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Yerba Mate Consumption and Exercise Performance: Physiological Effects, Potential Benefits and Safety – A Narrative Review

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Abstract:

Introduction. Yerba mate, a traditional beverage prepared from the leaves of *Ilex paraguariensis*, originates from South America but has gained increasing popularity worldwide. It has also attracted considerable interest among physically active individuals due to its high content of methylxanthines, chlorogenic acids, saponins, polyphenols, and other bioactive compounds. Its potential ergogenic and health-promoting properties have made yerba mate an increasingly important subject of research in the field of sports medicine and exercise science.

Background. Current evidence suggests that yerba mate exerts pleiotropic health-promoting effects on the human body and may influence exercise performance through multiple physiological mechanisms. Studies indicate that yerba mate consumption may modulate glucose homeostasis, lipid metabolism, and cellular metabolism, while also exerting stimulatory effects and enhancing antioxidant capacity. However, the available evidence remains heterogeneous, and the assessment of yerba mate effects requires careful critical evaluation.

Aim: This narrative review aims to summarize and discuss the current evidence regarding the physiological effects of yerba mate consumption and its potential benefits for exercise performance. In addition, this review synthesizes the available evidence on the safety profile of yerba mate and the potential risks associated with its consumption.

Conclusions. Yerba mate appears to be a promising natural supplement with potential ergogenic and health-promoting benefits. Nevertheless, the current evidence remains limited. Further studies are required to confirm its efficacy and clarify the underlying physiological mechanisms.

Key words: Yerba mate, *Ilex paraguariensis*, physical activity, supplements, physical activity

1. Chemical Composition

Nutrition is one of the fundamental factors influencing the body's capacity to perform and adapt to physical exercise (1). Beyond meeting energy and nutrient requirements, increasing attention has been directed toward foods containing bioactive compounds that may modulate physiological responses and selected aspects of exercise performance (2). One of the products that has attracted considerable scientific interest in recent years is yerba mate, a traditional South American beverage prepared from the leaves of *Ilex paraguariensis* A.St.-Hil., which is now consumed worldwide (3). Interest in yerba mate may have grown due to an increasing number of studies evaluating its potential effects on energy metabolism, physiological responses to exercise, and selected markers of exercise performance (4). In addition to its potential effects on exercise-related outcomes, it is important to assess the safety of yerba mate consumption and to identify the mechanisms underlying its observed physiological effects (5). A critical synthesis of the current knowledge on the effects of yerba mate consumption on exercise performance and the safety of its use appears warranted.

Yerba mate is a beverage prepared from the dried leaves and young stems of Paraguayan holly (*Ilex paraguariensis* A.St.-Hil., *Aquifoliaceae*), which has been consumed for centuries as part of the cultural heritage of South American countries, particularly Argentina, Paraguay, Uruguay, and southern Brazil. Originally, the beverage was consumed by indigenous populations, especially the Guaraní people, who attributed stimulating properties to yerba mate and used it to alleviate hunger and fatigue. During the sixteenth and seventeenth centuries, the cultivation and trade of yerba mate were expanded by Jesuit missionaries, contributing to its widespread use and economic importance throughout the region. Traditionally, the infusion is prepared by pouring water at approximately 65–80°C over the dried plant material in a vessel known

as a matero and consumed through a metal filtering straw called *a bombilla*. A characteristic feature of yerba mate is that the same dried leaves can be infused repeatedly, allowing the beverage to be consumed over an extended period without replacing the leaves (5, 6).

In recent years, yerba mate has gained popularity beyond South America, attracting growing interest from both consumers and the scientific community. Moreover, the leaves of *Ilex paraguariensis* are recognized in EMA monographs and have also been included in a pharmacopoeial monograph (5). The aim of this review is to present and critically evaluate the current evidence regarding the effects of yerba mate consumption on physiological processes in the human body, exercise performance, energy metabolism, and safety.

2. Chemical Composition

The growing popularity of yerba mate in the commercial market and the increasing scientific interest in this beverage are attributed to its high content of various bioactive compounds, including phenolic acids, flavonoids, methylxanthines, and saponins. These compounds are thought to contribute to the broad range of biological effects attributed to yerba mate, including the modulation of lipid and glucose metabolism, as well as neurostimulatory, anti-inflammatory, and antioxidant effects (7, 8). This section describes the main bioactive compounds found in yerba mate.

