GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(REVIEW ARTICLE)

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The synergistic effects of robusta coffee consumption and exercise on enhancing muscle strength: A comprehensive review

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GSC Advanced Research and Reviews, 2024, 21(03), 260–265

Publication history: Received on 05 November 2024; revised on 14 December 2024; accepted on 16 December 2024

Article DOI: https://doi.org/10.30574/gscarr.2024.21.3.0501

Abstract

Coffee, rich in caffeine, is well-established for its ergogenic effects, which enhance both endurance and strength-based physical performance. Recent studies suggest that Robusta coffee, known for its high antioxidant content, and exercise may influence muscle strength. The purpose of this literature review is to explore the effects of Robusta coffee consumption and exercise on muscle strength levels. A total of 35 research papers published between the years 2019 to 2024 were accessed and used for this review that met the criteria. This review highlights that coffee consumption and exercise may enhance muscle strength and improve muscle health.

Keywords: Muscle Strength; Exercise; Robusta Coffee; Muscle Health

1. Introduction

Exercise is a cornerstone of physical fitness, providing a wide range of benefits to the body, including improved cardiovascular health, enhanced muscle function, better endurance, and reduced stress levels [1,2]. In addition to these physiological advantages, regular physical activity also plays a key role in improving brain function and promoting overall well-being [3]. However, as exercise becomes more integrated into modern social media culture, the motivation for engaging in physical activity may shift from health improvement to seeking social validation and competing with others for status and recognition [4]. This shift in motivation can lead to unhealthy exercise habits, with individuals pushing themselves beyond their physical limits in pursuit of greater achievements. Over time, excessive or unbalanced exercise routines, where intensity surpasses recovery, can lead to adverse effects such as muscle injuries, cardiovascular strain, immune dysfunction, reproductive irregularities, sleep disturbances, and disrupted energy balance [5]. Additionally, the increased oxygen demands of excessive physical exertion may result in oxidative stress, characterized by the accumulation of free radicals, which can further damage muscle tissue and impair recovery [6].

Muscle damage resulting from overexertion often manifests as fatigue, muscle soreness, inflammation, and a decline in muscle function. These symptoms are typically accompanied by elevated biomarkers such as myoglobin, blood urea nitrogen (BUN), creatine kinase (CK), troponin, and lactate dehydrogenase (LDH), all of which are indicators of muscle damage and oxidative stress [7]. Such oxidative stress is primarily caused by an imbalance between the body's energy production and the energy demands required for physical activity, leading to cellular stress and muscle tissue damage. To mitigate the damaging effects of oxidative stress and promote muscle recovery, antioxidants play a crucial role. Coffee, particularly Robusta coffee, is rich in antioxidants, including polyphenols and other bioactive compounds, that have the potential to combat oxidative stress and support muscle health [8]. The antioxidant properties of coffee may

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help reduce muscle inflammation and promote faster recovery following intense physical exercise, making it a promising natural remedy for exercise-induced muscle damage [9].

Robusta coffee, a popular beverage known for its high caffeine content, is widely consumed for its stimulating effects on the central nervous system. Caffeine, the primary active compound in coffee, has been shown to enhance physical performance by improving endurance, increasing strength, and reducing fatigue during aerobic and anaerobic exercises [10]. Caffeine acts as an ergogenic aid by stimulating the central nervous system, increasing alertness, reducing the perception of pain, and enhancing motor unit recruitment, all of which contribute to improved exercise performance [11]. Additionally, caffeine can increase the production of cyclic adenosine monophosphate (cAMP), which plays a key role in regulating energy metabolism, promoting lipolysis, and enhancing the availability of fatty acids as a fuel source during exercise [12]. As a result, caffeine can help spare muscle glycogen and extend endurance during prolonged exercise. Beyond its effects on energy metabolism, caffeine's antioxidant and anti-inflammatory properties may help protect muscles from oxidative damage caused by intense physical activity. This review examines the potential benefits of Robusta coffee consumption on muscle strength, endurance, and recovery, focusing on its ability to mitigate the adverse effects of oxidative stress and promote muscle health. By synthesizing current research on the interplay between exercise, muscle strength, and the effects of coffee, this review offers valuable insights into preventive and therapeutic strategies for managing exercise-induced muscle damage and optimizing performance.

