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Association between dietary pattern and sarcopenia in individuals with metabolic syndrome criteria: a systematic review

Asociación entre el patrón dietético y la sarcopenia en individuos con criterios de síndrome metabólico: una revisión sistemática

Dietary pattern and sarcopenia in individuals with metabolic syndrome criteria

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HIGHLIGHTS

- There is certainty that a good quality diet implies a lower risk of developing sarcopenia.
- Low fiber and vitamin C consumption were found to increase the risk of sarcopenia
- Dietary approaches to stop hypertension (DASH), Mediterranean, ovolactovegetarian and Brazilian traditional diets were associated with a lower risk of sarcopenia.

ABSTRACT

Introduction: The main objective of this systematic review was to explore the relationship between people with metabolic syndrome criteria, their dietary patterns and the development of sarcopenia.

Methods: A systematic review was performed in accordance with the standard of the PRISMA guidelines. The inclusion criteria were adult population (18 years and over), both sexes, diagnosed with metabolic syndrome (MS) or one of their components (obesity, dislipemia, hypertension or insulin resistance), cross-sectional, cohort studies or randomized controlled trials and articles in English or Spanish. The protocol registration number in PROSPERO is CRD42022369071.

Results: 662 articles were found, after screening and selection, 16 were analyzed. The aforementioned articles were 12 cross-sectional studies, 1 RCT and 3 cohort studies. The total sample studied was 21453 people. Heterogeneity was observed in the gathering of study information methods. The results were divided into three groups according to the data collection methods used in the study: dietary survey, Food Frequency Questionnaire (FFQ) and other methods. An association was found between low intake of fiber or vitamin C and unbalanced diets with the development of sarcopenia in people with MS. Otherwise, it was found an association between a diet rich in carbohydrates, *Dietary approaches to stop hypertension*, Mediterranean, ovolactovegetarian and Brazilian traditional diets and a lower risk of development sarcopenia.

Conclusions: It was found an association between low-fiber intake and unbalanced diets and a high risk of development sarcopenia while diet while good quality diets with a high content of vegetables, fiber and anti-inflammatory foods reduced the risk.

Funding: The authors declare that there has been no funding to carry out this study.

Keywords: Eating behavior, food habits, metabolic syndrome, sarcopenia and muscle strength.

RESUMEN

Introducción: El objetivo principal de esta revisión sistemática fue explorar la relación entre los patrones dietéticos y el desarrollo de sarcopenia en personas con criterios diagnósticos de síndrome metabólico.

Métodos: Se realizó una revisión sistemática de acuerdo con el estándar de las directrices PRISMA. Los criterios de inclusión fueron población adulta (mayor de 18 años), ambos sexos, diagnosticados de síndrome metabólico (SM) o alguno de sus componentes (obesidad, dislipemia, hipertensión o resistencia a la insulina), estudios transversales, de cohortes o ensayos clínicos aleatorizados y artículos en inglés o español. El número de registro del protocolo en PROSPERO es CRD42022369071.

Resultados: Se encontraron 662 artículos, tras el cribado y selección, se analizaron 16. Dichos artículos fueron 12 estudios transversales, 1 ECA y 3 estudios de cohortes. La muestra total estudiada fue de 21453 personas. Se observó heterogeneidad en los métodos de recogida de información de los estudios. Los resultados se dividieron en tres grupos según los métodos de recogida de datos utilizados en el estudio: encuesta dietética, Cuestionario de Frecuencia de Alimentos (FFQ) y otros métodos. Se encontró una asociación entre la baja ingesta de fibra o vitamina C y las dietas desequilibradas con el desarrollo de sarcopenia en personas con SM. Sin embargo, se encontró asociación entre una dieta rica en hidratos de carbono, *Dietary approaches to stop hypertension (DAHS)*, la dieta mediterránea, ovolactovegetariana y las dietas tradicionales brasileñas y un menor riesgo de desarrollo sarcopenia.

Conclusiones: Se encontró una asociación entre la baja ingesta de fibra y las dietas desequilibradas y un alto riesgo de desarrollo de sarcopenia, mientras que las dietas de buena calidad con un alto contenido en verduras, fibra y alimentos antiinflamatorios redujeron el riesgo.

Financiación: no existen fuentes de financiación para este estudio.