2.1. Factors Influencing the Chemical Composition of Yerba Mate

The chemical composition of yerba mate is not constant and depends on various factors related to the origin of the raw material, cultivation conditions, processing methods, and preparation of the infusion (7). The method of infusion preparation, particularly water temperature, extraction time, and the number of successive infusions, affects the amount of bioactive compounds released from the dried leaves into the beverage, thereby influencing its final chemical composition and biological properties (9).

2.2. Methylxanthines

The principal and most extensively studied compound in this group is caffeine. Caffeine exerts a stimulatory effect on the central nervous system. Adenosine receptors, which caffeine antagonizes, are involved, among other functions, in the regulation of sleep, memory, concentration, learning, and the perception of fatigue. Caffeine also exerts a diuretic effect (10). Studies have also demonstrated its potential ergogenic effects, including improvements in muscle strength and exercise performance (11). During the first infusion, the average caffeine

concentration in the liquid was 17.79 ± 3.49 mg/g (9). Apart from caffeine, yerba mate also contains theobromine and theophylline, which have also stimulatory effects on the central nervous system (12). However, high caffeine intake has also been shown to be associated with an increased risk of anxiety symptoms and sleep disturbances (13).

2.3. Polyphenolic Compounds and Flavonoids

Yerba mate is rich in polyphenolic compounds and flavonoids with antioxidant and anti-inflammatory properties. Among these polyphenols, chlorogenic acids are the predominant group (7). Studies suggest that chlorogenic acids may play a role in the regulation of glucose metabolism (14). The main flavonoid in yerba mate is rutin, which may modulate enzymes involved in pro-inflammatory pathways and exhibits anti-inflammatory, antioxidant, and antitumor potential (7, 15).

2.4. Saponins

Saponins represent one of the major groups of bioactive compounds found in yerba mate, beside methylxanthines and polyphenolic compounds.

Studies indicate that saponins present in yerba mate exhibit pleiotropic activities, including anti-inflammatory, hypocholesterolemic, and immunomodulatory effects (10). A study have demonstrated that yerba mate saponins exhibit anti-inflammatory activity, partly through the inhibition of the iNOS/NO and COX-2/PGE2 pathways, which play important roles in the development of the inflammatory response. In addition, yerba mate saponins have been shown to reduce the production of pro-inflammatory cytokines, such as interleukin-1 β (IL-1 β) and interleukin-6 (IL-6), and to limit the activation of the transcription factor nuclear factor kappa B (NF- κ B). Although saponins are present in yerba mate in lower concentrations than methylxanthines and polyphenolic compounds, the available evidence suggests that they may make a significant contribution to the overall health-promoting effects of this beverage (16).

3. Effects of Yerba Mate Consumption on Human Physiology

Due to its rich composition, yerba mate exerts a wide range of biological effects on the human body. This section provides a detailed overview of selected physiological effects of yerba mate that may be relevant to physical activity and exercise performance.

3.1. Glucose Metabolism

Several studies have investigated the effects of yerba mate on glucose metabolism. A meta-analysis published in 2025, which included seven randomized controlled trials, demonstrated a significant reduction in postprandial glucose levels ($p = 0.001$) among participants consuming yerba mate compared with control groups. Beneficial effects on glucose metabolism were also observed in terms of lower HbA1c levels (17).

Furthermore, yerba mate consumption has been associated with lower HOMA index values (17, 18). It shows the relationship between glucose and insulin dynamics and are used to assess insulin sensitivity. A lower HOMA index value indicates greater tissue sensitivity to insulin and lower insulin resistance (19, 20).

3.2. Lipid Metabolism

Gebara, K.S. et al. reported in a randomized crossover intervention study that, among individuals with a Framingham Risk Score classified as intermediate to high, consumption of yerba mate extract resulted in a 10% increase in high-density lipoprotein cholesterol (HDL-c) levels compared with baseline values. However, this effect was observed only in this specific subgroup. When all participants were analyzed independently of their cardiovascular risk category, no statistically significant differences in the lipid profile were observed (21).

A 2025 meta-analysis that included, among other studies, studies investigating the effects of yerba mate on lipid metabolism found that its impact on the lipid profile appears to be limited. (17) Another meta-analysis published in 2022 also found no significant differences in total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), or triglyceride levels. However, the authors noted that the available studies investigating the effects of yerba mate consumption on lipid metabolism were small and heterogeneous. Therefore, further research is needed to confirm these findings (22).

