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Revisiones

Potential of ascorbic acid during physical exercise to reduce oxidative stress: a systematic review



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ABSTRACT

Background: The increase in ROS during exercise is widely studied and reportedly appears to be interrelated with the pathology of several illnesses, including Alzheimer's disease, atherosclerosis, and metabolic syndrome.

Objectives: This study aims to determine whether supplementing ascorbic acid during exercise has an effect in reducing malondialdehyde levels as one of the markers of oxidative stress during exercise.

Material & Methods. For this study, a number of journal databases were searched, such as Pubmed, Science Direct, Web of Science, and Scopus. The research considered a number of factors, such as studies on physical exercise, ascorbic acid and malondialdehyde published in the last five years. Papers published in non-reputable journals were excluded from the analysis. A total of 127 papers were found using Pubmed, Science Direct, Web of Science, and Scopus databases. About 8 carefully selected, peer-reviewed papers addressed the need for this systematic review.

Results. Findings from the systemic analysis showed that ascorbic acid supplementing while working out has been demonstrated to lower malondialdehyde levels.

Conclusion. Ascorbic acid supplementation has been shown to reduce malondialdehyde levels after exercise in both humans and animals. However, further testing with specific human subjects and experimental studies are needed to confirm the potential effect of ascorbic acid in reducing MDA levels, a marker of oxidative stress.

Keywords: Physical exercise; Ascorbic acid; Malondialdehyde; Oxidative stress; Healthy lifestyle.

Potencial del ácido ascórbico durante el ejercicio físico para reducir el estrés oxidativo: revisión sistemática

RESUMEN

Antecedentes: El aumento de especies reactivas de oxígeno durante el ejercicio se ha relacionado con diversas enfermedades. El objetivo fue determinar si la suplementación con ácido ascórbico asociada al ejercicio reduce el malondialdehído, marcador de estrés oxidativo.

Material y métodos: Se realizó una búsqueda en PubMed, ScienceDirect, Web of Science y Scopus de estudios sobre ejercicio físico, ácido ascórbico y malondialdehído. De 127 registros identificados, ocho artículos revisados por pares cumplieron los criterios establecidos.

Resultados: La síntesis sistemática mostró que la suplementación con ácido ascórbico asociada al ejercicio redujo las concentraciones de malondialdehído.

Conclusión: La suplementación con ácido ascórbico puede reducir el malondialdehído después del ejercicio en humanos y animales; se requieren más estudios experimentales en humanos.

Palabras clave: Ejercicio físico; Ácido ascórbico; Malondialdehído; Estrés oxidativo; Estilo de vida saludable.

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Potencial do ácido ascórbico durante o exercício físico para reduzir o estresse oxidativo: revisão sistemática

RESUMO

Contexto: O aumento de espécies reativas de oxigênio durante o exercício tem sido relacionado a diversas doenças. O objetivo foi determinar se a suplementação com ácido ascórbico associada ao exercício reduz o malondialdeído, marcador de estresse oxidativo.

Material e métodos: Foi realizada uma busca no PubMed, ScienceDirect, Web of Science e Scopus por estudos sobre exercício físico, ácido ascórbico e malondialdeído. Dos 127 registros identificados, oito artigos revisados por pares atenderam aos critérios estabelecidos.

Resultados: A síntese sistemática mostrou que a suplementação com ácido ascórbico associada ao exercício reduziu as concentrações de malondialdeído.

Conclusão: A suplementação com ácido ascórbico pode reduzir o malondialdeído após o exercício em humanos e animais; são necessários mais estudos experimentais em humanos.

Palavras-chave: Exercício físico; Ácido ascórbico; Malondialdeído; Estresse oxidativo; Estilo de vida saudável.

