









# Energy and nutrient intake by people with and without sarcopenia diagnosed by the European Working Group on Sarcopenia in Older People: a systematic review and meta-analysis

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**Context:** There is growing evidence that insufficient dietary intake is associated with sarcopenia. **Objective:** In this systematic review and meta-analysis, the energy and nutrient intakes by people with and without sarcopenia were compared using only the European Working Group on Sarcopenia in Older People 2010 (EWGSOP1) and 2019 (EWGSOP2) consensus diagnostic criteria. **Data Sources:** Only observational studies that compared energy and nutrient intake from food alone by individuals with and without sarcopenia were included. Studies were searched in the following databases: Embase, PubMed, Scopus, Web of Science, Lilacs, Ovid, and Scopus. The review followed the PRISMA checklist and submitted the protocol to PROSPERO. **Data Extraction:** Data were extracted by 2 authors independently. The methodological quality of the studies was assessed using the Newcastle-Ottawa scale. **Data Analysis:** A total of 8648 articles were identified and 12 were selected. Among individuals with sarcopenia, lower intakes of energy and some nutrients, mainly with antioxidant properties, were observed compared with those without sarcopenia. Meta-analyses showed that individuals with sarcopenia consume fewer calories/day than individuals without sarcopenia ( $n = 10$  studies; standardized mean difference (SMD)  $-0.15$ ; 95% confidence interval:  $-0.29, -0.01$ ) diagnosed by EWGSOP1 and EWGSOP2. Individuals with sarcopenia consume less omega-3, folate, magnesium, phosphorus, selenium, zinc, and vitamins C, D, and E when compared with those without sarcopenia. **Conclusion:** The results of the present study suggest that insufficient intake of energy and nutrients with antioxidant potential may be associated with sarcopenia. **Systematic Review Registration:** PROSPERO registration no. CRD 42020195698.

**Key words:** energy, meta-analysis, nutrients, sarcopenia.

## INTRODUCTION

Sarcopenia is a syndrome defined by a decline in muscle quality, quantity, and strength. Sarcopenia is formally considered a muscle disease with a diagnostic code, International Classification of Diseases (ICD).<sup>1</sup> Although there is a diversity of methods available in the literature for sarcopenia diagnosis, which entails different prevalences, the criteria widely used in the scientific environment are proposed by the European Working Group on Sarcopenia in Older People (EWGSOP).<sup>1,2</sup>

The primary role in weight loss is insufficient nutrient intake. Changes in muscle mass, strength, and physical performance also are observed in weight loss.<sup>3</sup> Inadequate intakes of energy, macronutrients (carbohydrates, proteins, and lipids), and some vitamins and minerals are associated with people with sarcopenia compared with those without sarcopenia.<sup>4–6</sup> However, the diversity of methods used to diagnose sarcopenic syndrome may result in changes in the prevalence of sarcopenia and, consequently, differences in the association between sarcopenia and nutrition.

Given the various criteria used for the sarcopenia diagnosis in studies that evaluated the association of sarcopenia with food intake, the present study aimed to systematically review studies that compared the intakes of energy and nutrients by people with and without sarcopenia. For this analysis, only studies that used the consensus criteria of the EWGSOP were selected.

## METHODS

The study is registered in the International Prospective Registry of Systematic Reviews (PROSPERO) as a systematic review and meta-analysis under registration number CRD 42020195698. This review considers the provisions of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).<sup>7</sup>

### Inclusion criteria

Observational studies compared energy and nutrient intake and sarcopenia by persons of both sexes. The consensus criteria of the EWGSOP (EWGSOP1 for 2010 or EWGSOP2 for 2019) were used for the sarcopenia diagnosis. Studies needed to provide information on the total energy intake and nutrients ingested by individuals with and without sarcopenia, using any method of assessing dietary intake. Animal studies and in vivo or in vitro, systematic reviews, literature reviews, and intervention studies were not included.

### Exclusion criteria

Studies on interventions or use of dietary supplements were excluded, as well as those studies whose authors, after being contacted, did not provide data that were not available in the studies.

### Search strategy and selection of studies

Studies published in English, French, Italian, Spanish, or Portuguese, with no restriction on the year of publication, were searched in the Medline database via PubMed, Web of Science, Embase, Lilacs, Ovid, and Scopus in July 2020. The survey was updated in May 2021, April 2022, and April 2023. The PECO (Participants, Exposure, Comparison, and Outcome) criteria used for the survey questions were defined using only the E (exposure) and O component terms (outcome) to avoid undesirable specificities in the data search (Table 1).

The descriptors were defined based on the terms indexed by Medical Subject Heading (MeSH), descriptors in health sciences (DeCS), and the Emtree: “Energy Intake”, “Caloric Intake”, “Intake, Caloric”, “Calorie intake”, “Calory Intake”, “Dietary Energy”, “Energy Intake”, “Dietary Proteins”, “Proteins, Dietary”, “Dietary Protein”, “Protein Intake”, “Protein, Dietary”, “Nutrient Intake”, “Nutrient Intakes”, “Nutritional Intake”, “Dietary Intake”, “Macronutrient Intake”, “Macro-nutrient Intake”, “Sarcopenia”, and “Sarcopenias”. Boolean operators “AND” and “OR” were used in all combinations.

Two independent reviewers (N.S.A. and C.A.d.S.) selected studies identified in the databases that met the study eligibility criteria. Titles and abstracts were read independently, and those not meeting the selection criteria were excluded. All studies selected in the previous phase had their eligibility confirmed by reading the full article. Reference lists of relevant studies were examined to identify potentially eligible studies, not indexed in databases, but relevant for inclusion in this review.

