



Nutrological and metabolic considerations of oxyreduction mitochondrial activities in sports performance: a systematic review

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Abstract

Introduction: Diets are useful according to the nutritional deficiencies or needs of each individual in terms of health and aesthetics in general. In this sense, the search for weight loss is one of the constants that impact the population to solve the problem of obesity. It is important to highlight the association of MetS (metabolic syndrome) with cardiovascular diseases, increasing overall mortality by approximately 1.5 times and cardiovascular mortality by approximately 2.5 times the Mediterranean diet is the main therapeutic proposal for the treatment of MetS. **Objective:** This study presented the Mediterranean diet as a therapeutic proposal for the treatment and prevention of metabolic syndrome and evaluated its effectiveness as a nutritional benefit in quality of life. **Methods:** The model followed for the systematic review was PRISMA. The search strategy was carried out in the databases PubMed, Embase, Ovid and Cochrane Library, Web of Science, Science Direct Journals (Elsevier), Scopus

(Elsevier), and OneFile (Gale), from February to March 2025. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** 142 articles were found. A total of 32 articles were assessed in full and 25 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 18 studies with a high risk of bias and 21 studies that did not meet GRADE and AMSTAR-2. Most studies presented homogeneity in their results, with $X^2=92.3\%>50\%$. It was concluded that the beneficial effects of the Mediterranean diet in reducing the prevalence of metabolic syndrome, therefore, the dietary pattern described in the Mediterranean diet combined with physical activities can be used as a useful clinical tool in the treatment of metabolic syndrome. In addition, the suggested menu, with foods rich in fiber, is associated with a reduction in cardiovascular risk and, therefore, the Mediterranean diet is recognized as an

agent for promoting health and preventing obesity. In this sense, it is clear that dietary factors can play a fundamental role both in the individual components and in the prevention and control of metabolic syndrome. Recent data associate the presence of metabolic syndrome with a lower consumption of whole grains, fruits, and vegetables. Therefore, there is a close relationship between these foods and dietary fiber, and soluble fiber is probably more directly related to these effects.

Keywords: Diet. Mediterranean diet. Metabolic syndrome. Nutrology.

Introduction

Diets are useful according to the nutritional deficiencies or needs of each individual in terms of health and aesthetics in general. In this sense, the search for weight loss is one of the constants that impact the population to solve the problem of obesity. Excessive weight gain generates comorbidities, many of which are characterized as metabolic syndrome, in which the individual, to be diagnosed, must present three or more metabolic or anthropometric alterations such as increased waist circumference, systemic arterial hypertension, hyperglycemia, hypertriglyceridemia and reduced serum concentration of HDL levels [1,2].

It is important to highlight the association of MetS (metabolic syndrome) with cardiovascular diseases, increasing overall mortality by approximately 1.5 times and cardiovascular mortality by approximately 2.5 times [2]. The primary measures to address the changes that trigger MetS are the practice of physical activities, the reduction of caloric intake, and the reduction of body weight. These factors directly influence blood pressure stability, as well as the reduction of cholesterol and blood glucose levels and the reduction of waist circumference [1-3].

According to Chaves et al. (2021) [3], correctly planning your diet to prepare balanced meals is an important factor in regulating these rates. The combination of proteins, fats, and carbohydrates during different meals or snacks allows better control of blood glucose levels and less insulin release than when eating only meals or snacks composed mainly of carbohydrates. However, there is no consensus on the most appropriate nutritional strategy for the treatment of MetS.

Although current proposals are related to behavioral changes, such as changing eating habits and physical activity, nutritional recommendations can be established for healthy patients or those with

isolated changes and have different results, since the genetic and cultural history of each individual must be considered. The diet to be beneficial for most patients with MetS should include fruits, vegetables, dried legumes, cereals, unsaturated fat (mono and polyunsaturated), and low-fat dairy products in adequate amounts [1,4].