Introduction

Regular physical exercise is proven to increase endurance. Adequate nutrition accompanied by an optimal recovery phase can keep the body healthy and avoid sustained physical injury¹. Physical exercise has been shown to closely manage oxidative stress, a process that involves an rise in reactive nitrogen species (RNS) and reactive oxygen species (ROS)². Exercise intensity, duration, and state of health of these individuals influence the level of oxidative stress induced by exercise, and can even have a positive or negative impact on human survival³. The increase of ROS during exercise is widely studied and reportedly appears to be interrelated with the pathology of several illnesses, including alzheimer's disease, atherosclerosis, and metabolic syndrome⁴. Furthermore, oxidative stress levels have the ability to precipitate a number of chronic illnesses, including infections, cancer, neurological illnesses, and cardiovascular illnesses⁵. Overproduction of ROS can result in changes in cell structure and function causing chronic degenerative diseases and aging disease pathology⁶.

We already know from research reports that antioxidants can help reduce oxidative stress and can improve health, especially in the heart⁷. Increasing antioxidants has demonstrated the ability to lessen the negative consequences of oxidative stress⁸. During aerobic exercise, increased contractile activity raises oxygen consumption. This can lead to electron leakage from mitochondria, which in turn increases ROS production⁹. In this case, if free radical production outpaces the body's antioxidant capacity, it can be detrimental, leading to cellular damage and muscle dysfunction¹⁰. Although ROS are known to be bad and can damage cells, the presence of ROS also contributes significantly to the improvement of other cellular defense processes including the antioxidant defense system¹¹.

Vitamin C, sometimes referred to as ascorbic acid, is a popular and powerful antioxidant that scavenges free radicals¹². In addition, ascorbic acid can also protect cell membranes and DNA from oxidative stress damage¹³. Ascorbic acid has protective characteristics

that allow it to interact with free oxygen ions, superoxide ions, and hydroxyl ions while inhibiting inflammation¹². The results of the research report prove that antioxidant levels in the body have increased after 1000 mg ascorbic acid supplementation and cycling physical exercise intervention, in addition to preventing and reducing muscle damage triggered by sports training¹⁴. Likewise, other studies have shown a decrease in malondialdehyde levels in research subjects given 1000 mg ascorbic acid intervention and aerobic physical exercise intervention¹⁵.

However, there is very little discussion about ascorbic acid during physical exercise, and a detailed explanation of how ascorbic acid reduces malondialdehyde levels is still confusing among researchers. There is other evidence that ascorbic acid can not only reduce MDA levels during exercise, but can also boost the immune system in healthy individuals¹⁶. Therefore, the objective of this review is to discuss how the effect of ascorbic acid in lowering malondialdehyde levels, one of the oxidative stress biomarkers, during physical activity.

Materials and methods

Study Design

A systematic review, which evaluates scientific papers according to criteria set by the researchers, was the strategy employed in this investigation. To choose articles about how ascorbic acid lowers MDA levels following physical activity, the scientific literature was examined. The search engines Web of Science, Pubmed, Science Direct, and Scopus were used to locate the scientific literature. MDA levels, physical activity, and ascorbic acid were the search phrases used. Publications were chosen based on the following inclusion criteria: year of publication, experimental investigations, and human and animal-related literature.

Table 1. Inclusion criteria

Web search engines	Pubmed, Science Direct, Scopus, and Web of Science
Publishing period	2015 – 2025
Keyword	Ascorbic acid, physical exercise, and MDA levels
Language	English
Type of article	Original research article
Full Text	Articles matched the purpose and/or topic of the research

Eligibility criteria

Study inclusion criteria were established by examining current databases for information released between 2015 and 2025. An experimental research of the impact of ascorbic acid supplementation following physical activity on MDA levels was part of this study. MDA levels, physical activity, and ascorbic acid were among the search phrases used. Additionally, papers that did not fit the criteria for scientific validity or that were not listed in reputable search engines such as Scopus, Web of Science, PubMed, or Science Direct were not included in our analysis. As a result, we used our predetermined inclusion criteria to screen the chosen papers.

Procedure

Each publication's complete text, abstract, and title were added to the Mendeley database following review and verification. Using Scopus, Science Direct, Pubmed, and Web of Science, 127 papers were found during the initial screening stage. 76 appropriate papers were chosen for the second screening stage after duplicate articles were found and the reasons behind title mismatches were addressed. 43 papers were selected for the next stage based on the concordance of the title, abstract, and keywords analyzed. After going over each paper, we come to the following conclusions: the study had to be experimental, the parameter had to be the MDA biomarker, the intervention had to be physical exercise, and both human and animal samples had to be used. This was the last phase of the process. We carried out a screening procedure to find papers that satisfied our predefined inclusion criteria. Following a rigorous review and

scrutiny procedure, eight papers that satisfied the inclusion criteria were chosen for study. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were adhered to in this study. This study looked at earlier studies that met bioethical and ethical standards.