The identified disagreements were evaluated by the third evaluator (T.M.d.O.). The main reason for exclusion was recorded in a specific form, which makes up

**Table 1 PECO criteria for inclusion of studies**

Parameter	Criterion
Population	Adults and elderly diagnosed with sarcopenia according to EWGSOP1 or EWGSOP2
Exposure	Calorie and nutrient intake
Comparison	Not applicable
Outcome	Sarcopenia

*Abbreviations:* EWGSOP1, European Working Group on Sarcopenia in Older Persons 2010; EWGSOP2, European Working Group on Sarcopenia in Older Persons 2019.

the study selection flow. Publications were managed in Endnote Reference Manager (Clarivate Analytics, Philadelphia, PA), in its free online version, to remove duplicates.

### Data extraction

Independently, 2 authors extracted and recorded data in an electronic spreadsheet: author, year of publication, country of study, age, gender, sample size, the method used to define sarcopenia, energy, protein, and nutrients intake, and methods used to assess food intake. The main findings were collected and categorized into sarcopenic and non-sarcopenic. The diagnosis of sarcopenia recommended by the EWGSOP1 was adopted when there were 2 consensuses for the definition of sarcopenia. The corresponding author was contacted when an eligible study needed to provide more data.

### Evaluation of study quality

The methodological quality of the studies included in this review was assessed using the Newcastle-Ottawa scale, which consists of 8 questions in 3 main domains (participant selection, participant comparability, and outcome/exposure assessment).<sup>8</sup> The maximum total score that each cohort or case-control study could receive on this scale was 9 stars (2 stars for comparability). There are 6 questions for cross-sectional studies, and the maximum possible total score is 7. In this systematic review, studies were classified as having methodological quality when they received 7 (cross-sectional studies) or 9 (cohort or case-control studies) stars.<sup>9</sup> All studies, regardless of quality rating, were included in this review.

The quality of the evidence and the strength of the recommendation were evaluated according to the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) methodology. The GRADE system classifies the quality of the evidence as high, moderate, low, or very low, according to the study design limitations, indirect evidence, inconsistency of results, imprecision of results, and the significant likelihood of publication bias.<sup>10</sup>

### Statistical analysis

Quantitative data synthesis was performed using meta-analysis for studies that could be combined.<sup>11,12</sup> Thus, a meta-analysis was performed for available energy, macronutrients, and micronutrients. The extent of heterogeneity in the meta-analyses was tested by using Cochran's Q test and quantified by the inconsistency

test ( $I^2$  statistic). This statistic determines the magnitude of heterogeneity by the proportion of total variation between studies due to heterogeneity.<sup>11,12</sup> A *P* value is cited as an indication of the extent of variability between studies. Thus, the chi-square test was used to assess the significance of heterogeneity. A significance level of  $P < 0.10$  was used to detect the true heterogeneity between the results of the studies.<sup>11,12</sup>

The calculation of  $I^2$ , which varies from 0 to 100%, identified the magnitude of heterogeneity. An  $I^2$  close to zero suggests that all dispersion can be attributed to the study's random error and that there is no heterogeneity.  $I^2$  values close to 25% represent low heterogeneity between studies; those greater than 50%, moderate heterogeneity; and those above 75%, high heterogeneity.<sup>11,12</sup>

The standardized mean difference and the respective confidence intervals (CIs; 95% CIs) were calculated as a summary measure of the meta-analysis, considering that different methods obtained the mean consumption values of the macronutrients and micronutrients.<sup>12</sup> The results are presented using a forest plot.

The mean command was used with the specification of 6 variables, assuming that the sample size, mean, and standard deviation of each group (with and without sarcopenia) were the variables included in the analysis to generate the summary measure (mean difference between the groups).<sup>11,12</sup>

The clustering of the effect measure was calculated using random-effects models by the restricted maximum likelihood method (REML) due to the moderate-high heterogeneity identified between studies.

Considering the small number of studies included in the meta-analyses, it was impossible to explore the causes of heterogeneity between studies, either by subgroup analysis or by meta-regression. A funnel plot and Egger's test were performed to assess the presence of publication bias and the effect of small studies. Statistical analysis was performed using the STATA for MAC statistical software (version 16.0; StataCorp LP, College Station, Texas).

## RESULTS

### Study selection and characteristics

A total of 8648 studies were identified by searching electronic databases. Of these, 1648 studies were excluded after removing duplicates and 6888 after reading the title and abstract. Therefore, after a complete reading of 112 studies, 12 studies met the described criteria and were included for qualitative and quantitative syntheses.