2. Material and methods

This literature review utilized databases such as Google Scholar to retrieve studies using the keywords “Robusta Coffee” AND (Exercise) AND (“Muscle Strength”). Eligible studies included in-vitro, in-vivo, preclinical, and clinical research conducted between 2019 and 2024, focusing on the effects of Robusta coffee and exercise on muscle strength. The search, last conducted on December 12, 2024, identified studies addressing the individual and synergistic impacts of coffee and exercise, including caffeine's mechanisms. This review synthesizes relevant findings to provide a comprehensive understanding of Robusta coffee's influence on muscle strength and health.

3. Results

A Google Scholar search identified 1,120 results regarding the effects of Robusta coffee consumption and exercise on muscle strength, with 435 publications dated from 2019 to 2024. Among these, 105 focused specifically on the combined impact of coffee and exercise, but only 35 articles met the criteria for inclusion in this literature review. The selected studies explored the synergistic effects of Robusta coffee and exercise on muscle strength, as well as individual effects of coffee and exercise. Additionally, some highlighted Robusta coffee's antioxidant and anti-inflammatory properties and its broader health benefits.

4. Discussion

4.1. Muscle Strength

Muscle strength refers to the ability of a muscle or group of muscles to exert force against resistance during physical activity. It is a fundamental component of physical fitness and human performance, influenced by a combination of neural, muscular, and mechanical factors [9]. Muscle strength is essential for daily functional tasks, athletic performance, and overall physical health [11]. It depends on factors such as muscle size, fiber composition, motor unit recruitment, and training adaptations [13]. Strength levels can vary based on age, gender, and training regimens, making it a critical marker for evaluating physical capacity and the effects of interventions such as exercise or dietary supplements [14]. Muscle strength is not only pivotal for enhancing athletic performance but also plays a critical role in maintaining functional independence and preventing injury across various life stages. Factors influencing muscle strength include genetic predisposition, hormonal levels, nutrition, and the intensity, frequency, and type of physical training performed [15]. Progressive resistance training, for instance, has been shown to significantly increase muscle strength by promoting hypertrophy and improving neural adaptations [10]. This adaptability highlights the importance of targeted strength training in rehabilitation, aging populations, and performance optimization for athletes.

4.2. Exercise and Muscle Strength

Muscles are connective tissues in the body that contract to facilitate the movement of body parts and transport various substances within the body. Beyond changes in size, muscles can become stronger or weaker due to several factors, with physical exercise being a primary influence [16]. However, excessive physical exercise that surpasses the body's capacity can result in muscle damage [17]. Symptoms of muscle damage include fatigue, muscle pain or delayed onset

muscle soreness (DOMS), inflammation, and a reduction in muscle function [18]. Regular physical exercise induces positive adaptations, such as muscle fiber hypertrophy, increased capillary density, and enhanced connective tissue content, all of which contribute to improved muscle strength [19]. These structural changes are accompanied by intracellular adaptations, including increased mitochondrial number and size, denser cristae, and elevated oxidative enzyme activity, which support aerobic energy production [20].

However, when the intensity of physical exercise exceeds the body's limits, an energy imbalance occurs, with demand surpassing the body's capacity for production. This imbalance is a key mechanism underlying muscle damage [21]. Increased oxygen consumption during high-intensity exercise accelerates mitochondrial energy metabolism, placing abnormal stress on cells and leading to the overproduction of free radicals [22]. The accumulation of these reactive oxygen species (ROS) creates oxidative stress, a state that can impair muscle function and reduce muscle strength [23]. Prolonged oxidative stress may exacerbate muscle damage, emphasizing the importance of balanced exercise and effective recovery strategies.

4.3. Coffee and Muscle Strength

Coffee, renowned for its caffeine content, is widely recognized for its ergogenic properties, enhancing physical performance through central and peripheral mechanisms [24]. Caffeine is particularly effective in improving endurance during aerobic activities and increasing the capacity for repeated muscle contractions in resistance training [25]. Its primary mode of action is as an antagonist to adenosine receptors (A1, A2A, and A2B), which are distributed throughout the body in regions such as the thalamus, spinal cord, and peripheral tissues [26,27]. By binding to these receptors, caffeine reduces the perception of fatigue, delays the onset of exhaustion, and promotes wakefulness and alertness during physical activities [27]. These physiological effects are critical for improving both endurance and strength-based performance.

One of caffeine's mechanisms involves its influence on calcium dynamics within muscle cells. By inhibiting the reuptake of calcium into the sarcoplasmic reticulum, caffeine enhances calcium mobilization, promoting sustained muscle contraction [24]. This is achieved through its agonistic action on ryanodine receptors (RyRs), leading to increased calcium release from the endoplasmic reticulum [24,28]. However, this effect is dose-dependent, typically observed at higher caffeine levels [29]. Furthermore, caffeine inhibits phosphodiesterase activity, increasing levels of cyclic adenosine monophosphate (cAMP), which facilitates lipolysis and free fatty acid mobilization for energy use [27]. This glycogen-sparing effect is particularly advantageous for prolonged endurance exercises. Caffeine's competitive antagonism with type I adenosine receptors also stimulates lipolysis by overcoming inhibition, further enhancing fatty acid availability for muscle energy demands [10].