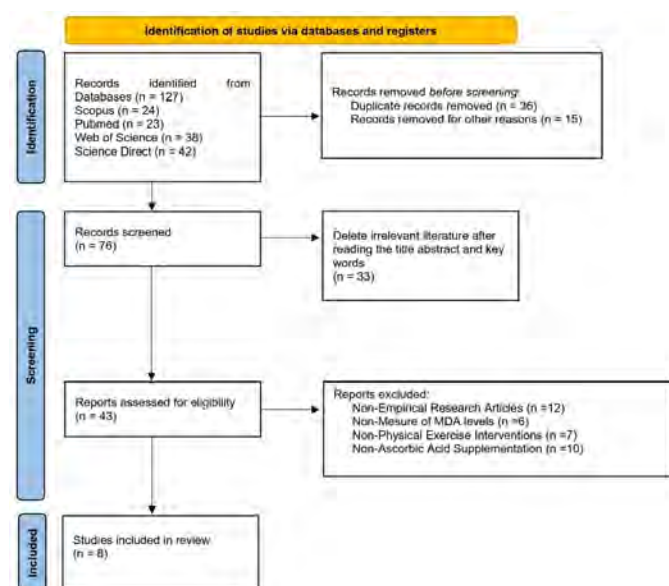


Figure 1. PRISMA flowchart of the article selection process

Results

Table 2. Results of Ascorbic Acid Supplementation During Physical Exercise in Reducing Malondialdehyde Levels as a Marker of Oxidative Stress

Author	Sample Characteristics	Study Design	Ascorbic Acid Dosage	Intervention	Results
(Bunpo et al., 2021) [17]	19 healthy women took part in the research and were split up into two groups: physical exercise + ascorbic acid supplementation intervention group and placebo + physical exercise + ascorbic acid supplementation intervention group. ascorbic acid supplementation and physical exercise + placebo intervention group.	Experimental	1000 mg	Moderate intensity exercise by cycling for 30 minutes.	The group's MDA levels have significantly dropped with physical exercise intervention + 1000 mg ascorbic acid supplementation.
(Bunpo et al., 2024) [18]	20 sedentary women took part in the research and were split up into two groups: a group with physical exercise intervention + 1000 mg ascorbic acid supplementation, and a group with physical exercise intervention + placebo.	Experimental	1000 mg	Moderate intensity exercise by cycling for 30 minutes.	The group's MDA levels have significantly dropped with physical exercise intervention + 1000 mg ascorbic acid supplementation.
(Wibawa et al., 2021) [15]	28 healthy In this study, males were split up into four groups: control group without physical exercise, control with physical exercise, physical exercise + ascorbic acid 500 mg, physical exercise + ascorbic acid 1000 mg.	Experimental	500 mg and 1000 mg	Moderate intensity physical exercise with 2400 meters of running for 12 minutes.	MDA levels in the blood significantly dropped in the ascorbic acid 1000 mg supplementation + physical exercise group.
(Boonthongkaew et al., 2021) [19]	This research included 24 participants with type 2 diabetes mellitus and were divided into 2 groups: physical exercise +	Experimental	1000 mg	Physical exercise test with moderate intensity on an ergometer for 20 minutes.	There was a significant decrease in MDA levels in the group with 1000 mg physical exercise intervention.