3.3. Cardiovascular System

In a randomized, controlled, blinded, crossover trial, participants in the intervention group consumed yerba mate for 8 weeks to assess its cardiometabolic effects. The study demonstrated a reduction in systolic blood pressure in the yerba mate group, while heart rate remained unchanged. In addition, reduction in LDL-c levels also was also observed. In the yerba mate group, reductions in ghrelin and glucose-dependent insulinotropic polypeptide (GIP) levels were also observed. Markers of inflammation, including tumor necrosis factor-alpha (TNF- α)

and interferon-gamma (IFN- γ), both of which are pro-inflammatory cytokines, were also reduced (23). Another significant contributor to cardiovascular risk is impairment of endothelial function (24). The study additionally assessed markers of vascular endothelial function. Investigations found that yerba mate consumption had no significant effect on the levels of vascular cell adhesion molecule-1 (VCAM-1) or intercellular adhesion molecule-1 (ICAM-1). Elevated levels of these adhesion molecules are associated with vascular inflammation and are markers of subclinical atherosclerosis and predictors of future cardiovascular events and mortality (23).

Gao et al. investigated the effects of yerba mate on vascular endothelial function in hyperlipidemic rats fed a high-fat diet. The study demonstrated reduced levels of endothelin (ET), which is involved, among other processes, in vasoconstriction, and thromboxane B₂ (TXB₂), which promotes platelet aggregation. In contrast, increased levels of nitric oxide (NO) and 6-keto-prostaglandin F_{1 α} (both exert vasodilatory effects) were observed. Furthermore, yerba mate consumption was associated with increased expression of the hepatic low-density lipoprotein receptor (LDL-R). These findings suggest that yerba mate may exert protective effects on vascular endothelial cells and may contribute to the prevention of atherosclerosis (25-28).

Another study evaluated the antioxidant effects of yerba mate. The findings showed that long-term yerba mate consumption increased the expression of antioxidant enzyme genes and total antioxidant status, as well as reducing lipid peroxidation (29).

3.4. Metabolism and Energy Homeostasis

Current evidence suggests that yerba mate may modulate energy metabolism through multiple physiological pathways, including mitochondrial function and adipose tissue metabolism. These effects may contribute to changes in body weight and body composition, although the available evidence remains heterogeneous.

Walton et al. in their study (2023) investigated mitochondrial efficiency in tissues involved in metabolic regulation, including skeletal muscle, adipose tissue, and the liver, in healthy adult mice. The study showed that mice consuming yerba mate for 4 weeks had greater mitochondrial efficiency in skeletal muscle, as indicated by a higher ATP:O₂ ratio, compared with mice that did not consume yerba mate. Moreover, the ATP:O₂ ratio in adipose tissue mitochondria was significantly lower in the yerba mate group than in the control group. No significant

changes in mitochondrial efficiency were observed in hepatocytes. Yerba mate consumption was also associated with a reduction in body weight in the mice (30).

Another study found that yerba mate consumption in ovariectomized mice increased the expression of sirtuin 1 (SIRT1) and uncoupling protein 1 (UCP1) in white adipose tissue. This protein expression profile may suggest the induction of “browning” of adipose tissue. Browning process is characterized by the transformation of white adipocytes toward a phenotype more resembling that of brown adipocytes, which are involved in thermogenesis (31). This phenomenon has been suggested to have beneficial effects in the context of various metabolic disorders (32).

There are studies that reported potential beneficial effects of yerba mate consumption on body weight reduction. A randomized, double-blind, placebo-controlled trial demonstrated that 12 weeks of yerba mate supplementation (a total daily dose of 3 g) was associated with significant reductions in body weight and body fat percentage ($p = 0.036$ and $p = 0.030$, respectively), as well as a significant decrease in waist-to-hip ratio (WHR) ($p = 0.004$), compared with the placebo group (33). However, a 2025 meta-analysis did not provide conclusive evidence of a weight-reducing effect of yerba mate. An analysis of eight randomized controlled trials found no statistically significant differences in BMI or waist circumference between participants consuming yerba mate and those in the control groups (17).

3.5. Nervous System and Cognitive Function

Yerba mate contains several compounds, which have well-established stimulatory effects on the central nervous system. These include primarily caffeine, as well as other methylxanthines – theobromine and theophylline (12).