Palabras clave: conducta alimentaria, síndrome metabólico, sarcopenia y fuerza muscular

INTRODUCTION

The *European Working Group on Sarcopenia in Older People* (EGWSOP) defines sarcopenia as the syndrome characterized by the progressive and generalized loss of muscle mass and strength with a risk of adverse problems such as disability, poor quality of life and death¹. Sarcopenia is a pathology with great implications for the daily life of the people affected, however, a single diagnostic criterion has not yet been established.

Various attempts have been made to standardize diagnostic criteria and cut-off points for diagnosing sarcopenia, most of them using combinations of measures of muscle mass, muscle strength, and gait speed. Among them, the most used definitions are the EGWSOP (2010) and the revised EGWSOP2 (2019)². The EGWSOP recommends the use of the presence of both defining factors (loss of muscle mass and decrease in strength) for diagnosis¹.

In accordance with the Petermann-Roche et al. systematic review, the prevalence of sarcopenia worldwide ranged from 10% to 27% in people 60 years old and over. In addition, the occurrence of severe sarcopenia in this age group fluctuated between 2% and 9%. These prevalence rates of sarcopenia and severe sarcopenia varied considerably according to the classification and cut-off point used in each study².

Parallely, the relationship between sarcopenia and metabolic syndrome (MS) is interesting. Skeletal muscle is a major organ of insulin-induced glucose metabolism. In addition, loss of muscle mass is closely linked to insulin resistance and MS. In recent years, it has become clear that sarcopenia is closely related to MS, type 2 diabetes mellitus (T2D), and cardiovascular disease. Skeletal muscle loss and accumulation of intramuscular fat are responsible for impaired muscle contractile function and metabolic abnormalities². MS forms a cluster of metabolic dysregulations including insulin resistance, atherogenic dyslipidemia, central obesity, and hypertension. The pathogenesis of MS encompasses multiple genetic and acquired entities³. The prevalence of T2D patients who live in old age is increasing. This longer life expectancy directly results from improvements in treatment and follow-up appointments. Likewise, the number of patients with sarcopenia is increasing⁴. Muscle loss and intramuscular fat accumulation could be linked to MS through a complex interaction of factors including feeding behavior, physical activity, body fat, oxidative stress, proinflammatory cytokines, insulin resistance and hormonal changes, and mitochondrial dysfunction⁵. There is a high proportion of MS in middle-aged and non-obese elderly people with sarcopenia, with MS being positively connected to sarcopenia in this age group⁶. MS and sarcopenia are also

interrelated through insulin resistance, adipose tissue, chronic inflammation, vitamin D deficiency and other factors. Parallely, a decrease in muscle mass and strength is associated with the development of MS, as well as physical inactivity has been linked to a major risk factor for both MS and sarcopenia⁷ as well as MS can be associated with sarcopenic obesity. Also, a study demonstrated that sarcopenia is independently associated with the risk of MS and might have a dose-response relationship⁸.

At the same time, another factor to consider is food intake, since it falls to about 25% between 40-70 years. Compared to younger people, older adults eat slower, have less sense of hunger, eat less at each meal, and snack less food between meals. This translates into a monotonous diet that can lead to inadequate nutrient intake. Thus, a vicious circle is created in which muscle mass and physical capacity are decreased⁹, the first one being one of the criteria for the diagnosis of sarcopenia. Food patterns can be defined as the quantities, proportions, variety, or combination of different foods and drinks in diets, and the frequency with which they are habitually consumed¹⁰. One of the most studied pattern is the Mediterranean diet. This food pattern consists of antioxidants, anti-inflammatory micronutrients and n-3 fatty acids and is characterized by a high intake of monounsaturated fat and fiber¹¹. Other food patterns examples are the Western diet and prudent pattern¹². All the reviewed literature states that new researches are needed in the future to reach definitive conclusions on the most beneficial dietary pattern¹¹⁻¹³.

Considering this, the aim of this systematic review was to explore the relationship between dietary patterns and the development of sarcopenia, focusing this objective on population with metabolic syndrome diagnostic criteria, due to its great relevance and the lack of in-depth literature reviews in this area.

METHODS.

Design

This systematic review was developed in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses guidelines (PRISMA)¹⁴ and was registered in PROSPERO with the number of register CRD42022369071.

