



POTENTIAL OF COCOA FLAVANOLS IN IMPROVING CARDIOVASCULAR ADAPTATION AND EXERCISE: A SCOPING REVIEW

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ABSTRACT

Cardiovascular fitness, quantified as maximal oxygen consumption (VO₂Max), is a significant indicator of exercise tolerance and cardiovascular health. Sedentary behavior and aging are determinants that contribute to endothelial dysfunction, arterial stiffness, and reduced cardiac output, leading to a decline in VO₂Max. Cocoa Flavanols (CFs), rich in (-)-epicatechin, have been found to enhance endothelial function, nitric oxide bioavailability, and reduce blood pressure and hence might be beneficial for cardiovascular adaptation and VO₂Max improvement. This scoping review explores the potential of CFs to enhance cardiovascular function and exercise tolerance. Method: Two randomized controlled trials were employed in this scoping review. The first trial examined the effect of 30-day CF supplementation (1000 mg/day) on cardiorespiratory fitness in healthy elderly adults. The second trial examined the effect of 7-day CF supplementation (400 mg/day) on pulmonary oxygen uptake kinetics and exercise tolerance in middle-age sedentary adults. Results: In older adults, CF supplementation improved VO₂peak, oxygen pulse, exercise capacity, and endothelial function and lowered blood pressure in middle-aged sedentary adults, CFs improved VO₂ kinetics during moderate-intensity exercise, indicating enhanced oxygen delivery, but not exercise tolerance during severe-intensity exercise. Such results highlight CFs' positive effects on vascular health and efficiency of moderate-intensity exercise. Conclusion: Cocoa flavanols may enhance cardiovascular adaptation and exercise performance by improving endothelial function, reducing arterial stiffness, and optimizing oxygen uptake during exercise. Further studies are required to evaluate their effect on maximal exercise performance and long-term cardiovascular outcomes.

Keywords: cardiovascular adaptation; cocoa flavanols; endothelial function; exercise capacity

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INTRODUCTION

Cardiovascular health is a major focus in the field of sports and health sciences, given the high morbidity and mortality rates due to heart disease worldwide. According to the World Health Organization (WHO), cardiovascular disease remains the number one cause of death globally, responsible for around 17.9 million deaths each year (World Health Organization, 2023). On the other hand, regular exercise has been shown to strengthen heart and blood vessel function, improve muscle work efficiency, and reduce the risk of chronic diseases. However, not all individuals get an optimal cardiovascular adaptation response from exercise, especially the elderly or those with certain metabolic conditions. This is where the urgency arises to explore additional safe and effective interventions, such as nutritional strategies, to optimize the benefits of exercise on the cardiovascular system (Zhong et al., 2025).

High intensity training and long-term competition can cause training fatigue (Cao et al., 2024). The decline in muscle function that begins with oxidative stress can cause fatigue in a person. In recent years, many studies have used plant extracts as performance enhancers and to speed up post-workout recovery and maintain overall physical health (Calvo, 2022). One of the nutritional compounds that has received attention is cocoa flavanol cocoa products contribute high levels of flavonoids among commonly consumed foods (Ahmed et al., 2020), a bioactive compound found in cocoa beans and its derivatives such as dark chocolate. Cocoa flavanols are known to have vasodilatory, antioxidant, and anti-inflammatory effects that contribute to improved blood flow and endothelial function (Baynham et al., 2024). Bioactive compounds including flavonoids, stilbenes, phenolic acids and lignans are often grouped into polyphenols (Shen et al., 2022). The largest subclass, flavonoids can be further classified into flavonols, flavanols, flavanones, anthocyanins, flavones and isoflavones (Berger et al., 2021). Of these, the majority of research has focused on flavanols with particular attention to cocoa, not only because of the palatability of chocolate but also because of the high proportion of monomers such as catechin, epicatechin and gallic acid collectively referred to as cocoa flavanols. These monomers are found in greater amounts in cocoa compared to other flavanol-containing foods such as tea and fruits, however, the amounts vary widely. In cocoa, the flavanol content depends on the type of bean such as the bean from which it is grown, the manufacturing process such as heavy alkalization and roasting temperature, and the final product (Corr et al., 2021).