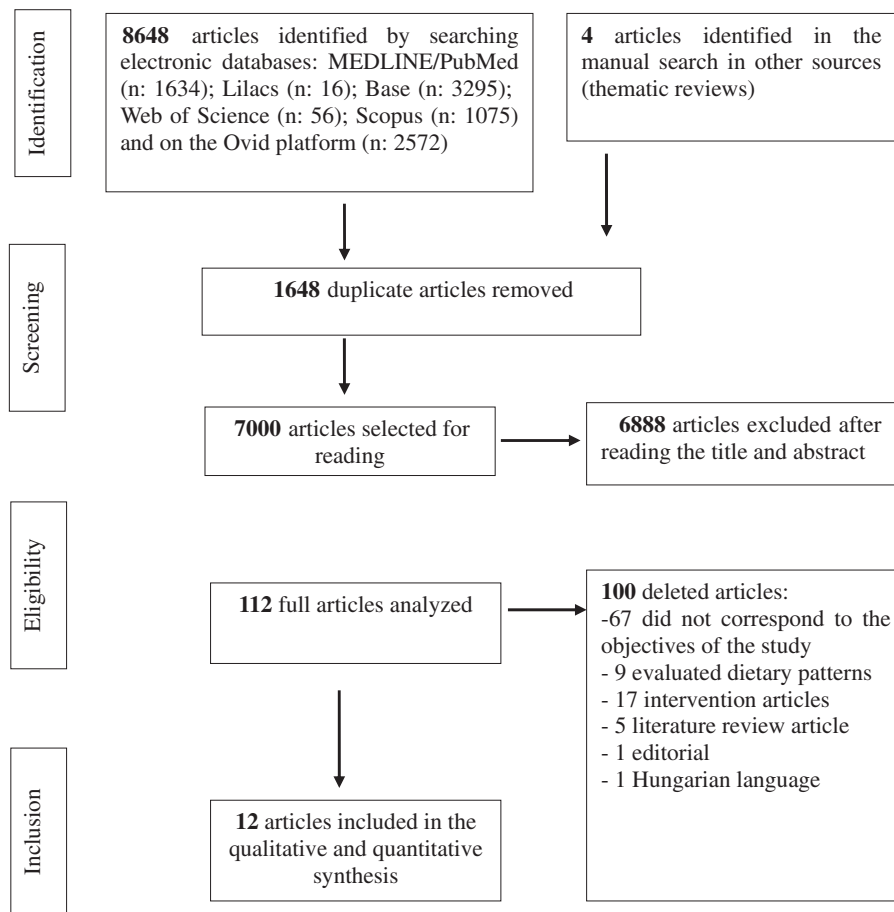


Figure 1 Flow diagram of the literature search process.

The reasons for study exclusion were as follows: not using the diagnostic criteria of the EWGSOP1 or EWGSOP2 for the diagnosis of sarcopenia, assessment of dietary patterns, and use of food supplements (Fig. 1).

The main characteristics and results of the selected studies are presented in Table 2.<sup>4,5,13–22</sup> The included studies were carried out in Europe,<sup>4,5,13–18</sup> America,<sup>19–21</sup> Asia,<sup>22</sup> and Oceania.<sup>18</sup> There was a predominance of cross-sectional studies and only 1 case-control study.

The sample sizes of the studies ranged from 14 to 127 patients with sarcopenia and from 16 to 438 participants without sarcopenia. In 5 studies, the mean age of individuals diagnosed with sarcopenia was between 65 and 73 years<sup>14,15,19,20,22</sup>; in 5 studies, the mean age was older than 77 years.<sup>4,5,13,16,17</sup> For those without sarcopenia, the mean age in most studies (n = 7) was between 65 and 75 years,<sup>4,5,14,15,19,20,22</sup> in 3 studies, the mean age was older than 75 years.<sup>13,16,17</sup>

Of the 12 studies included in this systematic review and meta-analysis, 8 used the EWGSOP1 algorithm, 2 used the EWGSOP1 and EWGSOP2 algorithms, and 2 used the EWGSOP2 algorithm. Six studies used a 3-day food record method, 3e used a food-frequency

questionnaire, and 3 used a 24-hour food recall to assess food intake.

### Risk of bias and assessment of the methodological quality

Most of the studies included in the meta-analyses had moderate quality scores on the Newcastle-Ottawa scale: 8 of them scored between 4 and 6 stars, with the case-control study scoring 8 stars, and the other 3 scoring 3 stars (Table 3).<sup>4,5,13–22</sup> (See the Newcastle-Ottawa scale assessment details in Tables S1 and S2 in the Supporting Information online.)

### Grade

The certainty of the evidence for the outcome of sarcopenia was downgraded from low to very low when evaluating the following exposures: energy intake, protein, carbohydrates, lipids, cholesterol, fiber, and vitamin B6, due to the inconsistency of the studies included in the meta-analyses of the respective variables. Considering the heterogeneity between the studies, caution should be exercised in the reliability of the information

Table 2 Characteristics of the studies included in this systematic review

Reference (Year)	Country	Study design	Sarcopenia		Food-intake methods	Nutrients studied	Main results
			Yes n; age (y) (SD); F/M; consensus used	No n; age (y) (SD); F/M			
Şimşek and Uçar (2022) <sup>17</sup>	Turkey	Cross-sectional	88; 85.35 (7.13); 49/39; EWGSOP2	84; 80.14 (6.58); 50/34	3-day food log	Energy, Ptn, Cho, total fat, SFA, MUFA PUFA, Chol, dietary fiber, Vit A, E, D, K, C, B6, B12, folic acid equivalents, Ca, Mg, Zn, Fe	In the fully adjusted model for age, gender, MNA-SF and EQ-5D scores, and FRAIL scale category, subjects with sarcopenia consumed a lower amount of energy (kcal and kcal/kg) and total fat (g) ( $P < 0.001$ ). Ptn intake (g/day and g/kg) was less in the sarcopenic group ( $P < 0.05$ ). The daily intake of micronutrients in the sarcopenic group was lower when compared with the non-sarcopenic group, and only Vit B6 and Fe intake were low in the fully adjusted model ( $P < 0.05$ ).
Rahman et al (2021) <sup>22</sup>	India	Cross-sectional	89; 65.7 (4.7); 17/72; EWGSOP1 and EWGSOP2	138; 64.9 (4.2); 56/82	24-hour food recall	Energy, Ptn, Cho, total fat	Energy consumption (kcal), Ptn (g), Cho (g), and total fat (g) did not differ between individuals with and without sarcopenia ( $P > 0.05$ ).
Yeung et al (2020) <sup>18</sup>	Netherlands, Australia	Cross-sectional	14; NR; NR/NR; EWGSOP1 and EWGSOP2	51; NR; NR/NR	3-day food log	Energy, Ptn	Energy and Ptn consumption did not differ between groups ( $P > 0.05$ ).
Jyväkorpi et al (2020) <sup>16</sup>	Finland	Cross-sectional	27; 88.0 (3.0); 0/27; EWGSOP2	51; 87.1 (2.9); 0/51	3-day food diary	Energy, Ptn, Ptn vegetable, animal meat, milk, fish, egg, Cho, starch, sugar, fiber, total fat, SFA, MUFA PUFA, Vit D	Sarcopenia was associated with lower energy consumption, fiber, total protein, vegetables, fish, total fat, MUFA, PUFA, and Vit D ( $P < 0.05$ ).
Beaudart et al (2019) <sup>4</sup>	Belgium	Cross-sectional	51; 77.6 (6.58); 32/19; EWGSOP1	280; 74.4 (5.64); 163/117	FFQ	Energy, Ptn, Cho, total fat, SFA, Na, K, Mg, P, Fe, Ca, Vit D, A, E, C, and K	In the model fully adjusted for age, gender, Geriatric Depression Scale score, Mini-Mental State Examination score, number of medications, and BMI, sarcopenic subjects consumed significantly lower amounts of Ptn, total fat, K, Mg, P, F, and vitamin K ( $P < 0.05$ ) compared with non-sarcopenic subjects.
Verlaan et al (2017) <sup>14</sup>	Belgium, Germany, Ireland, Italy, Sweden, and United Kingdom	Case-control	66; 71.1 (4.4); 39/27; EWGSOP1	66; 71.0 (4.4); 39/27	3-day food log	Energy, Ptn, Cho, total fat, folate, Ca, Mg, P, Se, Zn, Vit B6, B12, C, D, and E	Individuals with sarcopenia had lower consumption of Ptn (g/kg), Vit B12, D, Mg, P, Se and higher consumption of Cho (%) ( $P < 0.05$ )

