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Rosa damascena in exercise-induced neuroinflammation and recovery: A narrative review bridging traditional medicine and translational sports science

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ABSTRACT

Rosa damascena (Damask rose) has long been esteemed in traditional medicine for its neurocalming, anti-inflammatory, and antioxidant properties. Recent scientific interest highlights its potential to address exercise-induced physiological and psychological stress by modulating the neuroimmune axis. This narrative review synthesizes preclinical, clinical, and ethnobotanical evidence regarding *R. damascena*'s effects on neuroinflammation, oxidative stress, and post-exercise recovery. It aims to elucidate mechanistic pathways, assess translational applications, and propose evidence-based strategies for incorporation into sports medicine and athlete recovery protocols. A comprehensive literature search was conducted across biomedical databases up to May 2025. Eligible studies included *in vitro, in vivo*, and human research examining the physiological effects of *R. damascena* or its constituents in the context of neuropsychology, inflammation, oxidative damage, and exercise recovery. *R. damascena* exhibits multi-modal effects, including down-regulation of pro-inflammatory cytokines, attenuation of oxidative biomarkers, enhancement of parasympathetic activity, and modulation of serotonergic and GABAergic systems. Evidence supports its role in improving sleep quality, mood regulation, and cognitive function factors critical to athlete performance and resilience. Both preclinical and early phase human studies indicate potential benefits in reducing delayed-onset muscle soreness (DOMS), accelerating recovery, and supporting autonomic balance. A translational framework is proposed to guide future applications and clinical trials. With its unique blend of neuroprotective, immunomodulatory, and adaptogenic properties, *R. damascena* presents a promising phytotherapeutic agent for exercise recovery. Bridging ancient medical traditions and modern sports science, it warrants further interdisciplinary investigation to validate its efficacy, determine optimal formulations, and ensure safety in diverse athletic populations.

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Introduction

Rosa damascena (*RD*), commonly known as the Damask rose, is one of the most culturally, medicinally, and scientifically significant plants in human civilization. Its history dates back over two millennia, with its origins often traced to ancient Persia, where it was revered not only for its fragrance but also for its therapeutic attributes (1). Cultivated extensively in regions such as Iran, Bulgaria, Turkey, and India, *RD* has played a pivotal role in traditional rituals, spiritual ceremonies, and pharmacological practices (2). Botanically, it belongs to the *Rosaceae* family and is a hybrid between *Rosa gallica* and *Rosa phoenicia*. Its distinctive pink petals are not merely ornamental; they are rich repositories of essential oils, flavonoids, and bioactive molecules that have drawn increasing interest from modern scientific communities (3).

In Iranian traditional medicine (ITM), *RD* is esteemed as a multifaceted remedy. It is classified as "warm and dry" in temperament and is prescribed for conditions ranging from melancholia and cardiac discomfort to digestive irregularities and inflammatory disorders (4). Its application in aromatherapy, decoctions, and topical ointments reflects a longstanding integration into holistic healing systems. This reverence for *RD* has transcended cultural boundaries, finding a place in global phytotherapy and integrative medicine practices. Modern research has validated many of its traditional claims, including anxiolytic, anti-inflammatory, anti-oxidant, and antimicrobial effects (5-7).

Despite this broad pharmacological profile, the potential relevance of *RD* in exercise physiology remains vastly underexplored. Exercise, particularly at high intensities or durations, can induce physiological stress characterized by systemic inflammation, oxidative imbalance, mood fluctuations, and transient cognitive fatigue (8, 9). These responses, while adaptive, may be modulated by phytochemicals with neuroprotective, immunoregulatory, and stress-buffering capabilities. In this context, *RD*, with its polyphenolic content and essential oils such as

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citronellol and geraniol, emerges as a promising candidate for augmenting athletic recovery and performance (10, 11).

Furthermore, the neuromodulatory effects of *RD*, including enhanced serotonin regulation, improved sleep quality, and reduced cortisol levels, resonate closely with the psychological demands placed on both recreational and elite athletes (12). Its anti-oxidant profile suggests the potential to mitigate exercise-induced muscle damage and promote redox homeostasis (13). Collectively, these attributes form a compelling basis for investigating *RD* as a botanical intervention in sports science, a domain that increasingly embraces integrative and plant-based strategies.

This narrative review aims to explore the interplay between *RD* and exercise physiology comprehensively. Specifically, it addresses its phytochemical foundations, neuropsychological benefits, anti-inflammatory and anti-oxidant mechanisms, cardiometabolic impacts, and implications for sports performance and recovery. Drawing upon both preclinical and clinical evidence, this review synthesizes existing knowledge, highlights translational gaps, and proposes future directions for research and practice. Ultimately, the objective is to position *RD* not merely as a medicinal plant of cultural heritage, but as a scientifically grounded agent with the potential to redefine recovery and resilience in athletic populations.

