true passion for us, and it was a valuable experience to carry out a systematic review on this subject. We sincerely hope that our thesis will eventually lead to a better insight into the prevention and treatment of sarcopenia.

We would like to thank everyone that supported us in the process of writing this thesis. First of all, we would like to thank our supervisor Michael Tieland for providing feedback and knowledge, and for motivating us during the whole process. We would like to thank our examiner Anouk van der Steen for checking and providing us with feedback that took our thesis to a higher level. Above all, we want to thank the Amsterdam University of Applied Science, in specific Carliene van Dronkelaar and Jantine van den Helder, for giving us the opportunity to gain experience in performing field research, and for aiding us in carrying out research. We would also like to thank our groupmates of the VITAMINE project, as we helped each other out and motivated each other during the semester. Lots of thanks to our families, for always supporting us. A special note of thanks to Steffie Abdelrazek and Emily Seddon, for proof-reading this thesis. Lastly, we would like to thank you, the reader of this thesis, for showing interest in our review. We hope you will enjoy reading this.

Maya Abdelrazek and Aafke van Velzen

Amsterdam, June 2016
Abstract

Background
As the world’s population grows older, so grows the prevalence of sarcopenia, the age-related loss of muscle mass, muscle strength, and physical performance. To counteract sarcopenia, nutrition might play an important role. So far, there is no complete overview of the data of various observational or interventional studies on the effect of minerals to treat or prevent sarcopenia.

Objectives
The aim of this systematic review was to assess the impact of various minerals on muscle mass, muscle strength, and physical performance in the elderly.

Methods
This review draws upon results collected from a systematic search in the PubMed database. The studies that were used as the basis of this review were selected using pre-defined eligibility criteria. Studies were included if they examined the effect of the dietary intake of minerals or mineral blood concentrations, on muscle mass, muscle strength, or physical performance in healthy or frail human populations with an average age of 65 years. Studies were assessed on relevance and quality by two independent researchers.

Results
A total of thirteen studies have been included in this review. Calcium was positively associated with muscle mass and physical performance in men, but not in women. The effect of calcium on sarcopenia remains unclear. The intake of iron was significantly associated with gait speed in men, but not in women. Magnesium supplementation is shown to have a significant effect on physical performance, and sarcopenic elderly people had a significantly lower intake of magnesium. Intake of phosphorus and selenium was also significantly lower in sarcopenic elderly individuals. The association between dietary selenium and physical performance is still unclear. Serum magnesium and serum selenium are positively related to muscle strength and serum selenium is shown to have a positive effect on muscle mass. No significant relation between serum iron and physical performance was found. No studies were found that discussed the effects of sodium or potassium on muscle mass, muscle strength, or physical performance.

Conclusions
Minerals could potentially play an important role in preventing and treating sarcopenia. An adequate intake of minerals in the elderly should be emphasized; especially magnesium shows to have a positive effect on sarcopenia, in particular on physical performance. More research into the role of minerals in muscle mass, muscle strength, and physical performance is desired, since evidence is poor.

Keywords: sarcopenia, elderly, minerals, ageing
Table of contents

1 BACKGROUND 5

2 METHODS 7
   2.1 SEARCH STRATEGY 7
   2.2 SELECTION AND QUALITY ASSESSMENT 7
   2.3 REPORT CHARACTERISTICS 8

3 RESULTS 9
   3.1 CHARACTERISTICS OF STUDIES 10
   3.2 CALCIUM 11
   3.3 IRON 13
   3.4 MAGNESIUM 14
   3.5 PHOSPHORUS 14
   3.6 POTASSIUM 16
   3.7 SELENIUM 16
   3.8 SODIUM 16
   3.9 SERUM CONCENTRATIONS 17

4 DISCUSSION 20

5 CONCLUSION AND RECOMMENDATIONS 24

REFERENCES 25

APPENDIX A: SEARCH STRINGS 1

APPENDIX B: QUALITY ASSESSMENT TOOL FOR QUANTITATIVE STUDIES IV
1 Background
The share of the world’s population aged 65 and over is growing exponentially. In 2014, 8.1 percent of the total world population was aged 65 or older. In the United States, 14.4 percent of the citizens were 65 or older and in Europe this percentage was even higher, namely 18.8 percent (1). Furthermore, the proportion of people aged 65 and older is expected to increase in size. It is estimated that in 2050, 16 percent of the world’s population will consist of people aged 65 and older (2).

The growing of the world’s elderly population partly has to do with the fact that people live longer. In 2013, the average life expectancy worldwide was 70.7 years, whereas the life expectancy in 1990 was 64 years. In the United States the average life expectancy grew from 71 years in 1990 to 76.7 years in 2013. In Europe the average life expectancy was 72 years in 1990 and 76.2 years in 2013 (3). However, the healthy life expectancy is a lot lower. Worldwide, the average healthy life expectancy in 2013 was 62 years. In the United States the average was 69 years and in Europe 67 years (4).

Ageing is associated with a loss of muscle mass, a loss of muscle strength, and a decrease in physical performance (5). The loss of muscle mass, also called sarcopenia, occurs in elderly people and emerges more and more often worldwide (6). In most cases, sarcopenia is accompanied by a loss in muscle strength and a decrease in physical performance (5). Sarcopenia is associated with a decrease in quality of life (7,8) and an increase in mortality (9). The process of the loss of muscle mass starts around the age of 40. Muscle mass decreases at a rate of 8 percent per decade till the age of 70. After this age, the loss of muscle mass amounts to 15 percent per decade (10). The loss of muscle strength, also called dynapenia, amounts to 3 to 4 percent per year in men, and to 2.5 to 3 percent in women aged 75, which is significantly higher than the loss of muscle mass (11). In 5 to 13 percent of elderly people aged 60 and older, sarcopenia is assessed. This percentage accrues to 50 percent in elderly people aged 80 and older (6).

In addition to an increase in costs, sarcopenia has many other negative consequences that affect the health of individuals (12). Sarcopenia is the most important cause of frailty, and leads to a loss of mobility and physical function, falls, and increase of mortality. People who suffer from sarcopenia run an increased risk of osteoporosis, COPD, kidney failure, and heart problems (6). Research shows that both sarcopenia and dynapenia are independent predictors of death (13).

Sarcopenia is caused by old age, illness, a decline in physical activity, or a deficient food intake (14). Due to a reduced intake of food and a lower efficiency of the digestive system, elderly people run a higher risk of deficiencies. There is evidence that the intake of calcium, magnesium, potassium, and iron in elderly people is lower than recommended (15,16). However, a complete overview of the intake of minerals in elderly people is not available.