(continued)

Table 2 Continued

Reference (Year)	Country	Study design	Sarcopenia		Food-intake methods	Nutrients studied	Main results
			Yes n; age (y) (SD); F/M; consensus used	No n; age (y) (SD); F/M			
ter Borg et al (2016) <sup>5</sup>	Netherlands	Cross-sectional	53; 81 (77–86); 28/25; EWGSOP1	174; 72 (68–76); 89/85	FFQ	Energy, Ptn, Cho, total fat, n-3 FA, ALA, EPA, FA, Ca, Mg, Se, Zn, Vit B6, B12, C, D, and E	Analyzing food intake only, the sarcopenic group had a lower intake of Ptn (g/d), n-3 FA, ALA, Vit B6, FA equivalents, Vit E, Mg, and Se ( $P < 0.05$ ). The amount of energy and other nutrients did not differ between groups with and without sarcopenia.
Isanejad et al (2016) <sup>15</sup>	Finland	Cross-sectional	127; 67.9 (1.9); 127/0; EWGSOP1	369; 67.7 (1.8); 369/0	3-day food log	Energy, Ptn, Cho, fat	The group of women diagnosed with sarcopenia had higher energy intake (kJ), Ptn (g/kg), Cho (g), fat (g), and fat (%) ( $P < 0.05$ ).
Valentim et al (2016) <sup>21</sup>	Brazil	Cross-sectional	18; NR; 14/4; EWGSOP1	47; NR; 27/20	3-day food diary	Energy, folate, Ca, P, Mg, Fe, Zn, Se, Ptn, Cho, fat, Vit A, D, B12, C, and E	Only Vit C showed a significant difference ( $P < 0.05$ ) between groups with and without sarcopenia. For the other nutrients, there was no statistically significant difference between the groups.
Martins (2015) <sup>19</sup>	Brazil	Cross-sectional	51; 72.7 (7.1); 31/20; EWGSOP1	85; 69.9 (6.9); 75/10	3-day food diary	Energy, Cho, Ptn, animal Ptn, vegetable Ptn, fat, Chol, SFA, MUFA, PUFA, total fibers, SF, IF, Vit D, E, C, Ca, P, Fe, Zn, Na, K, Se, and n-3 FA	Male individuals with sarcopenia had higher energy intake (kcal) ( $P < 0.05$ ) and lower Vit C intake ( $P < 0.05$ ). Female individuals with sarcopenia had lower intakes of Cho (g), Ptn (g/kg) and Ptn (%), SF, Vit C, and n-3 FA ( $P < 0.05$ ). There was no statistically significant difference in the consumption of other nutrients between male and female individuals with and without sarcopenia.
Goltz (2014) <sup>20</sup>	Brazil	Cross-sectional	26; 72.30 (6.57); 26/0; EWGSOP1	16; 68.43 (3.36); 16/0	3-day food log	Energy, Ptn, Cho, fat	Ptn consumption (%) was lower in the group of elderly women with sarcopenia ( $P < 0.05$ ). No statistically significant difference existed between energy intake (kcal), Cho, and fat.
Volpato et al (2014) <sup>13</sup>	Italy	Cross-sectional	55; 83.8 (5.92); NR; EWGSOP1	483; 76.3 (4.96); NR	FFQ	Energy, Ptn, Vit D	Energy consumption (kcal), Ptn, and Vit D did not differ between individuals with and without sarcopenia ( $P > 0.05$ ).

**Abbreviations:** ALA,  $\alpha$ -linolenic acid; BMI, body mass index; Ca, calcium; Cho, carbohydrate; Chol, cholesterol; EPA, eicosapentaenoic acid; EQ-5D, European quality of life-5 dimensions; EWGSOP1, European Working Group on Sarcopenia in Older Persons 2010; EWGSOP2, European Working Group on Sarcopenia in Older Persons 2019; F, female; FA, folic acid; Fe, iron; FFQ, food-frequency questionnaire; FRAIL scale (Fatigue, Resistance, Ambulation, Illnesses, & Loss of Weight); IF, insoluble fiber; K, potassium; M, male; MNA-SF, mini nutritional assessment-short form; Mg, magnesium; MUFA, monounsaturated fatty acids; n-3 FA, omega-3 fatty acid(s); Na, sodium; NR, not reported; P, phosphorus; Ptn, protein; PUFA, polyunsaturated fatty acids; SD, standard deviation; Se, selenium; SF, soluble fiber; SFA, saturated fatty acids; Vit, vitamin; Zn, zinc.