Criteria for inclusion of studies

The inclusion criteria were defined as adult population (18 years and over), all sexes, diagnosed with MS or one of their components (obesity, dislipemia, hypertension and insulin resistance) and which contrast the relationship between sarcopenia and dietary pattern, with a cross-sectional, randomized controlled trials (RCT) or cohort design and published in English or Spanish language. Systematic reviews, congress publications, and populations with specific pathologies not related to MS as oncological pathologies and Chronic Obstructive Pulmonary Disease were defined as exclusion criteria.

Bibliographical search method

The strategy search used in the mentioned databases (Web of Science (all collections) and Scopus) can be found in [supplementary material 1](#). The search was carried out in May 2023.

Selection of studies and data management

A first investigator (DCP) searched in the databases, downloaded the articles and eliminated the duplicated. After that, a first filtering phase was carried out by title and abstract by two independent researchers (DCP, PYG), both blinded to the opinions of the other. The discrepancies between DCP and PYG were contrasted by a third author (IDF). Having decided which articles were chosen, a complete reading of the articles was carried out by DCP, LBJ and AMD, following this, the read articles were selected for analysis. Afterwards, DCP and LBJ completed the data extraction about those articles: names of the authors, year of publication, place where the sample of the study that has been carried out was found, type of study, numerical data of the sample analyzed in each article (sample size, arithmetic average and age range, and distribution by sex), instrument used to collect information on diet, and conclusions. AMD, AFS and VMS participated in the cross-checked data extraction. The software used for the selection of studies was Excel®.

Assessment of methodological quality

A determination of the methodological quality and the risk of bias of the included studies was made following the Critical Appraisal Checklist of the Joanna Briggs Institute (JBI)¹⁵ and the specific checklist for cross-sectional, cohort or RCT studies for each article according to their design.

The checklist for prevalence data uses nine items, each component was scored as "Yes", "No", "Unclear" or "Not applicable". With 1-3 scores of "Yes", the risk of bias rating was considered high, with 4-6 scores of "Yes" it was considered moderate and with "7-9" it was considered low. The JBI checklist for cohorts uses eleven criteria, and the JBI for RCT uses thirteen criteria, in these cases, with 1-4 'Yes' scores the risk of bias rating was considered high, with 5-8 'Yes' scores it was considered moderate and with 9-11 'Yes' (9-13 for RCT) the score was of low risk. For inclusion in the review, articles were required to have a moderate or low-risk of bias score.

Synthesis methods

A qualitative synthesis of the data was carried out using a summary table of findings. It was completed according to the effect of nutritional patterns on sarcopenia, divided into three groups; the group of studies that use dietary survey, the group of articles that used Food Frequency Questionnaire (FFQ) and other one with the articles that used other methods to assess feeding. Specific effect measures were used for each one of the articles, these being mainly the Odds Ratio and the beta coefficients, accompanied by the p-value or the 95% confidence interval (95%CI).

RESULTS

Study selection

The PRISMA flow diagram (Figure 1) shows the results of the process of revision. Also, the PRISMA checklist can be found as supplementary material 2. In total, 662 articles were found, 144 were eliminated because they were duplicated, and therefore 518 articles were analyzed by title. They were analyzed by title, abstract and complete text. The including articles were the following¹⁶⁻³⁰. Articles excluded after full-text evaluation can be checked in supplementary material 3.