At the moment, there are no clear guidelines for the prevention and treatment of sarcopenia (17). However, there are specific nutritional dietary guidelines for older adults aged 51 and over (18). Research shows that a variety of guidelines for nutrient intake needs to be reviewed, since requirements vary between countries (19). Up until now, there is no medication that has a positive effect on preventing and treating sarcopenia. Multiple intervention studies describe the positive effects of physical activity and the supplementation of amino-acids, vitamin D, and omega-3 fatty acids (20). There are general guidelines for the elderly related to the daily intake of proteins, and vitamin D (21,22). So
far, not much attention has been paid to the role of minerals in the prevention and treatment of sarcopenia (20,23-25).

Of several minerals it is known that they play a role in muscle metabolism and muscle function. Calcium is necessary for healthy muscle and nerve activity. A deficiency as well as an excess of calcium in the blood can cause muscle spasms (26-29). Magnesium is shown to have a positive effect on muscle metabolism, could improve muscle function, and reduce muscle spasms (30-32). Potassium and sodium both play an important role in the conduction of nerve impulses, and the contractions of muscles. A potassium deficiency can lead to muscle weakness (28,33,34). Selenium deficiency is associated with several muscular diseases. However, the exact role of selenium on muscle development, muscle function, and muscle maintenance remains unclear (35). Iron is part of myoglobin in muscles, which makes oxygen available for the muscle function. Low iron levels can lead to a reduced exercise capacity (36). A lack of phosphorus can lead to muscle weakness and musculoskeletal pain (37).

Although it is clear that these minerals play an important role in muscle functioning and physical functioning in general, a complete and unambiguous overview of their effect on sarcopenia in the elderly is lacking. The aim of this systematic review is to give an outline of minerals and their effect on muscle mass, muscle strength, and physical performance in the elderly. The minerals calcium, iron, magnesium, phosphorus, potassium, selenium, and sodium will be discussed. In addition, the relation between serum concentrations of minerals and muscle mass, muscle strength, and physical performance will be reviewed.
2 Methods

2.1 Search strategy
The data used for this qualitative systematic review has been collected between March and May 2016. A systematic electronic search in PubMed has been performed. Table 1 shows the keywords that were used for the search. Synonyms as well as included keywords are shown. A variety of exclusion keywords has been used to exclude animal studies and excluded research methods from the search results. A combination of the keywords as seen in the columns 1. Population, 2. Minerals, and 3. Outcome were made to construct search strings, which are attached in appendix A. The search for relevant studies was conducted by looking for specific keywords referenced in titles and/or the abstract. Additionally, MeSH terms were used to get more relevant search results.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elderly OR older people OR older person OR senior OR aged OR aging OR ageing OR independent living OR community dwelling OR frail elderly OR aged, 80 and over</td>
<td>Calcium OR dietary calcium</td>
<td>Muscle mass OR muscles OR lean body mass OR skeletal muscle OR fat free mass OR muscular atrophy OR muscle waste OR muscle loss OR sarcopenia</td>
</tr>
<tr>
<td>Magnesium OR dietary magnesium</td>
<td>1. Muscle strength OR strength OR dynapenia OR strength loss OR muscle weakness</td>
<td></td>
</tr>
<tr>
<td>Sodium OR dietary sodium</td>
<td>2. Physical performance OR physical function OR functional mobility OR activities of daily living OR mobility limitation OR physical fitness</td>
<td></td>
</tr>
<tr>
<td>Potassium OR dietary potassium</td>
<td>Iron OR dietary iron OR ferrum</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>3. Physical performance OR physical function OR functional mobility OR activities of daily living OR mobility limitation OR physical fitness</td>
<td></td>
</tr>
<tr>
<td>Phosphorus OR dietary phosphate OR phosphor</td>
<td></td>
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</tr>
</tbody>
</table>

2.2 Selection and quality assessment
Primarily, all search results were screened on their title, using the eligibility criteria. Subsequently, abstracts were assessed for relevance and validity. The articles that met all eligibility criteria based on abstract were assessed on full text. The Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies was used to evaluate the quality of the articles (38,39). This tool has been attached in appendix B. Studies were reviewed for risk of bias, study design, confounders, method of blinding, data collection methods, and withdrawals. A manual search of reference lists of included and other relevant articles has been performed to increase the number of potentially useful articles. A standardized data extraction form has been used to summarize the information from the articles. Also, a cross-check for data extraction has been performed.

The complete search and assessment of articles has been performed by two independent researchers. The search strategy and eligibility criteria were determined beforehand and approved by two supervisors. The review and selection of articles was performed in duplicate by the two researchers, after which they discussed the selection and assessment with each other. The justification of the eligibility of the used articles, including reasons for exclusion, can be found in the flowchart in figure 1, chapter 3.
2.3 Report characteristics
Eligibility criteria were used to decide whether an article should be included for this systematic review. Table 2 shows the eligibility criteria that were used for the selection of articles. Information from books has not been used, since books contain secondary data. Due to the limited number of available studies, no criteria have been established for the length of follow-up or the minimal number of participants. Articles without a full text available were not included. The effect of dietary intake of minerals on muscle mass, muscle strength, and physical performance have been studied. Studies that investigated the effect of minerals in combination with macronutrients, vitamins, bioactives, and exercise were excluded. A large amount of studies reported on the relation between serum concentrations of minerals and muscle mass, muscle strength, and physical performance. Research showed that serum concentrations of minerals were related to dietary intake (40-43). For this reason, a paragraph about serum concentrations has been added to chapter 3 Results.

Table 2: Eligibility criteria articles

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publication from 2006 to 2016</td>
<td>Non-human and in vitro research (44)</td>
</tr>
<tr>
<td>Randomized Controlled Trials, (Controlled) Clinical Trials, epidemiological research, cross-sectional research, case-control research, longitudinal research, cohort studies (45)</td>
<td>Research on the effect of other macro and micro nutrients other than minerals, including the combination between minerals and other nutrients (46)</td>
</tr>
<tr>
<td>Research on healthy and frail elderly people with an average age of 65</td>
<td>Research on the effect of the combination of minerals and exercise (23)</td>
</tr>
<tr>
<td>Use of validated methods of measurement (table 3: Selection criteria methods of measurement)</td>
<td>Research on subjects suffering from diseases that influence protein synthesis or muscle mass¹</td>
</tr>
<tr>
<td>Articles in English language</td>
<td>Information from books</td>
</tr>
<tr>
<td>Free full-text articles</td>
<td></td>
</tr>
</tbody>
</table>

¹The following diseases were excluded due to their impact on muscle mass, muscle strength, or physical performance: muscle disorders (47), neoplasms (48,49), heart failure (50), cirrhosis (51,52), HIV (53), renal insufficiency (54), Chronic Obstructive Pulmonary Disease (55), hyperparathyroidism (56), and hyponatremia (57).

Table 3 shows the eligibility criteria for the methods of measurement. For each outcome is shown which methods are included and excluded. The methods of measurement were screened during the assessment based on title, abstract, and full text.