**Table 3 Newcastle-Ottawa quality assessment results of studies included in the systematic review**

Reference	Selection	Comparability	Result	Total
Şimşek and Uçar (2022) <sup>17</sup>	**	**	**	6
Rahman et al (2021) <sup>22</sup>	**	**	**	6
Yeung et al (2020) <sup>18</sup>	*	—	**	3
Jyväkorpi et al (2020) <sup>16</sup>	*	—	**	3
Beaudart et al (2019) <sup>4</sup>	**	**	**	6
Verlaan et al (2017) <sup>14,a</sup>	****	**	**	8
ter Borg et al (2016) <sup>5</sup>	**	**	**	6
Isanejad et al (2016) <sup>15</sup>	**	**	**	6
Valentim et al (2016) <sup>21</sup>	**	—	*	3
Martins (2015) <sup>19</sup>	**	**	**	6
Goltz (2014) <sup>20</sup>	**	—	**	4
Volpato et al (2014) <sup>13</sup>	**	**	**	6

Cross-sectional studies: Maximum score of 7 asterisks (or stars); moderate quality: 4 to 6 stars; low quality: ≤ 3 stars.

<sup>a</sup>Case-control studies: Maximum score of 9 asterisks (or stars); moderate quality: 6 to 8 stars; low quality: ≤ 5 stars.

presented. The level of evidence has yet to be downgraded for methodological quality, imprecision, indirect evidence, or publication bias. When evaluating the other nutrients, the certainty of the evidence remained low, considering the design of the included studies (observational) and because they needed to follow the criteria that could increase the certainty of the evidence. Thus, more robust studies are needed to increase confidence in the results reported in this systematic review and meta-analysis.

### Energy and macronutrient intake and sarcopenia

A total of 1971 participants (n = 610 with sarcopenia, n = 1361 without sarcopenia) were included in 11 studies that assessed total energy intake.<sup>4,5,14–22</sup>

The meta-analysis did not identify a statistically significant difference in energy intake between individuals with and without sarcopenia (see Fig. S1 in the Supporting Information online). However, by excluding the study by Şimşek and Uçar,<sup>17</sup> which presented very discrepant results, it was shown that individuals with sarcopenia consume fewer kilocalories per day than individuals without sarcopenia (SMD −0.15; 95% CI −0.29, −0.01) diagnosed by the EWGSOP1 and EWGSOP2 consensus (Fig. 2).<sup>4,5,14–16,18–22</sup>

Protein intake (g/kg/body weight/day) was assessed in 9 studies<sup>4,5,13–17,19,20</sup> with 2107 individuals (n = 544 with sarcopenia, n = 1563 without sarcopenia) (SMD −0.10; 95% CI −0.53, 0.32) (Fig. 3),<sup>4,5,13–17,19,20</sup> and the intake of carbohydrates (g/day) and lipids (g/day) in 10 studies<sup>4,5,14–17,19–22</sup> with the same number of individuals (1096; n = 596 with sarcopenia; n = 1310 without sarcopenia; SMD −0.31; 95% CI −0.78, 0.16 and SMD −0.05; 95% CI −0.30, 0.20 respectively) (Fig. 4<sup>4,5,14–17,19–22</sup> and Fig. 5<sup>4,5,14–17,19–22</sup>). Meta-analyses for these macronutrients did not identify statistically significant

differences in the intake of carbohydrates, proteins, and lipids in individuals with and without sarcopenia.

The results of the funnel plot analysis and Egger's tests indicated that there was no presence of publication bias and the effect of small studies, respectively, in the meta-analyses for energy ( $P = 0.780$ ), carbohydrate ( $P = 0.764$ ), lipids ( $P = 0.346$ ), and protein ( $P = 0.472$ ).

### Micronutrients and other nutrient intake

Individuals with sarcopenia had a lower folate (SMD −0.32; 95% CI −0.61, −0.04), magnesium (SMD −0.42; 95% CI −0.59, −0.25), phosphorus (SMD −0.28; 95% CI −0.50, −0.06), selenium (SMD −0.21; 95% CI −0.39, −0.03), zinc (SMD −0.25; 95% CI −0.43, −0.06), vitamin C (SMD −0.23; 95% CI −0.42, −0.05), vitamin D (SMD −0.27; 95% CI −0.42, −0.12), and vitamin E (SMD −0.23; 95% CI −0.42, −0.05) intake when compared with individuals without sarcopenia. The other vitamins, minerals, fiber, and cholesterol showed no statistically significant differences in intake between the groups (Table 4).<sup>4,5,13,14,16,17,19,21</sup>

The meta-analysis for omega-3 (g/day) identified lower intakes of this nutrient by individuals with sarcopenia (SMD −0.29; 95% CI −0.53, −0.06) (Table 4).