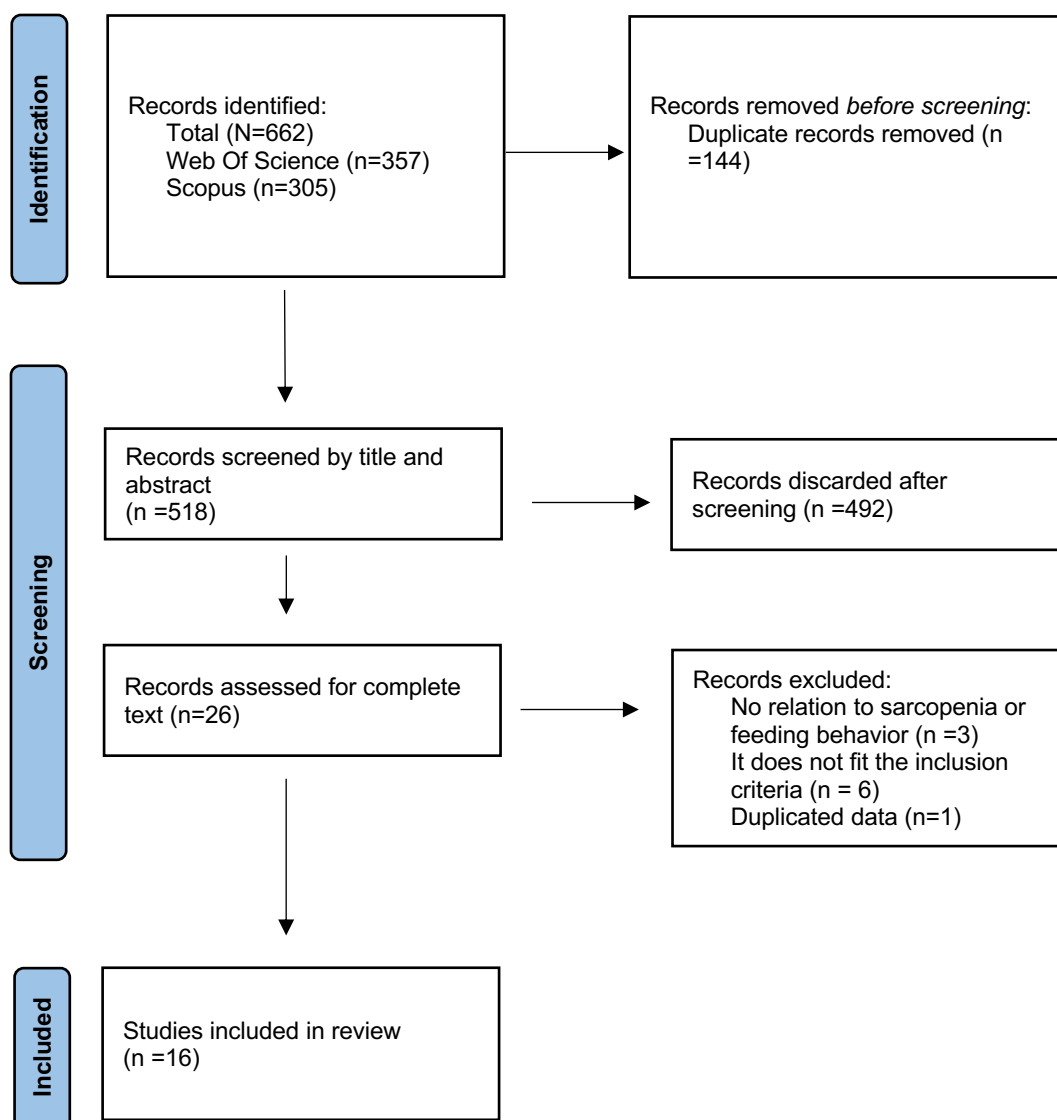


Figure 1. PRISMA flow chart of the article selection process.

Study characteristics

The characteristics of the chosen studies can be seen in Tables number 1-3. Twelve cross-sectional studies^{16–19,21,23–26,28,29}, three cohort studies^{20,27,30} and one RCT²² were analyzed. The results were grouped according to the dietary data collection methods used. Four studies used a dietary survey (25%)^{19,21,25,30}, in five the information collection method was the FFQ (31.2%)^{17,20,24,28,29} and seven used neither FFQ nor dietary survey (43.8%)^{16,18,22,23,26,27}. The earliest published study included was from 2014²⁴. Seven of the studies were conducted in Asia (43.8%)^{17,19,23,27–29}, five in Europe (31.2%)^{18,20,21,24,26} and four in America (25%)^{16,22,25,30}. The total sample studied was 21453.

Analysis of risk of bias

After applying the JBI cohorts, cross-sectional or RCT studies checklists, respectively, no articles were removed due to high risk of bias. The obtained results were 1/3 moderate-risk and 2/3 low-risk for cohort studies, 1/1 low-risk in RCT, 11/12 low-risk and 1/12 moderate-risk for the cross-sectional studies. The complete analysis and evaluation items for each checklist can be found in supplementary material 4.