Table 3: Eligibility criteria methods of measurement

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle mass (58-62)</td>
<td>CT-scan, DEXA, MRI-scan, BodPod, BIA, DPA</td>
<td>Skinfold measurement, MAC</td>
</tr>
<tr>
<td>Muscle strength (63-68)</td>
<td>Hand grip strength, knee/leg extension, leg pressure strength, elastic bands</td>
<td></td>
</tr>
<tr>
<td>Physical performance (69-71)</td>
<td>SPPB, chair stand, balance test, gait speed test, 400 m walking test, 6MWT, TUG test</td>
<td></td>
</tr>
</tbody>
</table>

CT-scan = Computed Tomography scan; DEXA = Dual Energy X-ray Absorptiometry; MRI-scan = Magnetic Resonance Imaging scan; BIA = Bioelectrical Impedance Analysis; DPA = Dual-Photon Absorptiometry; MAC = Mid-Arm Circumference; SPPB = Short-Physical Performance Battery; 6MWT = 6 minutes walking test; TUG test = Timed Up and Go test
3 Results

The figure below shows the search strategy and screening process. The flow-chart indicates whether or not a study was included, as well as the reason for its exclusion. In total, 3206 articles met one or more of the pre-selected keywords. An additional six articles were found through references in the selected studies and reviews. Initially, after duplicates were removed, 2689 articles were screened on title. Secondly, 219 articles were screened on abstract, of which 178 articles were excluded, for reasons presented in the figure below. The remaining 41 articles were screened on full text. A total of thirteen studies were ultimately included in the review.

Figure 1: Flow-chart of search strategy and study selection
3.1 Characteristics of studies
This systematic review included thirteen studies, in which totally 8,615 subjects participated. The sample size of the studies ranged from 124 (72) to 1,433 (73) subjects. Three studies only included women (72,74,75), the rest of the studies were a mix of men and women. Of all subjects, 62 percent were women. The average age of the participants was 71.0 years, ranging from 66.7 (76) to 77.4 (75). All studies included community-dwelling elderly individuals. Two articles included community-dwelling women that were moderately to severely disabled (74,75). Furthermore, two studies used data from the KNHANES population (73,77), two studies used data from the InCHIANTI population (76,78), and two studies used data from the WHAS I population (74,75). One randomized controlled trial (72), three longitudinal studies (74,78,79), one case-control study (80), and one cohort study (81) were included in this review. The rest of the studies were cross-sectional studies. Two studies discussed muscle mass (77,82), three studies discussed muscle strength (75,76,78), five studies reported on physical performance (72,74,79,81,83), and four studies reported on sarcopenia (73,77,80,84). Five articles were found that reported on dietary calcium (73,77,80,83,84), one on dietary iron (83), one on serum iron (79), three on dietary magnesium (72,80,84), two on serum magnesium (76), one on dietary phosphorus (80), three on dietary selenium (80,81,84), and four on serum selenium (74,75,78,82). No studies that reported on potassium or sodium were found.
3.2 Calcium
Table 4 shows the relation between calcium and muscle mass, muscle strength, and physical performance. One study discussed muscle mass and sarcopenia (77), three studies discussed sarcopenia (73,80,84), and one study reported on physical performance (83). No studies were found that reported on muscle strength. Oh et al (73) and Ter Borg et al (84) investigated the correlation between calcium intake and sarcopenia, Seo et al (77) investigated calcium intake and sarcopenia as well as muscle mass, and Waters et al (83) investigated calcium intake and gait speed. Verlaan et al (80) used muscle mass, muscle strength, and physical performance as inclusion criteria for subjects, but did not specify any data about those outcomes.

3.2.1 Muscle mass
Seo et al (77) found that calcium intake was positively correlated with muscle mass (P = 0.001) and sarcopenia (P = 0.009). Participants with sarcopenia had a significantly lower calcium intake than participants that did not suffer from sarcopenia. Daily calcium intake showed to have a mildly positive correlation with appendicular skeletal muscle mass (rho = 0.276). A total of 1339 community-dwelling elderly people from the KNHANES population were enrolled for this study. Calcium intake was measured using a 24-hour recall survey.

3.2.2 Muscle strength
No studies were found that described the relation between muscle strength and calcium.

3.2.3 Physical performance
Waters et al (83) studied the association between nutritional intake and gait speed in 315 community-dwelling elderly individuals. Dietary intake was measured through 3-day dietary intake records. A slow gait speed was associated with a lower calcium intake in men (P = 0.05). Men with a low gait speed were two times more likely as men with a normal gait speed to have a low daily calcium intake (OR = 2.18), but this value was not significant (95% CI = 0.67 – 7.09). In women, no significant association between calcium intake and gait speed has been shown (OR = 1.15, P = 0.37).

3.2.4 Sarcopenia
Oh et al (73) investigated the correlation between calcium intake and sarcopenia. A total of 1433 community-dwelling elderly individuals from the KNHANES population were enrolled for this study. Calcium intake was measured using a 24-hour dietary recall survey. Sarcopenic as well as non-sarcopenic elderly people had a mean calcium intake below the RDA. Only in male subjects a significant difference in calcium intake between sarcopenic and non-sarcopenic subjects had been shown (M: P = 0.002, F: P = 0.949). Verlaan et al (80) studied the association between nutritional intake and sarcopenia. Sixty six sarcopenic and sixty six non-sarcopenic elderly individuals were included for this study. Dietary intake was measured through 3-day dietary intake records. No significant relation between calcium intake and sarcopenia was shown (P = 0.506). Ter Borg et al (84) studied the differences in nutrient intakes between 227 community-dwelling, sarcopenic and non-sarcopenic elderly people. Dietary intake was assessed with food frequency questionnaires and additional data on supplement intake was collected. No significant differences in dietary intake and total nutritional intake (dietary and supplement intake) of calcium between sarcopenic and non-sarcopenic elderly participants was found (P = 0.726, P = 0.884, respectively).
Table 4: Relation between calcium and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oh et al (73)</td>
<td>2015</td>
<td>Cross-sectional</td>
<td>-</td>
<td>Community dwelling elderly KNHANES 2010</td>
<td>68.6</td>
<td>1433 (54%)</td>
<td>Moderate</td>
<td>M: P=0.002</td>
<td>-</td>
<td>Sarcopenia</td>
</tr>
<tr>
<td>Seo et al (77)</td>
<td>2013</td>
<td>Cross-sectional</td>
<td>-</td>
<td>Community dwelling elderly KNHANES 2010</td>
<td>70.1</td>
<td>1339 (53%)</td>
<td>Moderate</td>
<td>P=0.001</td>
<td>Rho=0.276</td>
<td>Muscle mass (DXA)</td>
</tr>
<tr>
<td>Ter Borg et al (84)</td>
<td>2016</td>
<td>Cross-sectional</td>
<td>-</td>
<td>Community dwelling</td>
<td>74.0</td>
<td>227 (52%)</td>
<td>Weak</td>
<td>P=0.726</td>
<td>P=0.884</td>
<td>Sarcopenia</td>
</tr>
<tr>
<td>Verlaan et al (80)</td>
<td>2015</td>
<td>Case-control</td>
<td>-</td>
<td>Community dwelling</td>
<td>71.0</td>
<td>132 (59%)</td>
<td>Weak</td>
<td>P=0.506</td>
<td>-</td>
<td>Sarcopenia</td>
</tr>
<tr>
<td>Waters et al (83)</td>
<td>2014</td>
<td>Cross-sectional</td>
<td>-</td>
<td>Community dwelling</td>
<td>76.5</td>
<td>315 (62%)</td>
<td>Weak</td>
<td>M: P=0.05</td>
<td>M: OR=2.18</td>
<td>Gait speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F: P=0.37</td>
<td>F: OR=1.15</td>
<td>(95% CI=0.55-2.41)</td>
</tr>
</tbody>
</table>