In this sense, the Mediterranean diet is the main therapeutic proposal for the treatment of MetS, since it corresponds to caloric limitations without altering the patient's adequate nutritional status. According to Kang et al. (2025) [4], the traditional Mediterranean diet is characterized by a high intake of cereals, vegetables, fruits, and olive oil; a moderate intake of fish and alcohol, especially wine; and low intake of dairy products, meats, and sweets. The Mediterranean diet has a high content of unsaturated fat since olive oil is abundantly used in cooking. Dried fruits with a high content of unsaturated fat are also foods commonly consumed in the Mediterranean diet.

Evidence from epidemiological and clinical studies indicates that regular intake of nuts can have a positive effect on adiposity, insulin resistance, and other metabolic disorders related to MetS [1-5]. Thus, this study presented the mediterranean diet as a therapeutic proposal for the treatment and prevention of metabolic syndrome and evaluated its effectiveness as a nutritional benefit in quality of life.

Methods

Study Design

This study followed the international systematic review model, following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) rules. Available at: <http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1>. Accessed on: 03/10/2025. The AMSTAR-2 (Assessing the methodological quality of systematic reviews) methodological quality standards were also followed. Available at: <https://amstar.ca/>. Accessed on: 03/10/2025.

Research Strategy and Search Sources

The literature search process was carried out from February to March 2025 and developed based on Scopus, Embase, PubMed, Science Direct, Scielo and Google Scholar, covering scientific articles from various periods to the present day. The following health science descriptors (DeCS/MeSH Terms) were used: "*Diet. Mediterranean diet. Metabolic syndrome. Nutrology*", and the Boolean "and" was used between the MeSH terms and "or" between the historical findings.

Study Quality and Risk of Bias

Quality was classified as high, moderate, low, or very low regarding the risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. Low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using Cohen's d test.

Results and Discussion

Summary of Findings

A total of 142 articles were found and submitted to eligibility analysis, with 16 final studies selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. Biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies presented homogeneity in their results, with $X^2=92.3\%>50\%$. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 18 studies with a high risk of bias and 21 studies that did not meet GRADE and AMSTAR-2.

Figure 1. Articles included in the systematic review.

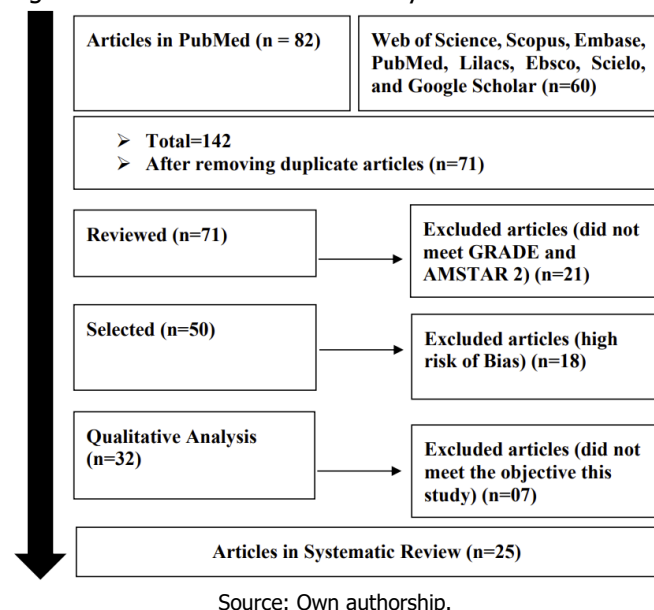
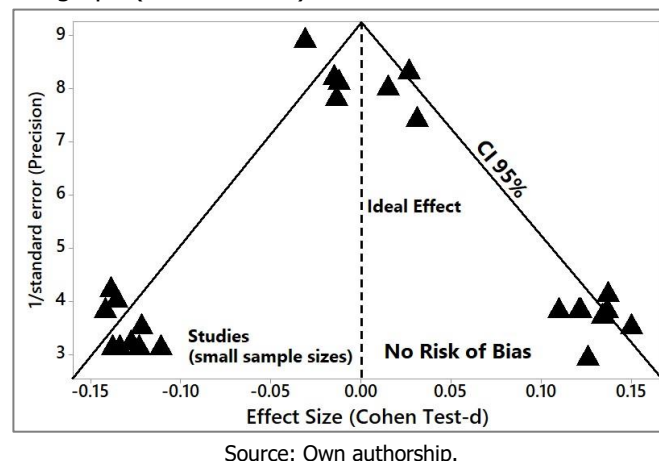


Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using Cohen's Test (d). Precision (sample size) was determined

indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, suggesting no significant risk of bias, both among studies with small sample sizes (lower precision) that are shown at the base of the graph, and in studies with large sample sizes that are shown at the top.

Figure 2. The symmetrical funnel plot suggests no risk of bias among the studies with small sample sizes that are shown at the bottom of the graph. Studies with high confidence and high recommendation are shown above the graph (n=25 studies).



Key Findings and Clinical Considerations

MetS is composed of a set of metabolic abnormalities, of which insulin resistance (IR) stands out [6]. The most relevant individual components of the metabolic syndrome and the possible interventions for them are described below, highlighting preventive measures related to diet. Obesity, now known as an "epidemic" disease, is considered by the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) as the main reason for the increase in the prevalence of MetS. It contributes to hypertension, low HDL, high cholesterol and hyperglycemia, factors that are associated with an increased cardiovascular risk [1-4].

As a primary intervention measure, dietary approaches are adopted that can vary in the prescription of total energy value and macronutrients. However, the reduction of daily energy intake is the most important determinant of effective weight loss. It should be remembered that the association of diet with physical activity increases weight loss and decreases abdominal fat [6,7]. Blood pressure as a component of metabolic syndrome is a factor that increases the likelihood of cardiovascular disease, as well as cardiovascular and renal morbidity and mortality. Among the environmental factors related to blood pressure levels, diet appears to play an important role in both the prevention and treatment of systemic arterial hypertension [5-7].

Hypertriglyceridemia results from the elevation of lipoproteins responsible for transporting triglycerides and is slightly associated with obesity. Reducing triglyceride levels can be achieved by reducing the consumption of rapidly absorbed carbohydrates, as well as the consumption of omega-3 fatty acids derived from saltwater fish [8].

Hyperglycemia is defined as impaired fasting blood glucose, impaired glucose tolerance, or Type 2 Diabetes Mellitus (T2DM). Diets that take into account the glycemic index (GI) of foods are among the current proposals for the management of hyperglycemia, especially for patients with MetS. Among these proposals, high fiber intake, especially soluble fiber, which has beneficial effects on glucose and lipid metabolism, stands out [5,9-15].

The prevalence of MetS worldwide has reached worrying rates. In the United States, it is estimated at 24%, and in people over 60 years of age, this number rises to 43.5%. In general, the prevalence of MetS has increased and these findings are associated with the epidemic of obesity and diabetes mellitus [9,16].

Although the data alert society, there are still few studies that report statistics on the syndrome in some countries, and, therefore, more studies on the prevalence of MetS are needed that prioritize awareness and its risks. However, studies in different populations, such as Mexican, North American, and Asian, reveal a high prevalence of MetS, depending on the criteria used and the characteristics of the population studied, with rates ranging from 12.4% to 28.5% in men and from 10.7% to 40.5% in women [9,10].

Studies conducted by DiBello et al. [17] found that a more modern dietary pattern associated with a high intake of processed and refined foods, including rice, French fries, and pancakes, was positively associated with the presence of MetS. Thus, Noel et al. [18] identified that a traditional dietary pattern rich in rice, beans and fat, in addition to sugar-rich sweets, sugary drinks and dairy desserts was associated with a higher probability of having MetS and low HDL-cholesterol concentrations. In this context, the Mediterranean diet has been presented as the main element in the treatment of MetS.