Results of individual studies

For the synthesis, the studies were divided into three categories: the articles that used the dietary survey, the articles that used the FFQ³¹ and the articles that used other different methods, such as the Brief Self-administered Diet History Questionnaire (BDHQ)³², the Dietary Approaches to Stop Hypertension (DASH)¹⁶ and the Mediterranean Diet Adherence Screener (MEDAS) test, which measures therapeutic adherence and its impact on the prevention of cardiovascular disease³³.

Regarding the four articles that used the dietary survey (Table 1) it was observed that low fiber intake in individuals with MS²¹ and diabetic individuals who consumed less protein than recommended²⁵ was related to a higher risk of developing sarcopenia, otherwise, diet and physical exercise in diabetic men³⁰ and a diet that fulfill the recommendations about carbohydrate intake¹⁹ were associated with a lower risk of developing sarcopenia .

Regarding the FFQ, according to the studies that used it (Table 2), which were 5 of the total of 16 articles, daily red meat consumption²⁰ (OR=0.25), a diet high in carbohydrates²⁴ (OR=0.70),

the ovolactovegetarian diet¹⁷, the DASH diet²⁸ (OR=0.20) and the healthy beverage index²⁹ (OR=0.20) were associated with a lower risk of developing sarcopenia.

Other data collection methods that made up the third block (Table 3) which were grouped 7 of the 16 articles analyzed are BDHQ, own validated scales and MEDAS.

The BDHQ questionnaire confirmed that T2D diabetes patients, not having reached the daily protein requirements, increased the probability of developing sarcopenia²⁷ (OR=0.94); and miso soup intake was confirmed as preventive of developing sarcopenia in women²³ (OR=0.2).

Two articles based on MEDAS showed that the Mediterranean diet is related to an increase in grip strength²⁶ (OR = 0.126–0.454) and a protective factor against sarcopenia¹⁸.

The rest of the studies categorized the following as facilitators of the development of sarcopenia: diabetes and the consumption of more saturated fats and less vitamin C, a low amount of vitamins B6, C¹⁸, unbalanced diets¹⁹ and increased protein in the diet¹⁶. Brazilian traditional diet improves handgrip strength and has also been associated with a reduction in total body fat in severely obese individuals²².

Table 1. Results of studies in which the data collection method is the dietary survey

First author, year of publication	Location	Type of study	Sample	Diet information collection instrument	Main results	Method of measuring sarcopenia	Diagnostic criteria for MS	Risk of bias
Rahi et al. 2014 ³⁰	Canada	C	N=156 (M _{age} =74.6, SD=4.2) (39.7% women)	Three non - consecutive 24 hours' dietary recall. Then adapted score for C-HEI (Canadian healthy eating index)	After 3 years of follow up, diabetic males with Hight diet quality and stable physical activity were the group with best muscle strength maintaining, compared to the other groups with low diet quality or low physical activity (<i>p-value</i> =0.031). High quality diet includes high scores for fruits and vegetables intake, total fat, saturated fat, cholesterol and sodium, while	Changes in muscle strength	Diabetes	Mode rate risk

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					there were no differences with the other groups in protein intake. These results were not conclusive in females.			
Montiel-Rojas et al. 2020 ²¹	Europe	CS	N=981 (M _{age} :72, SD=4) (58% women)	7-day dietary survey	Elder women with higher fiber intake than average had higher strength muscle index compared to those below ($24.7 \pm 0.2\%$ vs. $24.2 \pm 0.1\%$, <i>p-value</i> = 0.011) While in men, the same association was only evident in those without MS. It suggests a beneficial impact of fiber intake on skeletal muscle mass in older adults.	DXA	All criteria	Low risk
Lee JH, et al. 2021 ¹⁹	South Korea	CS	N=3828 (57.2% women)	24 hours dietary survey	An increment of 100 calories of total and 1 increment for carbohydrate intake (g/kg/day), showed a protective power for the development of SO, with OR: 0.95	DXA	Obesity	Low risk

					(0.91–0.99) and OR: 0.83 (0.74–0.94), respectively.			
Fanelli SM, et al. 2021 ²⁵	United States of America	CS	N=2583, 31 years and older (40.4% women)	24 hours dietary survey	Adults with diabetes had more frequency of physical limitations (mean: 68.0 in low protein intake (<0.8 g/kg/day) and 64.6 in normal protein intake (>0.8 g/kg/kg) than those with non-diabetes (mean: 73.8 in low protein intake and 72.6 in normal protein intake), and adults with diabetes who consumed less protein than recommended had further increased limitations.	Grip strength and dynamometer	Diabetes	Low risk

Explanation of the studies found which use a dietary survey (of various amounts of times) specifying their most important characteristics.