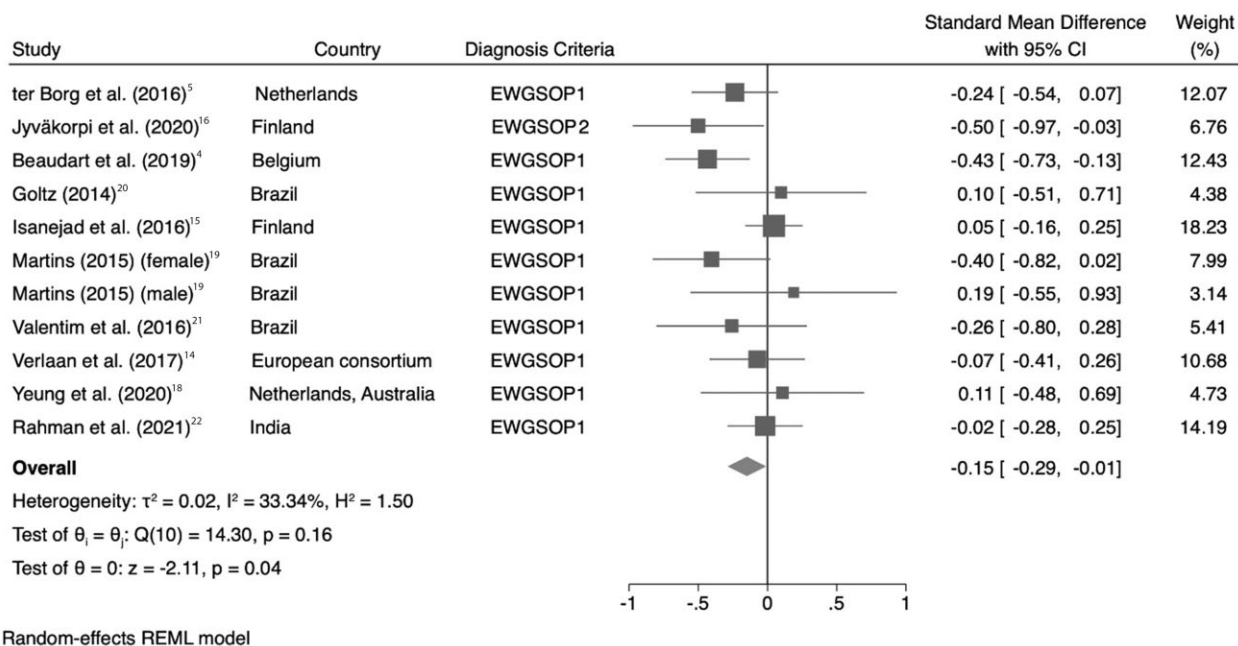
### Subgroup analysis

In the subgroup analysis, taking into account the diagnosis of sarcopenia by EWGSOP1 and EWGSOP2, for energy, protein, carbohydrates, lipids, vitamin D, cholesterol, and fiber, there were no changes in the findings (see Figs. S2–S9 in the Supporting Information online).

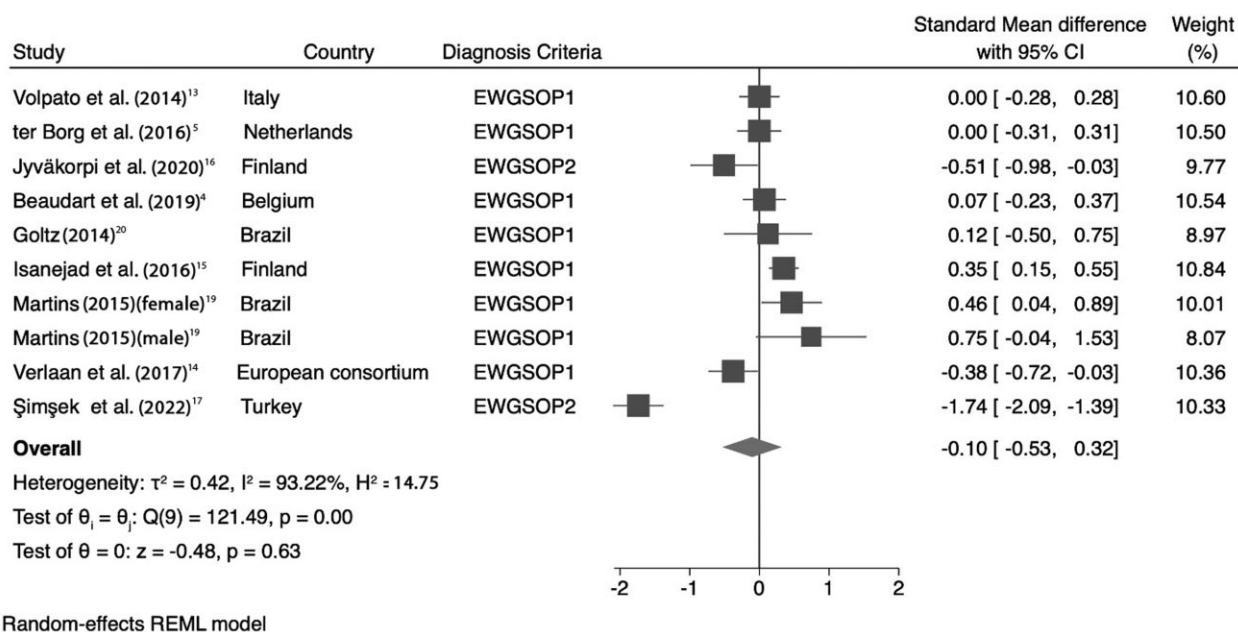
## DISCUSSION

The present study showed that individuals with sarcopenia consume fewer kilocalories per day and less omega-3, folate, magnesium, phosphorus, selenium, zinc, and vitamins C, D, and E than individuals without sarcopenia when diagnosed by the EWGSOP1 or EWGSOP2 consensus. To our knowledge, this is the first systematic review with meta-analysis that compared energy and nutrient intake by people with and without sarcopenia, restricting it to studies that used only the EWGSOP diagnostic criteria.

The results show that not only the lack of certain nutrients can be associated with sarcopenia but the energy content of the food intake also should be considered. In a condition in which the energy intake is insufficient to meet needs, muscle and body fat are catabolized for energy generation. Consequently, adequate energy intake is essential to maintain muscle mass and physical performance.<sup>23</sup>



**Figure 2 Analysis of energy intake in individuals with and without sarcopenia.** Abbreviations: CI, confidence interval; EWGSOP1, European Working Group on Sarcopenia in Older People 2010; EWGSOP2, European Working Group on Sarcopenia in Older People 2019; REML, restricted maximum likelihood method.