Author	Sample Characteristics	Study Design	Ascorbic Acid Dosage	Intervention	Results
	ascorbic acid 1000 mg group, and physical exercise + placebo group.				
(Chaoqun et al., 2021) [20]	81 male Sprague-dawley rats took part in the research and were split up into three treatment groups consisting of exercise only, exercise + 4% H ₂ , exercise + ascorbic acid 500 mg.	Experimental	500 mg	Aerobic physical training of rats for 60 minutes on a treadmill.	There was a significant decrease in MDA levels in the group with physical exercise intervention + 500 mg ascorbic acid supplementation.
(Eatemadyboroujeni et al., 2021) [21]	50 male rats participated in this study and were divided into 5 groups: exercise group, exercise + ascorbic acid, exercise + polluted air, exercise in polluted air + ascorbic acid, and control group.	Experimental	Aerobic physical training on a treadmill 30 minutes per day, 5 days a week for 12 weeks.	20 mg per kg of body weight.	There was a decrease in MDA levels in the physical exercise group in polluted air + ascorbic acid.
(Alves et al., 2021) [22]	84 male athletes participated in the pre-test and post-test research.	Experimental	Test run to exhaustion on the treadmill.	87 mg per day	There was a decrease in MDA levels after the exercise intervention post test.
(de Oliveira et al., 2019) [23]	21 soccer athletes took part in the research and were split up into two groups: placebo and ascorbic acid and vitamin e supplementation groups.	Experimental	Plyometric jump test, strength and endurance training until exhaustion.	Ascorbic acid 500 mg and Vitamin E 500 UI.	There was a decrease in the lowest MDA levels after 72 hours after the intervention of ascorbic acid and vitamin E supplementation.

Discussion

Physical exercise increases ROS (reactive oxygen species)

Cell damage is triggered by an increase in ROS levels in the body. ROS increases one of which is caused by exercise²⁴. It is evident that the pathophysiology of diabetes mellitus, cancer, cardiovascular disease, hypertension, and a number of neurological illnesses is linked to persistent oxidative damage²⁵. Other reports suggest that regular exercise provides significant health benefits through blood sugar regulation and cardiovascular health in the general population. It is evident that regular physical exercise proves to have a lower risk of cardiovascular disease²⁶. ROS during exercise is a physiological response caused by exercise. However, if high ROS exceeds the antioxidant capacity, it will also adversely affect health. The adverse effects of high ROS include alterations to lipids, proteins, and nucleic acids²⁷.

When the level of oxidative stress surpasses the protective capacity in the body, it will result in cell damage and lipid peroxidation. Additionally, redox imbalance has a strong correlation with a number of illnesses, including aging and cancer²⁸. There is an increase in oxygen during activity demand by active muscles due to acute exercise causing an increase in oxygen consumption concentration and mitochondrial activity, which consequently increases the synthesis of reactive oxygen species (ROS), including superoxide radicals (O₂⁻), which causes oxidative stress²⁹. Recent research reports have shown that low- or moderate-intensity exercise can cause oxidative stress, the failure of the antioxidant defense system is the main mediator of exercise-induced oxidative stress³⁰. The findings of 25 Wistar rats were studied who were given a high-intensity physical exercise intervention with swimming 1 hour per day, 5x a week for 8 weeks said that MDA levels increased after physical exercise³¹. The results of other studies also prove that there is an increase in MDA levels when subjects are given a physical

exercise intervention of 2400 m for 12 minutes¹⁵. It is evident that MDA increases during physical exercise.

Ascorbic Acid During Physical Training Lowers Malondialdehyde Levels

The results prove that ascorbic acid 1000 mg supplementation supplied to 19 women with moderate level of intensity physical exercise intervention for 30 minutes is proven to reduce MDA levels as one of the markers of oxidative damage¹⁷. The outcomes of further studies are also the same that 1000 mg ascorbic acid supplementation is proven to reduce MDA levels after physical exercise using an ergocycle¹⁸. The results of another study comparing supplementing with 1000 mg of ascorbic acid and a dose of 500 mg during physical exercise showed that a dose of 1000 mg lowered MDA levels than 500 mg¹⁵. The results of various studies prove that by exercising it will make the body healthier by improving physical fitness, cardiorespiratory, heart health, muscle and bone strength, cardiometabolic health³². Furthermore, a research revealed that ascorbic acid administration effectively decreased exercise-induced lipid peroxidation and that MDA levels increased considerably immediately following physical activity. These outcomes also support earlier research showing ascorbic acid may be used as a treatment to reduce ROS production and boost the body's antioxidant capacity¹⁸.