1 = dietary intake; 2 = dietary and supplement intake; M = male; F = female; DXA = dual energy x-ray absorptiometry; rho = correlation coefficient; OR = odds ratio; CI = confidence interval
3.3 Iron
Table 5 shows the relation between iron and muscle mass, muscle strength, and physical performance. The included study reported on physical performance (83). No studies that reported on muscle mass or muscle strength were found.

3.3.1 Muscle mass
No studies were found that described the relation between muscle mass and iron.

3.3.2 Muscle strength
No studies were found that described the relation between muscle strength and iron.

3.3.3 Physical performance
Research of Waters et al (83) showed a significant relation between iron intake and physical performance in men (OR = 4.81, P = 0.05), but not in women (OR = 0.94, P = 0.17). A total of 315 subjects completed a 3-day dietary intake record to assess iron intake.

Table 5: Relation between iron and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waters et al (83)</td>
<td>2014</td>
<td>Cross-sectional study</td>
<td>-</td>
<td>Community dwelling</td>
<td>76.5</td>
<td>315 (62%)</td>
<td>Weak</td>
<td>M: P=0.05</td>
<td>M: OR=4.81 (95% CI=1.51-15.31)</td>
<td>Gait speed</td>
</tr>
</tbody>
</table>

M = male; F = female; OR = odds ratio; CI = confidence interval
3.4 Magnesium
Table 6 shows the relation between magnesium and muscle mass, muscle strength, and physical performance. No studies reported on muscle mass or muscle strength. One study reported on physical performance (72). Both studies of Ter Borg et al (84) and Verlaan et al (80) reported on the relation between magnesium and sarcopenia. Those studies are discussed in chapter 3.3.4 Sarcopenia.

3.4.1 Muscle mass
No studies were found that discussed the relation between muscle mass and magnesium.

3.4.2 Muscle strength
No studies were found that discussed the relation between muscle strength and magnesium.

3.4.3 Physical performance
Veronese et al (72) found a significant effect of oral magnesium supplementation on physical performance in 124 community-dwelling elderly women. During this 12 weeks intervention subjects took a 900 mg/d of oral magnesium oxide, corresponding to 300 mg/d bioavailable magnesium. Veronese et al found a significant effect of oral magnesium supplementation on the Short-Physical Performance Battery ($\Delta = 0.41 \pm 0.24$ points, $P = 0.03$), chair stand ($\Delta = -1.31 \pm 0.33$ s, $P = 0.0001$), and gait speed ($\Delta = 0.14 \pm 0.03$ m/s, $P = 0.006$) compared to the control group.

3.4.4 Sarcopenia
A significant relation between magnesium and sarcopenia has been shown. Ter Borg et al (84) measured dietary intake of 227 community-dwelling elderly individuals through a food frequency questionnaire. Magnesium intake was significantly lower in sarcopenic elderly subjects compared to non-sarcopenic elderly subjects ($P = 0.024$). Verlaan et al (80) found a significantly lower intake of magnesium in sarcopenic elderly individuals compared to the non-sarcopenic controls ($P = 0.015$).

3.5 Phosphorus
Table 7 shows the relation between phosphorus and muscle mass, muscle strength, and physical performance. Verlaan (80) reported on the association between phosphorus and sarcopenia. No studies were found on the relation between phosphorus and muscle mass, muscle strength, or physical performance.

3.5.1 Muscle mass
No studies were found that discussed the relation between muscle mass and phosphorus.

3.5.2 Muscle strength
No studies were found that discussed the relation between muscle strength and phosphorus.

3.5.3 Physical performance
No studies were found that reported on the relation between physical performance and phosphorus.

3.5.4 Sarcopenia
Verlaan et al (80) compared body composition and functional and nutritional status between sarcopenic and non-sarcopenic elderly individuals. Nutritional status was assessed through 3-day dietary intake records. Verlaan found that dietary nutrient intake of phosphorus was significantly lower in sarcopenic elderly people ($P = 0.014$).
### Table 6: Relation between magnesium and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ter Borg et al (84)</td>
<td>2016</td>
<td>Cross-sectional study</td>
<td>-</td>
<td>Community-dwelling</td>
<td>74.0</td>
<td>227 (52%)</td>
<td>Weak</td>
<td>P=0.009(^1) P=0.024(^2)</td>
<td>P=0.024(^2)</td>
<td>Sarcopenia</td>
</tr>
<tr>
<td>Verlaan et al (80)</td>
<td>2015</td>
<td>Case-control study</td>
<td>-</td>
<td>Community-dwelling</td>
<td>71.0</td>
<td>132 (59%)</td>
<td>Weak</td>
<td>P=0.015</td>
<td>-</td>
<td>Sarcopenia</td>
</tr>
<tr>
<td>Veronese et al (72)</td>
<td>2014</td>
<td>Randomized controlled trial, 900 mg oral magnesium oxide</td>
<td>12 weeks</td>
<td>Community-dwelling</td>
<td>71.5</td>
<td>124 (100%)</td>
<td>Strong</td>
<td>P=0.03</td>
<td>(\Delta = 0.41 \pm 0.24) points (\Delta = -1.31 \pm 0.33) s (\Delta = 0.14 \pm 0.03) m/s</td>
<td>SPPB Chair stand Gait speed</td>
</tr>
</tbody>
</table>

\(^1\) = dietary intake; \(^2\) = dietary and supplement intake; SPPB = Short-Physical Performance Battery

### Table 7: Relation between phosphorus and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verlaan et al (80)</td>
<td>2015</td>
<td>Case-control study</td>
<td>-</td>
<td>Community-dwelling</td>
<td>71.0</td>
<td>132 (59%)</td>
<td>Weak</td>
<td>P=0.014</td>
<td>-</td>
<td>Sarcopenia</td>
</tr>
</tbody>
</table>

15
3.6 Potassium
None of the found articles about potassium met the eligibility criteria. Therefore, no data had been found about this subject.