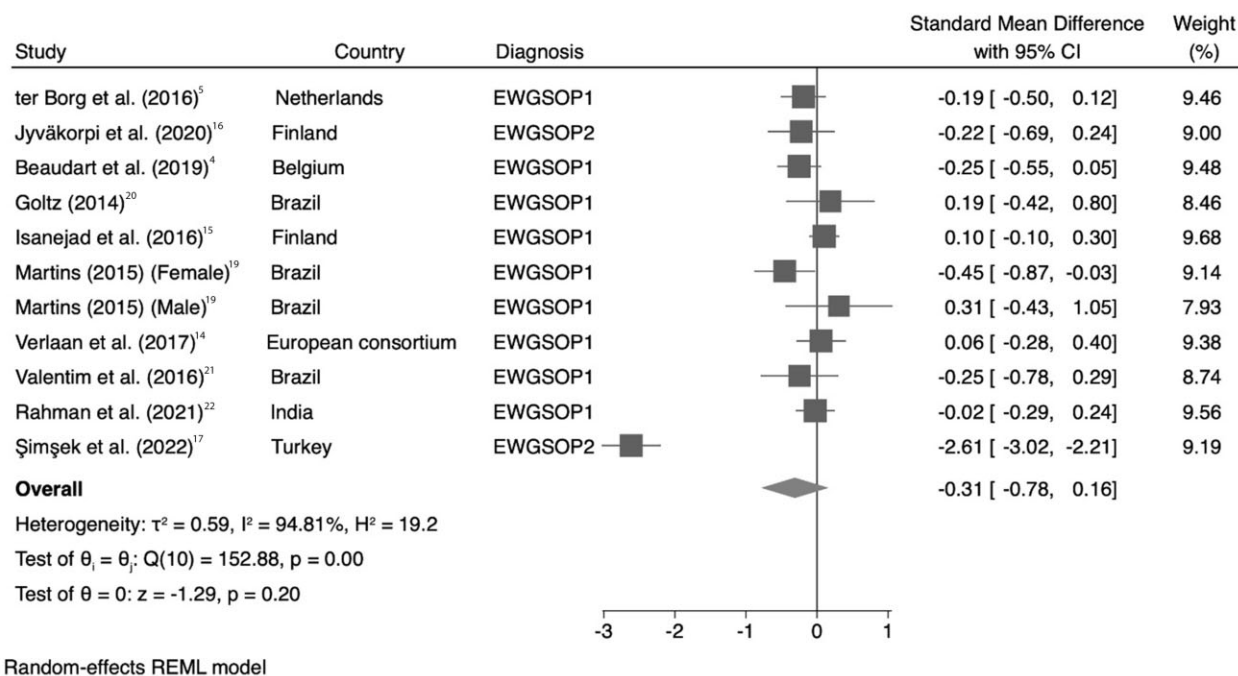


**Figure 3 Analysis of protein intake in individuals with and without sarcopenia.** Abbreviations: CI, confidence interval; EWGSOP1, European Working Group on Sarcopenia in Older People 2010; EWGSOP2, European Working Group on Sarcopenia in Older People 2019; REML, restricted maximum likelihood method.

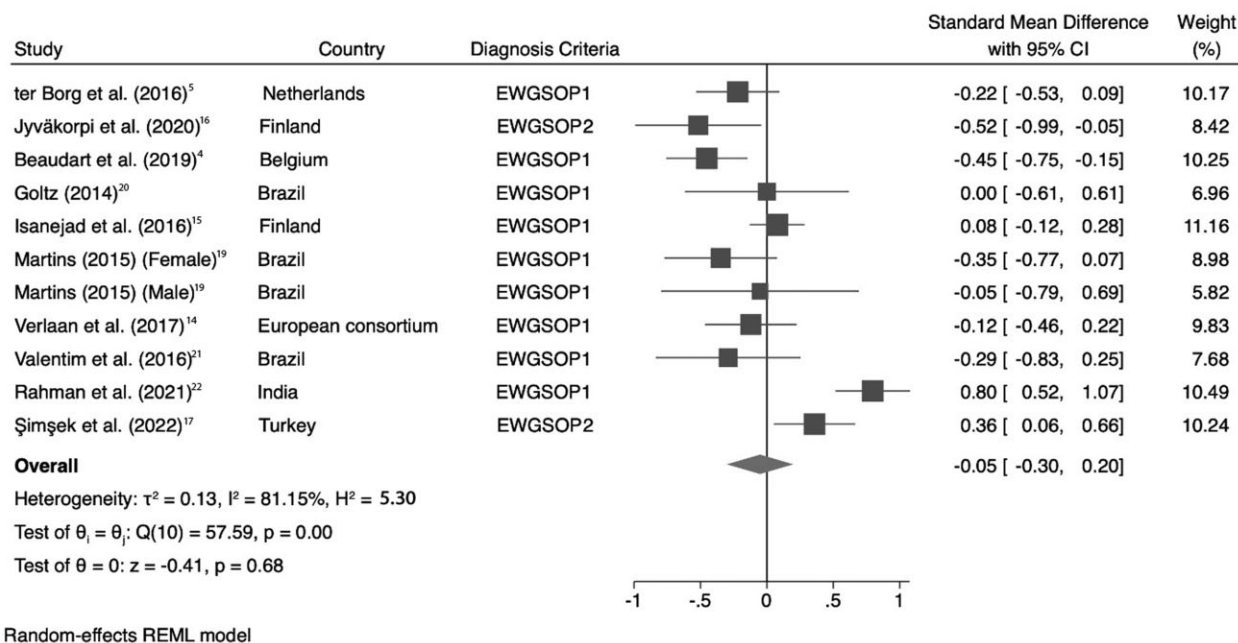
The reduction in food intake, characteristic of aging, is usually associated with specific changes, such as lack of appetite, changes in taste and smell, reduced gastric-emptying rate, hormonal changes, changes in chewing or swallowing, and medication use. All of these factors can contribute to inadequate energy

and nutrient intake, favoring weight loss and sarcopenia.<sup>24–26</sup>

A recent systematic review with meta-analysis<sup>6</sup> also found the lowest energy intake in individuals with sarcopenia. However, studies that used different diagnostic criteria to assess sarcopenia were included, and it was



**Figure 4 Analysis of carbohydrate intake in individuals with and without sarcopenia.** Abbreviations: CI, confidence interval; EWGSOP1, European Working Group on Sarcopenia in Older People 2010; EWGSOP2, European Working Group on Sarcopenia in Older People 2019; REML, restricted maximum likelihood method.