Caffeine additionally modulates the central nervous system, reducing pain perception, enhancing motor unit recruitment, and improving neuromuscular efficiency [27]. Its ergogenic effects extend to improving sodium-potassium ATPase pump activity, which supports muscle excitability during repeated contractions [30]. Studies consistently highlight caffeine's effectiveness in enhancing sports performance, including increased 1-repetition maximum strength, isokinetic peak torque, vertical jump height, and muscular endurance across various exercise protocols [24]. Systematic reviews affirm caffeine's role as a potent ergogenic aid, particularly in endurance and strength performance, with doses ranging from 3-6 mg/kg of body weight yielding optimal benefits without adverse effects [24,31].

4.4. The Synergistic Effects of Coffee and Exercise on Muscle Strength

The synergistic effects of coffee consumption and exercise on muscle strength are becoming a topic of growing interest in sports science. Coffee, a beverage widely consumed for its caffeine content, is well-known for its ability to enhance athletic performance. Caffeine, a key ergogenic aid, acts as an antagonist to adenosine receptors in the brain, which helps to increase alertness and reduce fatigue, ultimately improving exercise performance [10]. This heightened CNS stimulation allows individuals to push through fatigue during prolonged exercise and repetitive physical activities, thus enhancing muscle endurance and performance [32]. Studies have demonstrated that caffeine improves performance in activities ranging from endurance-based exercises to high-intensity resistance training by increasing muscle strength and the ability to sustain physical effort [33].

Beyond its effects on the CNS, caffeine directly influences muscle function through intracellular mechanisms. One of the most significant impacts of caffeine on muscle strength is its ability to enhance calcium mobilization in muscle cells [29]. Caffeine binds to ryanodine receptors in the sarcoplasmic reticulum, promoting the release of calcium, which is crucial for muscle contraction [24,29]. This increased calcium availability enhances muscle contractility, leading to improved force production during physical activity. Additionally, caffeine elevates cyclic adenosine monophosphate (cAMP) levels in muscle cells, which promotes lipolysis and increases the availability of fatty acids as a fuel source during exercise

[26]. These mechanisms help to preserve glycogen stores in muscles and extend endurance during prolonged or high-intensity exercise, leading to sustained muscle strength and performance [24].

Exercise itself, particularly resistance training, plays a crucial role in muscle strength development by inducing muscle hypertrophy and optimizing neuromuscular function [34]. However, excessive exercise, particularly without adequate recovery, can lead to muscle damage, oxidative stress, and inflammatory responses that impair muscle function and delay recovery [18]. In this context, coffee's antioxidant properties are particularly beneficial. Coffee, especially Robusta coffee, contains polyphenols and other bioactive compounds that have potent antioxidant and anti-inflammatory effects, which can help mitigate the oxidative damage caused by intense physical exercise [8,35]. Antioxidants found in coffee may reduce the accumulation of free radicals and oxidative stress, promoting faster recovery, reducing muscle soreness, and preventing long-term muscle damage [10].

The integration of coffee into an exercise regimen appears to offer a dual benefit: it enhances immediate performance through its ergogenic effects while also supporting long-term recovery through its antioxidant and anti-inflammatory properties [32]. Given that exercise-induced muscle damage is often characterized by increased oxidative stress and inflammation, coffee may help balance the effects of intense physical exertion and promote muscle health. Caffeine's positive influence on muscle strength and performance, combined with coffee's antioxidative capabilities, positions it as an effective supplement for athletes seeking to optimize their training and recovery outcomes [32].

5. Conclusion

In conclusion, the combination of coffee consumption and exercise offers a promising approach to enhancing muscle strength, endurance, and recovery. Caffeine provides an immediate ergogenic benefit by stimulating the CNS and increasing muscle contractility, while coffee's antioxidant properties help combat the oxidative stress associated with intensive physical activity. As exercise regimens continue to emphasize both performance and recovery, understanding the synergistic relationship between coffee and exercise can provide valuable insights into optimizing muscle strength and overall physical performance.

Compliance with ethical standards

Acknowledgments

The authors thank the Department of Physiology, Faculty of Medicine, Universitas Airlangga for facilitating this project.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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