3.7 Selenium
Table 8 shows the relation between selenium and muscle mass, muscle strength, and physical performance. Martin et al (81) mentioned the effect of selenium on physical performance. Both Verlaan et al (80) and Ter Borg et al (84) reported on the relation between selenium and sarcopenia. No studies were found that discussed selenium and muscle mass.

3.7.1 Muscle mass
No studies were found that discussed the relation between muscle mass and selenium.

3.7.2 Muscle strength
No studies were found that discussed the relation between muscle strength and selenium.

3.7.3 Physical performance
One study described the effect of selenium on physical performance. Martin et al (81) examined the relation between selenium and gait speed. Selenium intake was measured through frequency food questionnaires. Higher dietary intakes of selenium were significantly associated with gait speed in elderly women ($\beta = -0.091$, $P = 0.015$). However, this correlation was not found in elderly men ($\beta = -0.012$, $P = 0.657$). The chair stand test showed no significant correlation for both men ($\beta = 0.983$, $P = 0.138$) and women ($\beta = 0.983$, $P = 0.25$).

3.7.4 Sarcopenia
Two studies described the relation between selenium and sarcopenia. Verlaan et al (80) compared the functional and nutritional status of sarcopenic versus non-sarcopenic elderly individuals. Nutrient intake was assessed through 3-day dietary intake records. Verlaan found that selenium intake was significantly lower in the sarcopenic elderly compared to the non-sarcopenic elderly ($P = 0.039$). Ter Borg et al (84) investigated the differences in nutrient intake between 227 sarcopenic and non-sarcopenic elderly subjects. Nutrient intake was measured with food frequency questionnaires. A significant difference in dietary selenium intake was found between the two groups ($P = 0.02$). However, no significant difference in total nutrient intake, dietary intakes as well as supplement intake, was found ($P = 0.632$).

3.8 Sodium
None of the found articles about sodium met the eligibility criteria. Therefore, no data had been found about this subject.
Table 8: Relation between selenium and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin et al</td>
<td>2011</td>
<td>Cohort</td>
<td>-</td>
<td>Community-dwelling Hertfordshire Cohort Study 1998</td>
<td>67.9</td>
<td>628</td>
<td>(45%)</td>
<td>Weak</td>
<td>M: P=0.657</td>
<td>F: P=0.015</td>
<td>M: β=-0.012 (95% CI=-0.065-0.041) F: β=-0.091 (95% CI=-0.165-0.018)</td>
</tr>
<tr>
<td>Ter Borg et al</td>
<td>2016</td>
<td>Cross-sectional study</td>
<td>-</td>
<td>Community-dwelling</td>
<td>74.0</td>
<td>227</td>
<td>(52%)</td>
<td>Weak</td>
<td>P=0.02(^1)</td>
<td>P=0.632(^2)</td>
<td>-</td>
</tr>
<tr>
<td>Verlaan et al</td>
<td>2015</td>
<td>Case-control study</td>
<td>-</td>
<td>Community-dwelling</td>
<td>71.0</td>
<td>132</td>
<td>(59%)</td>
<td>Weak</td>
<td>P=0.039</td>
<td>-</td>
<td>Sarcopenia</td>
</tr>
</tbody>
</table>

\(^1\) = dietary intake; \(^2\) = dietary and supplement intake; M = male; F = female; CI = confidence interval

3.9 Serum concentrations
Table 9 shows the relation between a variety of serum concentrations and muscle mass, muscle strength, and physical performance. Bartali et al (79) reported about the relation between serum iron and physical performance. Chen et al (82) examined the association between serum selenium and muscle mass, and Alipanah et al (74) studied the relation between serum selenium and physical performance. Dominguez et al investigated the relation between serum magnesium and muscle strength (76). Beck et al (75) and Lauretani et al (78) examined the relation between serum selenium and muscle strength.

3.9.1 Iron
Bartali et al (79) examined the relation between serum micronutrient concentrations and physical performance in 698 elderly individuals. No significant relation was shown between serum iron values and physical performance (OR = 1.10, P = 0.60).
3.9.2 Magnesium

Dominguez et al (76) studied the relation between serum magnesium and muscle strength in the InCHIANTI population. Data of 1138 subjects was used for this study. The correlation between serum magnesium and muscle strength was shown through hand grip strength ($\beta = 2.0 \pm 0.5, P = 0.0002$), lower-leg muscle power ($\beta = 31.2 \pm 7.9, P = 0.001$), knee extension torque ($\beta = 8.8 \pm 2.7, P = 0.0001$), and ankle extension strength ($\beta = 3.8 \pm 0.5, P = 0.0001$).

3.9.3 Selenium

Both Beck et al (75), and Lauretani et al (78) described the relation between selenium and muscle strength. Beck et al (75) hypothesized that low serum selenium concentrations were associated with poor hand grip strength. Beck found that low serum selenium was significantly associated with poor hand grip strength among 676 moderately to severely disabled older women in the community ($P = 0.04$). Lauretani et al (78) examined the relation between plasma selenium and muscle strength in 891 elderly people. Lauretani found that low plasma selenium was significantly associated with muscle strength. Muscle strength was assessed through knee strength ($P = 0.009$) and hand grip strength ($P = 0.008$). Accordingly, subjects with low plasma selenium had a greater risk of poor knee and hand grip strength than participants in the higher quartiles of plasma selenium. Chen et al (82) examined the relationship between serum selenium and muscle mass in 327 community dwelling elderly. Lower serum selenium was associated with a higher risk of low muscle mass ($P<0.001$). Muscle mass was measured by bioelectrical impedance analysis. Alipanah et al (74) measured serum selenium at baseline, 12 and 24 months in 687 moderately to severely disabled women. Gait speed was assessed every six months for 36 months. Mean serum selenium was associated with mean gait speed over three years of follow-up ($\beta = 0.002, P = 0.0003$), but not with the rate of change of gait speed ($\beta = 0.00006, P = 0.26$).