Mediterranean Diet

The Mediterranean region is composed of parts of three continents. The countries of Europe - Italy, Spain, Greece, Yugoslavia, France, and Albania; of Africa - Egypt, Libya, Tunisia, Algeria, and Morocco; and Asia - Turkey, Israel, Syria, and Lebanon represent the region bathed by the Mediterranean Sea. Despite the great cultural, social, and economic differences between these countries, certain common geographical elements, such

as relief, climate, soil, and hydrography, influenced agriculture and, consequently, eating habits, making them co-founders of Mediterranean cuisine [13].

Since the mid-20th century, researchers have identified an epidemic of cardiovascular disease in industrialized countries. However, studies have shown that the incidence of cardiovascular disease was much lower on the island of Crete, located in the Mediterranean [14]. This incidence is probably due to the population's use of monounsaturated fatty acids, such as olive oil. Several studies have sought to confirm the unique characteristics and establish the benefits of Mediterranean food [15].

Recognized gastronomically and nutritionally for its excellent combination of tasty flavor and healthy effects on the body, the Mediterranean diet is promoted as an ideal dietary model. Shaped by the region's climate and agricultural tradition, it consists of a high consumption of vegetables, fruits, cereals, legumes, oilseeds, fish, olive oil, and wine and a low intake of animal products, simple sugars, and saturated fats [16].

In this context, the traditional Mediterranean diet is known for the health and longevity benefits it provides. It is characterized by a high consumption of unsaturated fat since olive oil is widely used in cooking. Dried fruits with a high content of unsaturated fat are also commonly consumed foods in the Mediterranean diet. Evidence from epidemiological and clinical studies indicates that regular intake of nuts may have a positive effect on adiposity, insulin resistance, and other metabolic disorders related to MetS [19-22].

The results of a review conducted by Babio et al. [23] indicated that a healthy dietary pattern characterized mainly by high consumption of vegetables, fruits, nuts, olive oil, legumes, and fish; moderate alcohol consumption and reduced consumption of red meat, processed meat, refined carbohydrates, and high-fat dairy products are beneficial for individuals at increased risk or individuals with MetS.

In addition, Gouveri et al. [24], in a multivariate analysis, revealed that the Mediterranean diet is associated with a 20% reduction in MetS (odds ratio: 0.80; 95% CI: 0.65-0.98), after adjusting for age, sex, smoking, light physical activity, LDL cholesterol and γ -glutamyl transferase concentrations, diabetes, cardiovascular disease, family history of hypertension and/or hyperlipidemia. In 1993, the World Health Organization (OMETS) and the Oldways Preservation & Exchange Trust, together with researchers from the Harvard Center for Nutritional Epidemiology, promoted the development of food guides in the form of pyramids. At this conference, the Mediterranean Diet food pyramid was organized, which is based on the dietary patterns

existing in the 1960s, typical of the island of Crete.

The base of the Mediterranean food pyramid is formed by whole grains and olive oil, which can be consumed daily. Next, the food groups are represented by vegetables and fruits. Above, legumes, nuts, and cooked vegetables. Near the top of the pyramid are eggs, fish and seafood, poultry, milk, and dairy products, which should be consumed a few times a week. At the top of the pyramid are red meats, simple sugars, and saturated fats, which should not be consumed more than once a month. This population has a habit of regular physical activity, consumption of plenty of water, and moderate consumption of wine [14]. Thus, the Mediterranean diet is spreading as a health perspective, when adopted correctly followed by habits of physical activity and dissociated from tobacco and excessive alcohol, and has satisfactory results in quality of life and in the prevention of diseases that constitute the metabolic syndrome [2-4].

Diet versus Benefits

The word diet is of Greek origin and means lifestyle. Although it socially represents deprivation and renunciation, the term expresses the connection between man and the region in which he lives. The diet present in Mediterranean countries seems to confer a link with health and longevity in the population. Following the dietary principles suggested by the diet, it is possible to benefit and prevent many factors that trigger metabolic syndrome [1,2].