Furthermore, some evidence suggests that yerba mate may exert neuroprotective effects. In a study involving mice treated with pentylenetetrazole to induce seizures, yerba mate consumption was associated with a lower frequency and shorter duration of tonic-clonic seizures compared with the water-treated control group (34).

In a study using cultured dopaminergic neurons, yerba mate promoted neuronal development and exhibited dose-dependent neuroprotective effect. Chlorogenic acid and theobromine, both compounds present in yerba mate, also demonstrated neuroprotective potential when tested individually. However, their effects were weaker than those of yerba mate, although stronger than effect of caffeine (35). These findings suggest that yerba mate may have potential

protective effects against Parkinson's disease. However, these findings are based on in vitro evidence, and further studies are needed to confirm this effect.

3.6. Antioxidant and Anti-inflammatory Effects

Walton et al. demonstrated in a 2023 study in mice that yerba mate consumption was associated with alterations in the glutathione (GSH)/glutathione disulfide (GSSG) redox potential in liver cells. This change was associated with a significant increase in GSH concentrations ($p = 0.0449$), while GSSG concentrations remained relatively stable ($p = 0.0251$). These findings suggest that yerba mate consumption promotes a more reduced intracellular environment and may enhance the cellular capacity to buffer oxidative stress (30).

In another randomized crossover intervention study published in 2020, a significant reduction of 19% in IL-6 concentrations was observed in the group receiving *Ilex paraguariensis* A.St. Hil. extract. This finding may be relevant given that IL-6 is a pro-inflammatory cytokine involved in the regulation of inflammatory responses (21).

In another study, the researchers observed suppression of nuclear factor kappa B (NF- κ B). This factor is a key transcription factor involved in pro-inflammatory signaling pathways (36). The study also demonstrated reduced expression of p-I κ B- α and p-GSK-3 β , molecules located upstream within this pro-inflammatory signaling pathway (37). Furthermore, in a study conducted in mice with pleuritis, yerba mate consumption not only reduced the release of pro-inflammatory cytokines but also increased levels of interleukin-10 (IL-10), an anti-inflammatory cytokine (36).

4. Yerba Mate and Sport

Current evidence suggests that yerba mate may influence exercise performance and physiological responses to physical activity. This section presents selected evidence on the effects of yerba mate on sports performance and physical activity.

4.1. Effects on Physical Performance

A randomized controlled trial involving 11 well-trained male cyclists demonstrated that participants who consumed 5 g of yerba mate daily for 5 days had higher resting adrenaline concentrations than those in the placebo control group ($p = 0.002$). Moreover, the study demonstrated a small but statistically significant improvement in performance during a cycle ergometer test ($p = 0.0278$). Furthermore, the yerba mate group exhibited 23% greater fat utilization at 30–50% of maximal oxygen uptake (VO_{2max}) than control group (4).

Due to its high caffeine content, yerba mate may increase energy expenditure both at rest and during exercise. A randomized study involving 14 participants demonstrated that yerba mate consumption increased energy expenditure derived from fatty acid oxidation by 24% during exercise at submaximal intensities below 70% of peak oxygen uptake (VO_{2peak}). Moreover, the greatest increase was observed at 40% and 50% of VO_{2peak} . Moreover, no negative effect of yerba mate consumption on maximal exercise performance was found (38). Additionally, in a 2022 study involving 10 healthy men, no statistically significant differences in muscle strength were observed one hour after yerba mate consumption compared with the placebo group. These findings suggest that acute yerba mate intake does not significantly affect muscle strength during exercise (39).

4.2. Psychological Effects of Yerba Mate on Exercise

Evidence regarding the effects of yerba mate on psychological responses to exercise is limited. In a randomized controlled trial published in 2017 and involving 12 healthy women, Alkhabib et al. investigated perceived satiety, Profile of Mood States, and fatty acid oxidation. During exercise, participants consuming yerba mate showed significantly higher Profile of Mood States scores for focus, energy, and concentration compared with the placebo group ($p < 0.05$). In contrast, scores for prospective food consumption, hunger, and desire to eat were significantly lower in the yerba mate group ($p < 0.05$) (40).

It should also be noted that yerba mate contains caffeine, theobromine, and theophylline, which have well-established stimulatory effects on the central nervous system (12).