Acronyms: C (cohort), CI (Confidence interval), CS (cross-sectional), DXA (Dual energy X-ray absorptiometry), M_{age} (Mean age), MS (metabolic syndrome), SD (standard deviation).

Table 2. Results of studies in which the information collection method is the FFQ

First author, year of publication	Location	Type of study	Sample	Diet information collection instrument	Main results	Method of measuring sarcopenia	Diagnostic criteria for MS	Risk of bias
Atkins et al. 2014 ²⁴	England	CS	N=4252 (M _{age} : 70.3)	FFQ	Eating a diet high in carbohydrates was related to reduced risk of sarcopenia in the elderly (OR: 0.7 95%CI: 0.5-1.0).	MAMC and FFMI	Insulin resistance	Low risk
Pereira da Silva et al. 2018 ²⁰	Portugal	C	N=521 (M _{age} : 67.51) (77.8% women)	FFQ	Daily red meat consumption was associated with a lower risk of developing sarcopenia (OR = 0.25, 95%CI = 0.1–0.7, <i>p-value</i> = 0.006)	Bioimpedance	All criteria	Moderate risk
Rasaei N, et al. 2019 ²⁸	Iran	CS	N=301 (100% women)	FFQ	The association between DASH diet and SO was significantly negative (OR = 0.20, 95% CI: 0.05-0.77, <i>p-value</i> =0.01), the risk of sarcopenia reduced by 80%	Bioimpedance	Obesity	Low risk

Chen et al. 2021 ¹⁷	China	CS	N=3795	FFQ	The ovolactovegetarian dietary pattern was a protective factor against the development of SO (95%CI: 0.60-0.97, <i>p-value</i> =0.02)	Bioimpedance	Obesity	Low risk
Rasaei N, et al. 2023 ²⁹	Iran	CS	N=210 (100% women)	FFQ	There was a negative association between healthy beverage index and the risk of SO (OR = 0.2, 95% CI: 0.35-1.01, <i>p</i> =0.05)	Bioimpedance	Obesity	Low risk

Description of the studies found that use the FFQ specifying their most important characteristics. Acronyms: C (cohort), CI (Confidence interval), CS (cross-sectional), FFMI (fat-free mass index), FFQ (Food Frequency Questionnaire), OR (Odds ratio), M_{age} (Mean age), MAMC (midarm muscle circumference, SO (sarcopenic obesity).

Table 3. Results of studies that include various methods of collecting information, neither FFQ nor dietary survey

First author, year of publication	Location	Type of study	Sample	Diet information collection instrument	Main results	Method of measuring sarcopenia	Diagnostic criteria for MS	Risk of bias
Abete et al. 2019 ¹⁸	Spain	CS	N=1535 (M _{age} : 65.6) (48% women)	MEDAS	Adherence to the Mediterranean diet and vitamin C intake appeared as protective factors for the development of sarcopenia in individuals with metabolic syndrome. A statistically significant association was found between diabetes and high consumption of (<i>p-value</i> <0.05).	DXA	Overweight or obesity	Low risk
Cydne Perry et al. 2019 ¹⁶	EEUU	CS	N=36 (M _{age} : 70.7) (58% women)	Resting energy expenditure (REE)	An increase in protein in the diet implies a decrease in grip strength (<i>p-value</i> <0.001) and, therefore, is related to a higher risk of developing sarcopenia.	Handgrip strength, skeletal muscle mass	Obesity	Low risk

						(bioimpedance)		
Lee H, et al. 2019 ¹⁹	South Korea	CS	N=1802 (M _{age} : 55.72) (100% women)	Own validated survey	There was a correlation between middle-aged women's SO and their dietary patterns. In unbalance diet pattern the risk of SO increases 1.715 times (95%IC: 1.050-2.801, <i>p-value</i> <0.05)	DXA	Obesity	Low risk
Takahashi et al. 2020 ²³	Japan	CS	N=351 (M _{age} : 66.6) (45.3% women)	BDHQ	In women, prevalence of sarcopenia was lower in the group with habitual miso soup consumption (18.8% vs 42.3%, <i>p-value</i> =0.018). For adjusted regression model, habitual miso consumption was associated with a lower risk of sarcopenia (OR (95%CI) 0.2 (0.06-0.62), while this wasn't found among males.	Hand grip strength	Diabetes	Moderate risk