Table 9: Relation between serum concentrations and muscle mass, muscle strength, and physical performance

<table>
<thead>
<tr>
<th>Min</th>
<th>Author</th>
<th>Year</th>
<th>Type of study</th>
<th>Study duration + follow-up</th>
<th>Study population</th>
<th>Mean age</th>
<th>Sample size + female %</th>
<th>Quality</th>
<th>P-value</th>
<th>Effect size</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>Bartali et al</td>
<td>2008</td>
<td>Longitudinal study</td>
<td>Baseline + 3 year follow-up</td>
<td>Community-dwelling</td>
<td>73.7</td>
<td>698 (54%)</td>
<td>Moderate</td>
<td>$P=0.60$</td>
<td>OR=1.10 (95% CI=0.77-1.59)</td>
<td>Gait speed Chair stand SPPB</td>
</tr>
<tr>
<td>Mineral</td>
<td>Authors</td>
<td>Year</td>
<td>Study Type</td>
<td>Setting</td>
<td>Sample Size</td>
<td>N</td>
<td>P Value</td>
<td>Beta (SE)</td>
<td>Hazard Ratio (95% CI)</td>
<td>Outcome</td>
<td></td>
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<tr>
<td>---------</td>
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<td>----------------------</td>
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<td></td>
</tr>
<tr>
<td>Mg</td>
<td>Dominguez et al (76)</td>
<td>2006</td>
<td>Cross-sectional study</td>
<td>Community-dwelling elderly InCHIANTI</td>
<td>66.7</td>
<td>1138 (54%)</td>
<td>Moderate</td>
<td>P=0.0002</td>
<td>β=2.0 (SE ± 0.5 mg/dL)</td>
<td>Hand grip strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P=0.001</td>
<td>β=8.8 (SE ± 2.7 mg/dL)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P&lt;0.0001</td>
<td>β=31.2 (SE ± 7.9 mg/dL)</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P=0.0001</td>
<td>β=3.8 (SE ± 0.5 mg/dL)</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>Alipanah et al (74)</td>
<td>2009</td>
<td>Longitudinal study</td>
<td>Community-dwelling, moderately to severely disabled women WHAS I 1992</td>
<td>&gt;65</td>
<td>687 (100%)</td>
<td>Moderate</td>
<td>P=0.0003</td>
<td>β=0.002 (SE=0.00005)</td>
<td>Gait speed (mean over 3 years of follow-up)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P=0.26</td>
<td>β=0.00006 (SE=0.00006)</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>Beck et al (75)</td>
<td>2007</td>
<td>Cross-sectional study</td>
<td>Community-dwelling, moderately to severely disabled women WHAS I 1992</td>
<td>77.4</td>
<td>676 (100%)</td>
<td>Moderate</td>
<td>P=0.04</td>
<td>β=1.531 (SE=0.753 μmol/L)</td>
<td>Hand grip strength</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>Chen et al (82)</td>
<td>2014</td>
<td>Cross-sectional study</td>
<td>Community-dwelling</td>
<td>71.5</td>
<td>327 (68%)</td>
<td>Weak</td>
<td>P=0.001</td>
<td>OR=4.62 (95% CI=2.11-10.1)</td>
<td>Muscle mass (BIA)</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>Lauretani et al (78)</td>
<td>2007</td>
<td>Longitudinal study</td>
<td>Community-dwelling InChianti 1998</td>
<td>74.7</td>
<td>891 (56%)</td>
<td>Moderate</td>
<td>P=0.009</td>
<td>OR=1.94 (95% CI=1.18-3.19)</td>
<td>Knee strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P=0.008</td>
<td>OR=1.94 (95% CI=1.19-3.16)</td>
<td></td>
</tr>
</tbody>
</table>

Min = mineral; Ca = calcium; Fe = iron; Mg = magnesium; Ph = phosphorus; Se = selenium; r = correlation coefficient; OR = odds ratio; CI = confidence interval; SE = standard error
4 Discussion

The aim of this systematic review was to give an overview of minerals and their effect on muscle mass, muscle strength, and physical performance in elderly people. Thirteen studies were included. Calcium was significantly associated with muscle mass and gait speed in men. Iron intake was also significantly associated with gait speed in men. Magnesium had a significant effect on physical performance in women. Moreover, selenium was significantly associated with gait speed in women. No studies that reported on the effect of sodium and potassium on any of the outcomes were found. Intake of magnesium, calcium, phosphorus, and selenium was significantly lower in sarcopenic elderly individuals compared to non-sarcopenic elderly subjects. The effect of calcium on sarcopenia is still unclear, since the results of these studies were contradictory. In addition, blood selenium levels were associated with muscle mass, muscle strength, and gait speed. No significant association between serum iron concentrations and physical performance was shown. Furthermore, serum magnesium was found to be significantly associated with muscle strength.

A limitation of this review might be the poor overall quality of the included studies. Indeed, the majority of studies were poor to moderate quality according to the Quality Assessment Tool for Quantitative studies, as they were longitudinal observational or cross sectional studies. The latter are more difficult to draw conclusions from, as these studies do not reflect any causal relation between exposure and outcome. However, according to the Quality Assessment Tool, a study cannot be rated strong if it is not a randomized controlled trial or controlled clinical trial. Therefore, the fact that the quality of a study is rated moderate or weak does not necessarily mean that the study itself is badly executed. Secondly, only free full-text articles that were published in English, and during the last ten years were included for this systematic review. Furthermore, only studies with a study population with a mean age of 65 years were included. Due to these criteria, several articles that did meet the eligibility criteria were nonetheless excluded based on publication date, language, age of study population, or availability. Also, studies that examined the effect of a mineral combined with another nutrient, such as protein or vitamin D, were excluded. As a result, the total number of relevant studies was limited and the amount of studies reporting on each outcome was small, which makes it difficult to draw conclusions. Yet, by doing this, the analyses were restricted solely to the effect of minerals in elderly people, which increased the validity of this review.

To our knowledge, this is the first systematic review combining the available data on minerals and sarcopenia. Even though mostly cross sectional studies were used, this systematic review still gives a clear framework of the relation between minerals and sarcopenia. It also indicates that both longitudinal and experimental evidence of this subject is limited. More research is clearly warranted.

Although it is difficult to draw conclusions based on one study, the article on the effect of magnesium on physical performance (72) is of high quality, has a decent study sample size, and provides strong, significant evidence. Improvement in SPPB score was high enough to be clinically relevant (85,86). Comparing with the literature, a growing number of studies report the potential importance of magnesium (87-89). Moreover, a higher intake of dietary magnesium and magnesium supplementation has already been shown to be associated with enhanced muscle strength and physical performance in both young as adult individuals (90). The study of Veronese et al (72) showed that magnesium supplementation could also have an effect on physical performance in elderly women. However, more research is needed to examine if magnesium has the same effect in men. Ageing is often related to a magnesium deficiency (91). Although a magnesium deficiency in elderly people is mostly caused by an inadequate dietary intake of
magnesium, many different underlying mechanisms may also result in a magnesium deficit (92). Older people are more susceptible to a deficiency due to a reduced magnesium absorption, and increased urinary excretion of magnesium (91). Magnesium plays a role in many biochemical reactions throughout the body. In energy metabolism, magnesium is important for generating adenosine triphosphate (ATP), which is required for muscle fiber contraction, nerve transmission, and muscle contraction and relaxation (92). Furthermore, magnesium is involved in DNA processing. A deficit can lead to insufficient DNA repair, which can cause increased genetic instability, accelerated ageing, and age-related diseases (93). This might explain the findings of Verlaan et al (80) and Ter Borg et al (84), which show that sarcopenic elderly individuals had a significantly lower intake of magnesium than non-sarcopenic elderly subjects. The Recommended Dietary Allowances (RDA) for magnesium are currently set at 420 milligrams per day for men and 320 milligrams for women aged 51 and over. The Upper Tolerable Intake Level of magnesium from a pharmacological agent is 350 mg a day (94). Veronese et al (72) used a supplement of 900 mg of oral magnesium oxide, corresponding to 300 mg of bioavailable magnesium, and no severe adverse events were reported. Moreover, daily supplementation for twelve weeks seemed to improve physical performance in women significantly, in specific SPPB, gait speed, and chair stand times. The effects were more evident in subjects with a magnesium deficiency. This finding is supported by previous research where increased intake of magnesium only had beneficial effects on exercise performance in subjects with a magnesium deficiency (95). As indicated, deficiencies in elderly people are not uncommon, which is why adequate magnesium intake should deserve more attention.