**Figure 5 Analysis of lipid intake in individuals with and without sarcopenia.** Abbreviations: CI, confidence interval; EWGSOP1, European Working Group on Sarcopenia in Older People 2010; EWGSOP2, European Working Group on Sarcopenia in Older People 2019; REML, restricted maximum likelihood method.

impossible to compare them with the findings of this review. When evaluating only older Australian women, 2 cohort studies showed a significant reduction in energy intake and other nutrients during follow-up.<sup>24,27</sup>

The role of dietary protein has been highlighted in the literature as one of the main macronutrients associated with the development of sarcopenia.<sup>28</sup> Adequate protein intake stimulates protein synthesis, preventing

**Table 4 Analysis of intake of minerals, vitamins, and other nutrients by individuals with and without sarcopenia**

Micronutrient	Reference	Sarcopenia		SMD (95% CI)
		Yes	No	
<b>Minerals</b>				
Calcium (mg)	5, 14, 19, 21	188	372	-0.04 (-0.22, 0.15)
Folate ( $\mu$ g)	5, 14, 21	137	287	-0.32 (-0.61, -0.04)
Iron (mg)	4, 19, 21	120	412	-0.23 (-0.59, 0.13)
Magnesium (mg)	4, 5, 14, 21	188	567	-0.42 (-0.59, -0.25)
Phosphorus (mg)	4, 14, 19, 21	186	478	-0.28 (-0.50, -0.06)
Potassium (mg)	4, 19	102	365	-0.30 (-0.64, 0.04)
Selenium ( $\mu$ g)	5, 14, 21	188	372	-0.21 (-0.39, -0.03)
Sodium (mg)	4, 19	102	365	-0.09 (-0.51, 0.34)
Zinc (mg)	5, 14, 21	188	372	-0.25 (-0.43, -0.06)
<b>Vitamins</b>				
B6 (mg)	5, 14	119	240	-0.30 (-0.89, 0.28)
C (mg)	5, 14, 21	188	372	-0.23 (-0.42, -0.05)
D ( $\mu$ g)	5, 13, 14, 16, 19, 21	270	861	-0.27 (-0.42, -0.12)
E (mg)	5, 14, 19, 21	188	372	-0.23 (-0.42, -0.05)
<b>Others nutrients</b>				
Fiber (g/day)	16, 17, 19	166	220	-0.63 (-2.18, 0.92)
Cholesterol (mg/day)	17, 19	139	169	-0.68 (-1.95, 0.58)
Omega-3 (g/day)	5, 19	104	259	-0.29 (-0.53, -0.06)

Abbreviation: SMD: standardized mean difference; CI: confidence interval.

muscle proteolysis in sarcopenia.<sup>29</sup> The recent meta-analysis by Santiago et al<sup>6</sup> found low protein intake in individuals with sarcopenia. Coelho-Júnior et al<sup>30</sup> investigated the association between protein intake and the physical function of the older adults. They indicated that a protein amount above 1.0 g/kg of body weight is associated with improvement in the physical performance of lower limbs. On the other hand, a high protein intake ( $\geq 1.0$  g/kg body weight) was not associated with better performance in handgrip strength and lower limb strength assessed through the chair-rise test when compared with the low-intake group ( $< 0.8$  g/kg body weight). In this sense, the high-protein intake does not guarantee a higher score on all physical performance tests.

Some vitamins and minerals play a role in muscle metabolism and function. Inadequate intake of these micronutrients is associated with the onset of sarcopenia.<sup>6,31</sup>

The specific alterations of aging, in particular the loss of the ability to chew and poor oral health, can compromise the total intake of food and, consequently, most micronutrients,<sup>31</sup> justifying the low consumption of vitamins and minerals in this population age group.

For the most part, the studies included in this review showed a moderate risk of bias due to the lack of clarity in the selection and comparability of participants. In this sense, caution is needed in interpreting the results, as the items identified as risk of bias may have introduced bias in the original studies and consequently affected the final results of this review.

The present study had some limitations. First, the different methods for assessing food intake may have

overestimated or underestimated caloric and nutrient intake. However, in the food-intake analysis, the systematic error is attributed to the nature of the information obtained. Second, different instruments and cutoff points for assessing physical performance, muscle mass, and strength were used in the included studies, even when using the diagnostic criteria for sarcopenia from the EWGSOP consensus. Third, the cross-sectional nature of the studies included in this systematic review makes it impossible to establish causality in the relationships of interest, limiting the interpretation of results.

It should be noted that, during the review process, all stages of the methodology were respected to avoid possible prejudices. Two independent raters performed the search, data extraction, and risk-of-bias assessment to reduce the risk of errors and bias. To obtain the maximum number of articles published in the subject area, 6 relevant scientific database sources were used and the reference lists of the chosen manuscripts were evaluated.

## CONCLUSION

Based on the available literature, individuals with sarcopenia have low caloric and micronutrient intakes, such as omega-3, folate, magnesium, phosphorus, selenium, zinc, and vitamins C, D, and E, when compared with individuals without sarcopenia. Despite the relevant evidence pointed out by the present study, one should consider the moderate methodological quality of the included studies. Therefore, more well-designed, prospective studies are needed, with standardization of the

methods used to assess food consumption and diagnose sarcopenia.

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## Supporting Information

The following Supporting Information is available through the online version of this article on the publisher's website.

[Appendix S1 PRISMA 2009 checklist.](#)

[Table S1 Newcastle-Ottawa assessment scale transversal studies.](#)

[Table S2 Newcastle-Ottawa assessment scale case-control studies.](#)

[Figure S1 Analysis of energy intake in individuals with and without sarcopenia](#)

[Figure S2 Analysis of energy intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S3 Analysis of energy intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2, excluding the study by Şimşek and Uçar \(2022\)<sup>S11</sup>](#)

[Figure S4 Analysis of protein intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S5 Analysis of carbohydrate intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S6 Analysis of lipid intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S7 Analysis of vitamin D intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S8 Analysis of cholesterol intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

[Figure S9 Analysis of fiber intake in individuals with and without sarcopenia for subgroups, considering the criteria of EWGSOP1 and EWGSOP2](#)

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