Aparecida Silveira et al. 2020 ²²	Brazil	RCT	N=111 (93.7% women)	DieTBra dietary intervention	DieTBra improves handgrip strength. Brazilian traditional diet has also been associated with a reduction in total body fat (<i>p-value</i> = 0.041) and body weight (<i>p-value</i> = 0.003) in severely obese individuals.	Hand grip strength	Obesity	Low risk
Kawano et al. 2021 ²⁷	Japan	C	N=362 (36.7% women)	BDHQ	Energy intake was associated with muscle mass loss in older participants (<65 years) (OR (95%CI, 0.94 (0.88-0.996)); <i>p-value</i> =0.037, while this was not found in younger participants. So insufficient energy intake is associated with muscle mass loss in older people with T2D.	Skeletal muscle index	Diabetes	Low risk
Marcos-Pardo et al. 2021 ²⁶	Europe	CS	N=629 (M _{age} : 56.4)	MEDAS	A low protein diet was connected to an increased risk of developing sarcopenia. The consumption of	DXA	Obesity	Low risk

			(63% women)		more than one portion per day of red meat was a protective factor for sarcopenia development (OR = 0.126–0.454; all <i>p-value</i> < 0.01)			
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Explanation of the studies found which use the rest of the data collection methods, specifying their most essential characteristics. Acronyms: BDHQ (Brief Self-Administered Diet History Questionnaires), C (cohort), CI (Confidence interval), CS (cross-sectional), DASH (Dietary approaches to stop hypertension), DieTBra (extra-virgin olive oil + a traditional Brazilian diet), FFMI (fat-free mass index), FFQ (Food Frequency Questionnaire), M_{age} (Mean age), MAMC (midarm muscle circumference),), OR (Odds ratio), MEDAS (Mediterranean Diet Adherence Screener), RCT (randomized clinical trial), SO (sarcopenic obesity), T2D (Type 2 Diabetes).

DISCUSSION

This systematic review aimed to explore the relationship between feeding patterns and the development of sarcopenia in patients with metabolic syndrome criteria.

According to our findings, specific dietary patterns such as the ovolactovegetarian, DASH, Mediterranean and DieTBra diets, as well as diets with high content in fiber and carbohydrates were associated with a reduced risk of developing sarcopenia, also, our results suggest that a good quality diet (a term used to quantify the general healthiness of a dietary pattern based on its components)³⁴ reduces the risk of developing sarcopenia,

an assertion that is reinforced by articles on malnutrition, especially proteo-energetic³⁵, including unbalanced diets.

In relation to specific patterns, the ovolactovegetarian, and DASH diets were described as protectives against sarcopenia in this population^{17,28}. These diets have a high daily vegetable and fruit content, and both foods have been associated with a reduced risk of sarcopenia in older adults³⁶. Parallely, Mediterranean diet was also associated with a lower risk of developing sarcopenia¹⁸. This pattern that has also previously been associated with less abdominal fat accumulation³⁶ and its also associated in other studies with a low risk of development sarcopenia^{37,38} and with a “mioprotective” effect³⁹. Also, the DieTBra was found as a protective diet against sarcopenia. This diet is characterised as a healthy dietary pattern based on the consumption of rice, beans, a small portion of lean meat, raw and cooked vegetables together with fresh fruits, bread and milk²².

Metabolic syndrome is characterised by the accumulation of intramuscular fat, and other components, leading to the activation of pro-inflammatory pathways^{5,40}. The above diets include a large number of anti-inflammatory nutrients that could be beneficial for this population, in turn reducing the risk of sarcopenia as an inverse association has been observed between adherence to anti-inflammatory nutrient-based dietary patterns and odds of sarcopenia and low muscle strength⁴¹.

Regarding specific foods, low-fiber diets²¹ were associated with an increased risk of sarcopenia. High fiber intake, also present in the DASH diet, has also been linked to a reduction in inflammation due to its action on glucose absorption and microflora⁴². Low vitamin C intake was also associated with an increased risk of sarcopenia¹⁸. Patients with

MetS have been reported to consume less vitamin C, which also contributes to regulating low-grade inflammatory processes⁴³.