Even though no studies about potassium that met the eligibility criteria were found, a positive effect between an alkaline diet and muscle mass was found. A study about effect of an alkaline diet and muscle mass in women aged 18 to 79 years, showed a positive association between a more alkalinogenic diet and muscle mass, and thus suggests that an adequate intake of potassium and magnesium could play a role in the prevention of muscle loss (96). Research on a population with a mean age of 62 years showed no significant relation between potassium intake and muscle mass (97). However, Dawson-Hughes et al (98) found a significant association between urinary potassium and muscle mass. Calcium was associated with muscle mass and physical performance. There was a significant positive correlation between calcium intake and muscle mass. However, this correlation was quite weak. Comparing with the literature, a few other studies have shown that calcium intake is associated with muscle mass and physical performance. Childhood milk intake is shown to be positively associated with physical performance in older age (99), and a higher dairy intake in older women has a significant effect on muscle mass (100), but it has not been proven that this is attributable to daily calcium intake. Dairy intake is also positively associated with muscle mass and physical performance in older women (101). From the age of 60, absorption of calcium is lower, and from the age of 80, a significant malabsorption is shown (102). Vitamin D levels play an independent role in calcium absorption in the body (103,104). Both Seo et al (77) and Waters et al (83) did not take the intake or status of vitamin D in consideration when writing conclusions about the relation between calcium intake and muscle mass or physical performance. Oh et al (73) found significant lower vitamin D levels in sarcopenic elderly individuals compared to non-sarcopenic elderly people. However, significant effects of calcium intake on sarcopenia were only shown in men. Verlaan (80) found lower vitamin D intakes in both groups, but no adjustments for vitamin D intakes on the relation between calcium and sarcopenia have been made. Possibly due to the low vitamin D intakes in both groups no significant relation between calcium intake and sarcopenia was shown. Although more research is needed, calcium seems to be a potential nutrient to counteract sarcopenia.
Waters et al (83) found a lower iron intake in the group with a low gait speed. Only in men iron intake was significantly lower. However, no adjustments for confounders were made. Vitamin C plays an important role in the absorption of iron (105). Vitamin C intake was significantly lower in women with a slow gait speed, compared to women with a normal gait speed, whereas in men no significant difference in vitamin C intake was shown (83). The absence of a significant effect of iron intake in women regarding gait speed could possibly be assigned to a significant lower vitamin C intake. Bartali et al (79) found no significant relation between serum iron concentrations and physical performance. However, previous research shows that anemia is associated with a decline in physical performance (106,107) and muscle strength (107,108). Furthermore, low hemoglobin levels are associated with frailty (109). The relation between iron status and physical performance and muscle strength can be assigned to the relation between anemia and inflammation (110). Inflammation was shown to be negatively correlated with physical performance and muscle strength (111). Furthermore, a relation has been shown between iron deficiency and oxidative stress (112). Oxidative stress might cause a reduction of muscle strength (113) and was proven to lead to muscle degeneration (114). These findings suggest that iron could possibly have an effect on sarcopenia.

Although no correlations were found between selenium intake and physical performance in men, Martin et al (81) found that higher intakes of selenium were significantly associated with faster gait speed in women. Selenium is an essential part of selenoproteins, which are proteins that play an important role in muscle development and maintenance, and enzyme activity (115,116). A major group of selenoproteins are the antioxidant enzymes glutathione peroxidase (GPx). GPx is responsible for reducing lipid peroxidation, and therefore can protect cells against oxidative stress (117). Previous literature suggests that, after the age of 65, GPx activity declines with age in older women with disability (118). Furthermore, high oxidative stress might be an independent predictor of a decrease in gait speed in older, community-dwelling women (119). This could be an explanation of the findings of Martin et al (81). High oxidative stress has also been shown to play a role in the pathogenesis of age-related sarcopenia and losses of muscle strength and mobility (120,121). Verlaan et al (80) compared the nutritional status of sarcopenic and non-sarcopenic elderly subjects. Selenium intake was found to be significantly lower in the sarcopenic elderly. This might indicate a lower level of oxidative stress in the elderly with higher selenium intakes. Beck et al (75) and Lauretani et al (78) found that blood selenium was significantly associated with muscle strength. Subjects with low blood selenium had a greater risk of poor muscle strength than subjects in the higher quartiles of blood selenium. This is consistent with the idea that selenium is essential for normal muscle function (35,116). A potential underlying mechanism by which selenium affects the loss of muscle mass is through selenoprotein W. Selenoprotein W is reported to play a role in muscle metabolism (122). This might explain why a selenium deficit could lead to muscle disorders. Skeletal muscle disorders have been linked to the amount of selenium content in food (115). Selenium content is subject to changes, due to its dependence on many factors, such as soil content, soil pH, rainfall, and geochemistry (116). Consequently, selenium availability varies worldwide. There are no indications that current selenium recommendations for elderly people are too low (116,123). However, there is evidence that selenium intake and status is inadequate in populations in many countries, also among elderly groups. Sufficient dietary supply of selenium is needed for selenoenzyme activity and normal muscle function (122). Therefore, adequate selenium intake in elderly people needs proper attention.

No studies about sodium that met the eligibility criteria were found. However, research on the relation between sodium excretion and body composition in Korean individuals aged 45 and over, showed a
significant association between high salt intake and sarcopenia (124). A high salt intake can cause an imbalance of the renin-angiotensin-aldosterone system (125), which is shown to be associated with the development of sarcopenia (126).

Verlaan et al (80) found a significant lower dietary intake of phosphorus in sarcopenic elderly individuals compared to non-sarcopenic elderly individuals. Scott et al (97) found a correlation between dietary phosphorus intake and muscle mass in a population with a mean age of 62 years. Research showed that there is a relation between phosphate deficiency and muscle weakness, but the underlying mechanism is still unclear (127).