The Mediterranean diet has shown several benefits, both in the development of MetS [20] and at the level of its components. In a meta-analysis of 50 randomized controlled studies, involving a total of 534,906 participants, Kastorini [21] found a significant reduction in the risk of MetS in individuals following the diet, with a reduction in waist circumference, blood glucose, triglycerides, systolic blood pressure, and diastolic blood pressure and increased HDL-c levels when compared to other diets.

Regarding the factors of a dietary pattern rich in fruits and vegetables; moderate intake of low-fat dairy products; and low animal protein content, but with a substantial amount of vegetable protein, from legumes and dried fruits, they act to reduce systolic and diastolic pressure among hypertensive and normotensive individuals. In addition, the diet is associated with a lower risk of cardiovascular diseases and MetS [17].

The combination of a good eating plan and the regulation of physical activity practices are entirely related to the benefits of MetS [22]. It has been proven that this combination causes a significant reduction in abdominal circumference and visceral fat, significantly improves insulin sensitivity, reduces

plasma glucose levels [23], and can prevent and delay the onset of type 2 diabetes, a significant reduction in blood pressure and triglyceride levels, with an increase in HDL cholesterol [18].

Treatment and Prevention of Metabolic Syndrome

The treatment of MetS aims to improve resistance to the action of insulin. In this sense, weight loss represents the basis of treatment, as it improves insulin sensitivity, reducing the risk of cardiovascular complications [24-26]. According to Salas [6], the main focus of patients with MetS is the control of individual cardiovascular risk factors, which can be achieved through lifestyle changes, including dietary intervention. A balanced caloric intake is recommended, which, combined with physical activity, allows the ideal weight to be achieved and/or maintained. In this sense, it can be stated that implementing a diet plan for weight reduction, combined with physical exercise, is considered the first-choice therapy for the treatment of patients with metabolic syndrome [24].

As for prevention, the ideal is to adhere to healthy eating habits since obesity and IR play a central role in the pathogenesis of MetS, and all strategies used to improve them appear to be effective in its prevention and treatment. Maintaining a moderate to high level of physical activity and/or limiting sedentary activities, especially in children, is one of the points of interest in the prevention or treatment of MetS [3]. However, it is important to promote physical activity correctly, as there is a positive association between its practice and the reduction of body fat [12].

Given the exposure to MetS, it is clear that there is an urgent need to act immediately and effectively to prevent the growing trend that this problem tends to maintain since the proportion of children and young people who suffer from it is worrying. Therefore, lifestyle changes are undoubtedly necessary to minimize this problem and necessarily involve increasing the practice of physical exercise and the consequent reduction of sedentary activities (watching television, playing computer games, using mobile phones, etc.) [25-30].

Finally, changes in diet, especially in this age group, are essential, as high-energy-density foods are often used, which end up providing many calories; other measures must be taken, such as the use of medication or other types of more specific treatments, when the objectives are not achieved at all with the aforementioned lifestyle changes alone. It has been proven that even small reductions in body weight greatly improve the components of MetS and, since almost all individuals who suffer from it are overweight or even obese, perhaps starting a diet appropriate to their health problems and lifestyle is a good starting point [3,4].

Conclusion

It was concluded that the beneficial effects of the Mediterranean diet in reducing the prevalence of metabolic syndrome, therefore, the dietary pattern described in the Mediterranean diet combined with physical activities can be used as a useful clinical tool in the treatment of metabolic syndrome. In addition, the suggested menu, with foods rich in fiber, is associated with a reduction in cardiovascular risk and, therefore, the Mediterranean diet is recognized as an agent for promoting health and preventing obesity. In this sense, it is clear that dietary factors can play a fundamental role both in the individual components and in the prevention and control of metabolic syndrome. Recent data associate the presence of metabolic syndrome with a lower consumption of whole grains, fruits, and vegetables. Therefore, there is a close relationship between these foods and dietary fiber, and soluble fiber is probably more directly related to these effects.

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