Increasing the antioxidant capacity in the body is essential for protection against lipid damage. It is known that lipid damage can lead to serious health problems related to increased chronic inflammation and cardiovascular disease³³. If the body's antioxidant reserves aren't enough to combat free radicals, exogenous antioxidants are needed in an effort to reduce the adverse effects of free radicals. Ascorbic acid is an important cellular antioxidant that is responsible for detoxifying free radicals and scavenging ROS³⁴. The results of various studies show that ascorbic acid contains antioxidants and provides a protective impact against oxidative stress-related diseases³³. When the human body performs heavy

physical exercise, it will also have an adverse effect on the body and will also increase physical fatigue if not balanced with a good recovery process. Research has shown that supplementation with ascorbic acid protects the body and alleviates fatigue²⁰. Furthermore, ascorbic acid is listed as an effective and essential medicine published by the World Health Organization. Its main function is to protect cellular cells from oxidative stress triggered by ROS.

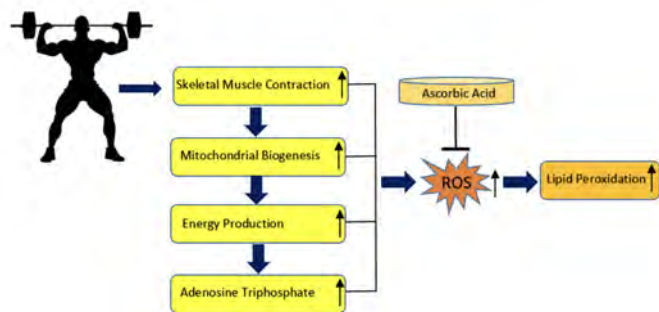


Figure 2. The Mechanisms of Ascorbic Acid Supplementation During Physical Exercise in Reducing Malondialdehyde Levels as a Marker of Oxidative Stress

The results of the study in rats given 500 mg ascorbic acid intervention and given physical exercise for 60 minutes on a treadmill demonstrated that there a significant reduction in MDA concentrations²⁰. The results of other studies in rats given ascorbic acid intervention and physical exercise also prove the same thing, namely a decrease in MDA levels after physical exercise²¹. So, it can be proven that ascorbic acid supplementation during physical exercise has a protective effort and can reduce MDA levels as one of the signs of oxidative stress brought on by physical activity. A significant reduction in MDA levels also occurred in athletes who had been given ascorbic acid intervention and physical exercise until they experienced fatigue³⁵. There is confusion and it is still unclear how protective ascorbic acid is in reducing MDA levels during exercise and what the underlying theory is. For future research, the topic of ascorbic acid is an interesting one to discuss as it has been shown to have strong antioxidant properties. This could be a recommendation especially for athletes to consume ascorbic acid supplements for muscle recovery³⁶.

Results Other studies also support the data that supplementation of ascorbic acid supplementation of 1,000 mg/day consistently for several weeks proved to be able to result in rehabilitation of muscular strength and a decrease in discomfort in males who are not trained who performed 90 minutes of running physical exercise³⁷. Ascorbic acid in its efforts to counteract free radicals is by donating electrons, so that ROS become more neutral and unreactive which can trigger lipid peroxidation and cell damage³⁸. But, of course in this systematic review there are still limitations in the analysis, namely only looking at how ascorbic acid as an endogenous antioxidant has a remarkable effect in reducing MDA levels during exercise. During physical exercise, it is known that ROS increases and this can have an impact on lipid peroxidation. However, it should also be noted that the increase in MDA levels during physical exercise is also a physiological response caused by physical training. For further research, it is necessary to study in depth how the molecular response of ascorbic acid in reducing MDA after physical exercise so that it can provide understanding to the public and academics related to the importance of ascorbic acid supplementation as an effort to protect cells from oxidative stress during exercise.

Conclusions

Ascorbic acid supplementation has been shown to reduce malondialdehyde levels after exercise in both humans and animals.

However, further testing with specific human subjects and experimental studies are needed to confirm the potential effect of ascorbic acid in reducing MDA levels, a marker of oxidative stress.

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Potential conflict of interest

The authors declare no conflict of interest.

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