4.3. Effects on Recovery After Exercise

Panza et al. investigated the effects of yerba mate consumption in healthy men on muscle strength and markers of oxidative stress following maximal isometric elbow flexion. The study showed that, 24 hours after exercise, the rate of strength recovery was 8.6% higher in the yerba mate group than in the control group. This finding may suggest a beneficial effect of yerba mate on the recovery of muscle strength. However, no significant differences were observed at 48 or 72 hours after exercise. The authors emphasized that the precise mechanisms underlying this effect remain unclear. They suggested that the observed differences may be related to the anti-inflammatory and antioxidant properties of yerba mate. However, these findings require confirmation in further studies (41).

Another study investigated the effects of a preparation containing *Ilex paraguariensis* extract on wound healing in malnourished mice. Selected wound-healing parameters assessed in the study indicated a potential beneficial effect of extract supplementation on tissue repair processes. However, these findings require further investigation and confirmation in subsequent studies (42).

5. Safety Profile

Yerba mate has potential to exert beneficial effects on human health; however, its consumption may also be associated with certain health risks.

5.1. Adverse Effects

There are some evidence that linked yerba mate consumption to an increased risk of esophageal cancer.

The International Agency for Research on Cancer (IARC) has classified the consumption of very hot beverages (above 65°C) as probably carcinogenic to humans (43). Moreover, Lubin, J.H. et al. in a study conducted in South America, demonstrated that the temperature at which yerba mate was consumed was linked to the risk of esophageal squamous cell carcinoma. Higher beverage temperatures were associated with a greater risk of esophageal cancer. In contrast, neither the duration nor the frequency of yerba mate consumption was associated with an increased risk (44). These findings suggest that the increased risk of esophageal cancer is primarily attributable to the consumption of very hot beverages rather than to consumption yerba mate consumption itself (45, 46).

Gastrointestinal adverse effects have also been reported, including nausea, heartburn, and irritation of the oral or gastric mucosa. Other reported adverse effects include insomnia and tachycardia (47, 48).

5.2. Contaminants

Ready-to-use *Ilex paraguariensis* A. St.-Hil. leaves used for infusion contain polycyclic aromatic hydrocarbons (PAHs), particularly benzo[a]pyrene. These compounds are recognized as harmful to human health and have been classified as carcinogenic to humans (49). PAHs are also present in fresh leaves; however, their concentrations in the final beverage may be influenced by leaf-processing methods, particularly roasting, as well as by the techniques used to prepare the infusion (50).

5.3. Interactions

Studies demonstrate that yerba mate inhibited the activity of cytochrome P450 3A4 (CYP3A4), cytochrome P450 1A2 (CYP1A2), and cytochrome P450 2E1 (CYP2E1) (10, 51). Inhibition of cytochrome P450 enzymes involved in drug metabolism may impair drug elimination, potentially resulting in drug accumulation or the accumulation of intermediate metabolites (52). However, there is currently insufficient evidence to establish that interactions between yerba mate and medications are clinically significant.

6. Conclusions

The available evidence indicates that yerba mate is a rich source of bioactive compounds, including polyphenols, methylxanthines, and saponins, which may exert potentially beneficial effects on human health and metabolism. Studies suggest that yerba mate may have a beneficial effect on glucose metabolism; however, its effects on lipid metabolism, in particular, remain unclear and require further investigation. Numerous studies have also reported potential anti-inflammatory, antioxidant, and neuroprotective effects of yerba mate. Nevertheless, the current level of evidence does not support considering yerba mate a significant therapeutic intervention for the treatment of disease, although it may constitute a component of a healthy diet.

Of particular interest are findings regarding the potential effects of yerba mate on physical performance, metabolic regulation during exercise, and post-exercise recovery. Studies suggest that yerba mate may have the potential to modulate energy metabolism during physical activity, improve mood, and promote post-exercise recovery. However, the available evidence is based mostly on studies involving small study populations. The rationale for the use of yerba mate in physically active individuals and athletes requires confirmation in larger, well-designed clinical trials.

Disclosure

Author Contributions:

Conceptualization: O.S., B.G., A.S., J.L.; methodology: O.S., B.G., G.K.; literature search and investigation: O.S., A.S., P.K., J.Pa., L.R; writing original draft preparation: O.S., G., A.S., J.L., D.K.-O., J.Prz.; review and editing: O.S., J.L., N.W.; supervision: O.S., M.W., M.B.

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