In the case of protein intake, it was observed that some articles confirm that low protein intake was related to an increased risk of sarcopenia^{4,25,26} being found the consumption of red meat a protective factor against sarcopenia^{20,26} and this same result has been observed by other authors in older adults⁴⁴. However, Cydne Perry et al.¹⁶ observed contrary results, observing that high protein intake led to a greater risk of developing sarcopenia. This disparity can best be understood as described by Dhillon R and Hasni S⁴⁵: "A decrease in the body's ability to synthesize protein, coupled with an inadequate intake of calories and/or protein to sustain muscle mass, is common in sarcopenia". This raises doubts as to whether the problem is intake or the body's capacity for synthesis.

Continuing with the macronutrients, carbohydrates stand out. Its low consumption is the one that best adapts as a predictor of the development of sarcopenia among all the macronutrients. It has also been seen that a diet high in carbohydrates intake was related to a reduced risk of sarcopenia in the elderly population^{19,24} as carbohydrates are the first source of energy for the muscles⁴¹. Also, total energy intake was associated with muscle mass loss in older people but was not in young individuals²⁷.

Finally, Takahashi et al.²³ revealed that miso soup, was found also as a protective food against sarcopenia. It includes vitamins, minerals, vegetable proteins, microorganisms, salts, carbohydrates, and fat.

The results of this study must be taken with caution since it has a series of limitations. Heterogeneous results were observed in the influence of diet and the occurrence of sarcopenia in patients with metabolic syndrome since diet is a very broad variable. This is due to the fact that most of the included studies analyze specifically, whether it is a dietary pattern or a specific macronutrient, and this in addition to the wide variety in the collection of information, as each author used a scale or a method of collecting information about a different eating pattern. That makes it difficult to obtain a specific conclusion now that macro and micronutrients can be specifically studied within the diet, dietary patterns for instance the Mediterranean and ovo-lacto-vegetarian or the intake of certain foods. Moreover, this heterogeneity prevented carried out a meta-analysis. However, having separated it by charts in the synthesis according to the

collection method, it is expected that this limitation is controlled. Since systematic reviews were not included as inclusion criteria, relevant information may have been lost. Regarding the strengths, a large number of articles have been analyzed in this review. Together with a unification of the diagnostic criteria and an updated and novel review of the evidence on this topic, especially focused on patients with metabolic syndrome criteria, which may be key for the implementation of guidelines in clinical practice.

In this way, the line of work in the future is justified with the general population that is increasingly getting older. In addition, it could be interesting to carry out work in which to determine the relationship between dietary patterns, but in a standardized way, using the same tool in each group of study, which would lead to greater clarity when extracting the results of the study. We also highlight the value of developing a decalogue or similar guidelines that serve as a dietary guide for patients at risk to improve their diet and prevent sarcopenia. Future research should be deepened to determine the role of eating patterns, isolated nutrients and specific foods to provide advances in this field.

CONCLUSIONS

In sum, there is evidence that a good quality diet implies a lower risk of developing sarcopenia in people with metabolic syndrome criteria. Low fiber and vitamin C consumption were associated with an increase of the risk of sarcopenia. Ovolactovegetarian, Mediterranean, DASH and DietBra diets were found as protective against sarcopenia. Also, diets that fulfil the recommendation about carbohydrates intake, daily red meat consumption and miso soup were associated with a lower risk of sarcopenia too. No solid conclusions were found regarding high or low protein intake and its relationship with sarcopenia. It is of particular interest that appropriate dietary patterns are followed in the metabolic syndrome population for the prevention and improvement of sarcopenia.

AUTHORS' CONTRIBUTIONS

Conceptualization was carried out by D.C.-P, L.B.-J, A.M.-D, data processing by D.C.-P, P.Y.-G and I.D.-F, methodology and visualization by D.C.-P, L.B.-J, A.M.-D, A.F.-S, V.M.-S, writing by D.C.-P, L.B.-J and A.M.-D, review and editing by all authors. All authors approved the final version of the manuscript.

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CONFLICTS OF INTEREST

The authors state that there are no conflicts of interest when writing the manuscript.

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