A recent study showed that cocoa flavanol consumption for two weeks increased VO_2Max by 2.31% and improved arterial function in male endurance runners (Vordos et al., 2021). Furthermore, a 30-day intervention with cocoa flavanol supplementation in healthy elderly showed a significant increase in maximal exercise capacity and a decrease in blood pressure (Gröne et al., 2023). These findings suggest the potential of cocoa flavanols as natural ergogenic agents that can support cardiovascular adaptation to exercise training. Although several studies have highlighted the benefits of cocoa flavanols on vascular parameters and aerobic performance, there is still a gap in knowledge regarding the specific mechanisms involved and the consistency of results across populations (Palma-morales et al., 2023). Some studies have shown improvements in mitochondrial function and oxygen transport, while others have not found significant changes in exercise biomarkers (Angel et al., 2022). Furthermore, most studies are still limited to specific populations, such as the elderly or experimental animals, and few have explored the medium- or long-term effects in populations of athletes or healthy active individuals. Therefore, it is important to critically review the available evidence and identify areas that require further research.

This article aims to comprehensively review the potential of cocoa flavanols in improving cardiovascular adaptation and exercise performance based on recent studies. The expected benefits of this article theoretically are to strengthen the understanding of the interaction between functional nutrition and physiological adaptations due to exercise. Practically, the results of this discussion can be a basis for health practitioners, sports coaches, and general consumers in designing performance enhancement strategies that are based on scientific evidence and safe for consumption.

METHOD

This method section includes the type of research, research subjects, data collection instruments, This review was conducted to summarize, identify, and present findings from studies using the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) framework (Peters et al., 2024). The design used in this study was a scoping review. The inclusion criteria for the articles were based on publications in both Indonesian and English, focusing on articles published from 2020 onward from all countries, specifically investigating chocolate and its effects on body performance using experimental research designs. Eligibility Criteria included studies met the following criteria: (1) published in a peer-reviewed journal, (2) involved human participants, (3) used cocoa flavanol supplementation as the intervention, and (4) assessed VO₂max or other indicators of cardiorespiratory fitness as the outcome. Articles were retrieved from several databases, including PubMed, ScienceDirect, and Google Scholar. The article search employed the following keywords: “(chocolate drink OR antioxidant OR VO₂Max) AND (chocolate OR agility) AND (cacao drink OR antioxidant OR endurance performance) AND (experimental study).” A total of 541 articles were collected, and full-text articles were assessed for eligibility. The screening process included the examination of titles and abstracts of the literature, including relevant articles that contributed to the research. Finally, the literature that met the inclusion criteria was selected for full-text reading and review. Article review was conducted using the mendeley application which was reviewed by evaluating the title and assessing based on inclusion criteria, non-human, Indonesian and English language, not cocoa supplements. Exclusion criteria, design and outcome of the intervention.

RESULT

A total of 541 articles were initially identified through a comprehensive search across three major databases: ScienceDirect (n = 249), PubMed (n = 63), and Google Scholar (n = 229). Following the removal of 36 duplicate articles, 505 articles remained for the initial screening process. These remaining articles were then carefully reviewed by evaluating their titles and assessing them based on predetermined inclusion criteria, which resulted in the elimination of 492 articles deemed irrelevant or not meeting the required scope. Consequently, 13 full-text articles were selected for further assessment of eligibility. During this stage, a more in-depth analysis was conducted to determine whether the studies aligned with the objectives and met the exclusion criteria. As a result, 11 articles were excluded for reasons such as inappropriate study design, irrelevant outcome measures, or lack of full-text availability. Ultimately, 2 articles were included in this review for final analysis, as they fulfilled all the inclusion criteria and did not meet any exclusion factors. The search and screening procedure is visually summarized in the PRISMA flow diagram (Figure 1).