Except for the interplay between potassium and magnesium, iron and vitamin C, and calcium and vitamin D, the effect of minerals was mostly discussed separately. However, it is often a combination of nutrients that has the biggest effect on sarcopenia, since many nutrients affect the function of others. For example, Scott et al (97) described the associations between nutrient intakes and sarcopenia, muscle mass, and muscle strength. Higher dietary intakes of magnesium, potassium, calcium, and phosphorus were positively correlated with muscle mass. Therefore, rather than focusing on one nutrient, it should be made sure that all nutrient intake is adequate.
5 Conclusion and recommendations

As the world population is ageing, the prevalence of sarcopenia is increasing. Even though a lot of research has been done on the relation between sarcopenia and nutrition, little substantiated information is available on the dietary intake of minerals and its connection to sarcopenia. Strong evidence was found on the effect of magnesium supplementation on physical performance. Evidence of the role of other minerals in muscle mass, muscle strength, or physical performance was poor to moderate. Calcium was positively correlated with muscle mass, and calcium and iron might play a role in physical performance. Intake of magnesium, phosphorus, and selenium was significantly lower in sarcopenic elderly individuals compared to non-sarcopenic individuals. In addition, a relation between blood selenium concentrations and both muscle strength and gait speed was found. Also, a significant relation between blood magnesium concentrations and muscle strength was found.

Solutions on dealing with sarcopenia can only come from a systematic and comprehensive analysis of the underlying mechanisms of ageing. Thus, effective treatment and prevention methods depend on substantiated scientific research and insight in the matter. Since magnesium seems to play a role in preventing or delaying a decline in physical performance, and the risk of susceptibility of elderly people developing a magnesium deficiency, we recommend an adequate daily magnesium intake, either by dietary intake or supplementation. However, rather than focusing on one mineral only, we suggest careful surveillance of all minerals, since so many of them affect each other, and evidence of possible gaps in the diet of elderly people was found. This indicates the importance of a varied diet, rich in (green) vegetables and whole grains, since these products are high in various minerals. Medical and paramedical professionals, such as general practitioners and nutritionists, should take notice of an adequate intake of minerals in the elderly, and could possibly prescribe magnesium supplementation in order to prevent a decrease in physical function.

We can conclude that more research is warranted in order to make any substantiated recommendations on the intake of minerals. In specific, randomized controlled trials are needed to investigate the dose-response relationships to provide further evidence for putting these suggestions into clinical practice and construct guidelines to prevent and treat sarcopenia.
References


(94) Food and Nutrition Board, Institute of Medicine, National Academies. Dietary Reference Intakes (DRIs): Elements. 2011; .


### Table 10: Search strings systematic review

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Search string</th>
</tr>
</thead>
</table>


Appendix B: Quality Assessment Tool for Quantitative Studies

QUALITY ASSESSMENT TOOL FOR QUANTITATIVE STUDIES

COMPONENT RATINGS

A) SELECTION BIAS

(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?

1. Very likely
2. Somewhat likely
3. Not likely
4. Can’t tell

(Q2) What percentage of selected individuals agreed to participate?

1. 80 - 100% agreement
2. 60 – 79% agreement
3. less than 60% agreement
4. Not applicable
5. Can’t tell

B) STUDY DESIGN

Indicate the study design

1. Randomized controlled trial
2. Controlled clinical trial
3. Cohort analytic (two group pre + post)
4. Case-control
5. Cohort (one group pre + post (before and after))
6. Interrupted time series
7. Other specify _______________________
8. Can’t tell

Was the study described as randomized? If NO, go to Component C.

No
Yes

If Yes, was the method of randomization described? (See dictionary)

No
Yes

If Yes, was the method appropriate? (See dictionary)

No
Yes
C) CONFOUNDERS

(Q1) Were there important differences between groups prior to the intervention?
1 Yes
2 No
3 Can’t tell

The following are examples of confounders:
1 Race
2 Sex
3 Marital status/family
4 Age
5 SES (income or class)
6 Education
7 Health status
8 Pre-intervention score on outcome measure

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?
1 80 – 100% (most)
2 60 – 79% (some)
3 Less than 60% (few or none)
4 Can’t Tell

D) BLINDING

(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?
1 Yes
2 No
3 Can’t tell

(Q2) Were the study participants aware of the research question?
1 Yes
2 No
3 Can’t tell

E) DATA COLLECTION METHODS

(Q1) Were data collection tools shown to be valid?
1 Yes
2 No
3 Can’t tell

(Q2) Were data collection tools shown to be reliable?
1 Yes
2 No
3 Can’t tell
F) WITHDRAWALS AND DROP-OUTS

(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?
1. Yes
2. No
3. Can't tell
4. Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).
1. 80 -100%
2. 60 - 79%
3. less than 60%
4. Can't tell
5. Not Applicable (i.e. Retrospective case-control)

<table>
<thead>
<tr>
<th>RATE THIS SECTION</th>
<th>STRONG</th>
<th>MODERATE</th>
<th>WEAK</th>
</tr>
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<tbody>
<tr>
<td>See dictionary</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

G) INTERVENTION INTEGRITY

(Q1) What percentage of participants received the allocated intervention or exposure of interest?
1. 80 -100%
2. 60 - 79%
3. less than 60%
4. Can't tell

(Q2) Was the consistency of the intervention measured?
1. Yes
2. No
3. Can't tell

(Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?
4. Yes
5. No
6. Can't tell

H) ANALYSES

(Q1) Indicate the unit of allocation (circle one)
community  organization/institution  practice/office  individual

(Q2) Indicate the unit of analysis (circle one)
community  organization/institution  practice/office  individual

(Q3) Are the statistical methods appropriate for the study design?
1. Yes
2. No
3. Can't tell

(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?
1. Yes
2. No
3. Can't tell
GLOBAL RATING

COMPONENT RATINGS
Please transcribe the information from the gray boxes on pages 1-4 onto this page. See dictionary on how to rate this section.

<table>
<thead>
<tr>
<th>Component</th>
<th>Rating Levels</th>
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<tr>
<td>A Selection Bias</td>
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<td>B Study Design</td>
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<td>C Confounders</td>
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<td>D Blinding</td>
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<td>E Data Collection Method</td>
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<td>F Withdrawals and Dropouts</td>
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<td>2</td>
<td>3</td>
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</tbody>
</table>

GLOBAL RATING FOR THIS PAPER (circle one):

1 STRONG (no WEAK ratings)
2 MODERATE (one WEAK rating)
3 WEAK (two or more WEAK ratings)

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-F) ratings?

No
Yes

If yes, indicate the reason for the discrepancy

1 Oversight
2 Differences in interpretation of criteria
3 Differences in interpretation of study

Final decision of both reviewers (circle one):

1 STRONG
2 MODERATE
3 WEAK