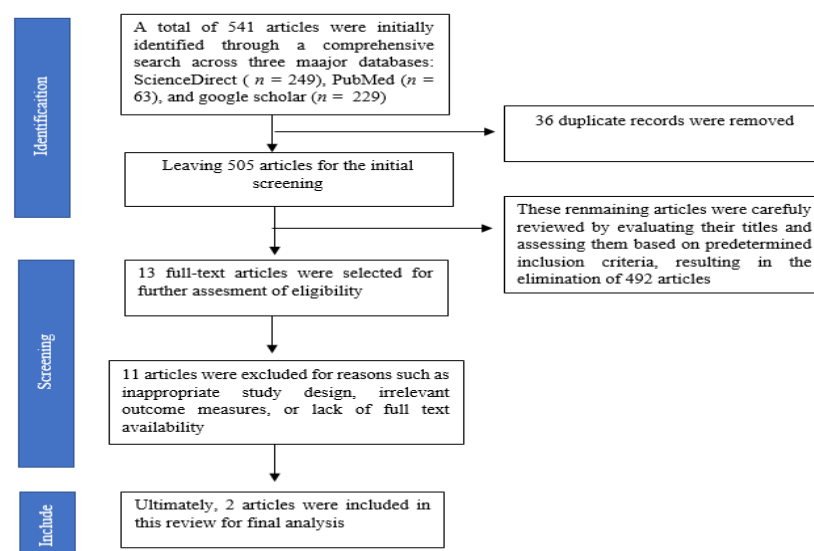


Fig. 1. PRISMA Flow Chart

Study Selection and Characteristics

The reviewed articles were articles conducted using experimental methods as the main data collection. The subjects used were elderly and sedentary individuals with moderate and high exercise intensity. Overall, differences in results between studies are likely influenced by several important interrelated factors. First, the dose and duration of supplementation play a major role; studies showing significant effects generally used high doses of cocoa flavanols (≥ 900 mg) with a minimum consumption duration of 30 days. Second, the characteristics of the target population also affect the response, where positive effects on cardiovascular function and exercise capacity are more consistently seen in healthy elderly compared to middle-aged individuals who are physically inactive. Third, the type and intensity of exercise also determine the results, where improvements in performance and oxygen efficiency are more prominent in moderate-intensity physical activity, while in high-intensity exercise the results tend to be inconsistent. These three aspects indicate that the benefits of cocoa flavanols are highly contextual and require an approach tailored to individual characteristics and the exercise protocol used.

Characteristics Of Research

After reviewing a number of articles, there were two studies that met the established criteria. Both studies explored the effects of chocolate interventions with various doses on cardiovascular and exercise adaptations

Table 1.
Characteristics Of Research

Researcher (Year)	Study Design	Intervention Duration	Population	Cocoa Flavanol Dose	Key Findings
Gröne et al., (2023)	RCT, double-blind	30 days	Healthy elderly (55–79 years)	500 mg twice daily (1000 mg total)	↑ Peak VO ₂ (+190 ml/min), ↑ VO ₂ /kg (+2.5 ml/min/kg), ↑ O ₂ -pulse, ↑ exercise capacity (+9.6 W), ↓ blood pressure, ↑ FMD
Sadler et al., (2021)	Crossover, placebo-controlled	7 days	Sedentary middle-aged adults (n=17)	400 mg/day	↓ VO ₂ time constant (phase II) by 15% (↑ oxygen efficiency)

Based on current evidence, consumption of cocoa flavanols shows great potential as a nutritional support strategy to improve cardiorespiratory capacity, particularly through improving VO_2 max, oxygen use efficiency, and vascular function. Findings from (Gröne et al., 2023) showed that a 30-day intervention with a high dose of flavanols (1000 mg/day) in healthy older adults significantly increased peak VO_2 and VO_2 per kilogram of body weight, indicating increased oxygen transport and utilization capacity during aerobic activity. In addition, there was a decrease in blood pressure and an improvement in endothelial function as measured by flow-mediated dilation (FMD), supporting the hypothesis that the vasodilatory effects of flavanols play a role in improving cardiac and circulatory system efficiency. These results are supported by Sadler et al., (2021), who showed that short-term consumption of cocoa flavanols (7 days) also increased the efficiency of the cardiorespiratory system, as indicated by a decrease in the phase II VO_2 time constant during the transition to submaximal exercise. These changes indicate an increase in the body's rate of adaptation to oxygen demand at the start of exercise, an important indicator of efficient aerobic performance. However, it is important to note that this study did not show an increase in exercise tolerance, suggesting that the duration or dose of the intervention may not have been optimal to produce broader performance effects.

According to the definition from Schramme (2023), health is a condition in which a person experiences overall well-being including physical, mental and social aspects—and not simply the absence of disease or weakness. At around 25 years of age, individuals are generally in optimal physical condition. However, as people age, especially after 45 years of age, subclinical disorders begin to appear and progress slowly, largely influenced by lifestyle and metabolic factors. When a person reaches the age of 65, structural and functional changes in the cardiovascular system begin to become apparent and increase the risk of conditions such as hypertension, coronary heart disease and heart failure. Thus, age is a major risk factor for the development of cardiovascular disease (Ibrahim & Ayze, 2024). Disorders of the cardiovascular system can directly reduce cardiorespiratory function, because efficient blood flow and oxygenation are very dependent on the health of the heart and blood vessels (Setyawati et al., 2022).

Consuming dark chocolate, which contains high levels of flavanols, is believed to support physical performance by improving cardiovascular function and the efficiency of oxygen use by muscles (Benedetti et al., 2025). Flavanols help improve blood flow, reduce oxidative stress, and support blood vessel dilation, all of which contribute to an indirect increase in aerobic capacity. When combined with regular physical activity, these effects have the potential to accelerate the body's adaptation to exercise and improve performance during activities that require high endurance. Regular consumption of dark chocolate (equivalent to 40 g per day) has been shown to reduce oxidative stress and markers of muscle damage during training sessions in elite soccer players. In contrast, supplementation with Montmorency cherries containing 600 mg of phenolic compounds and 40 mg of anthocyanins for 10 days prior to testing in men accustomed to strength training did not show significant changes in markers of oxidative stress, lipid peroxidation, or antioxidant activity after training (Cavarretta et al., 2018 ; Bojarczuk, 2023)

Physiologically, the main effects of cocoa flavanols appear to be related to the improvement of endothelial function through the Nitric Oxide (NO) pathway, which increases blood flow to muscles during physical activity and accelerates the fulfillment of oxygen requirements. This increase in muscle perfusion is also correlated with a decrease in the accumulation of metabolites such as lactate, which is associated with muscle fatigue. In addition, the antioxidant effects of flavanols can also reduce oxidative stress which usually increases during high-intensity exercise, there by maintaining muscle cell integrity and speeding

recovery. However, there was variation in results between studies that may be influenced by several factors such as intervention duration, subject population (older vs. younger athletes), and flavanol dose. Gröne et al. used a high dose for 30 days, while Ranchordas used a low dose for 7 days. This suggests that the response to cocoa flavanols may be population-specific and dose-responsive, and further research is needed to determine the optimal supplementation protocol for different user groups, including athletes, active adults, and individuals at cardiovascular risk. Furthermore, most of the existing studies are small in scale with limited population size. Meta-analytic studies or studies with larger samples and longer designs are needed to confirm the consistency of the benefits of cocoa flavanols, especially on long-term training adaptations and competitive performance

CONCLUSION

The results of this scoping review suggest that cocoa flavanols have great potential in improving cardiovascular adaptation and exercise capacity, mainly through mechanisms such as improving endothelial function, oxygen uptake efficiency, and lowering blood pressure. Interventions with high doses (≥ 900 mg/day) and a minimum duration of 30 days showed significant improvements in parameters such as peak VO_2 , oxygen pulse, and vascular function, especially in healthy elderly populations. Meanwhile, short-term consumption also showed benefits in pulmonary oxygen uptake efficiency during moderate-intensity exercise, although it did not consistently improve high-intensity exercise tolerance. These findings support the use of cocoa flavanols as an additional nutritional strategy to improve cardiorespiratory fitness, especially in groups with mild vascular dysfunction. However, more long-term studies and more diverse populations are needed to confirm the efficacy and safety of long-term cocoa flavanol use on exercise performance and cardiovascular health.

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