To facilitate navigation, this review first situates *RD* within its ethnobotanical and phytochemical context, then examines its neuropsychological, anti-inflammatory, anti-oxidant, and cardiometabolic properties. Building on this foundation, we synthesize preclinical and human evidence, explore its applications in exercise and sports science, and conclude by outlining practical recommendations alongside current challenges and future research directions.

Methods

To ensure transparency and methodological rigor in compiling this comprehensive narrative review, a structured and strategic literature search was conducted across multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar. These searches were also performed in several reputable Persian-language databases. Search terms were designed to capture the breadth of relevant studies and included combinations of keywords such as *"Rosa damascena," "rose oil," "exercise," "inflammation," "athletes," "mood," "oxidative stress," "cardiometabolic,"* and *"recovery."* Filters were applied to select peer-reviewed articles, conference proceedings, and preclinical or clinical research published in English and Persian from inception through May 2025. Eligibility criteria encompassed studies that investigated *RD* or its active constituents in physiological, neurological, or metabolic contexts relevant to exercise and human performance. A limited number of well-conducted *in vitro* and *in vivo* studies were included where human data were sparse but mechanistically informative.

Given the interdisciplinary nature of the topic, which intersects exercise physiology, phytotherapy, neuroscience, and immunology, this review adopts a narrative format rather than a systematic or scoping approach. This choice was intentional. Narrative reviews, when conducted rigorously and transparently, provide the necessary flexibility to integrate and interpret heterogeneous evidence from diverse sources. This format is particularly suited to emerging areas of research where controlled trials are limited and mechanistic insights remain scattered across domains. In the case of *RD*, the existing body of evidence spans ethnobotany, pharmacology, clinical nutrition, and exercise science. A systematic review risks excluding key mechanistic studies and relevant translational insights due to rigid inclusion criteria. Instead, this narrative synthesis enables a nuanced and critical evaluation of the literature, illuminating connections that may inform future hypothesis-driven research and practical applications in sports and recovery settings.

The methodological framework included iterative thematic synthesis, in which extracted data were grouped into major conceptual domains: phytochemistry, neuropsychology, inflammation, cardiometabolic regulation, and performance recovery. Within each domain, findings were assessed based on relevance to athletic populations, biological plausibility, and methodological quality. While formal risk-of-bias tools were not uniformly applicable due to the inclusion of various study designs, methodological soundness and reproducibility indicators were evaluated narratively. Limitations of current evidence, such as small sample sizes, short intervention durations, or lack of sport-specific outcomes, were critically considered to avoid overinterpretation.

This review aims not only to summarize but to bridge traditional knowledge and modern exercise physiology through an evidence-informed narrative. The structure was designed to move from foundational phytochemical insights to applied implications for human performance and recovery, with each section building on the previous to form an integrated, forward-looking perspective. The following section begins by exploring the phytochemical profile and pharmacodynamic actions of *RD*, laying the biochemical and physiological groundwork for understanding its potential role in modulating athletic health and performance.

Ethnobotanical and historical insights into Rosa damascena

Medicinal heritage across cultures

RD, commonly known as the Damask rose, holds a prominent place in traditional medicinal systems across diverse cultures. In Persian Traditional Medicine (PTM), it has been historically utilized as a mood stabilizer, cardiotonic, and digestive aid (14). Its "hot and dry" temperament classification under PTM aligns with its application in conditions marked by melancholy, fatigue, and neurovegetative imbalance (15). Persian scholars such as Avicenna extensively documented its use in the Canon of Medicine, highlighting rose oil and rosewater for neuropsychological complaints and physical exhaustion (16). In Ayurvedic medicine, *RD* is included in the category of Sheet Virya Dravyas, cooling agents that balance Pitta dosha. It is recommended for calming the mind, relieving heat-induced fatigue, and promoting restful sleep (17). Similarly, Unani medicine uses rose in formulations for heart palpitations and lethargy, as well as in nervine tonics (18). Meanwhile, in Traditional Chinese Medicine (TCM), although Rosa rugosa is the most frequently used rose species, the properties attributed to rose petals—especially their Qi-regulating and liver-soothing capabilities—resonate with *RD*'s bioactivity profile (19).

Traditional claims related to recovery, vitality, and mental calmness

Several ethnobotanical records associate *RD* with physical

revitalization, emotional balance, and post-stress recovery. Its pleasant aroma and calming effect were believed to help soldiers, athletes, and laborers recover after intense exertion. Historical texts from the Middle East mention rose elixirs as "elixirs of tranquility" used by royal guards and traveling caravans to sustain mood and reduce physical weariness (20). Topical application of rose oil was believed to relieve muscle stiffness and joint fatigue. In traditional Persian sports such as Varzesh-e Pahlavani, rose-infused baths or compresses were used for physical recovery (21). The integration of rosewater into cooling beverages (sharbat) was not merely cultural but also grounded in functional benefits that support hydration, thermoregulation, and emotional steadiness (22).

From tradition to application

While traditional claims may lack the rigor of contemporary clinical trials, the biochemical rationale underlying these historical practices aligns with modern sport physiology. The presence of compounds such as citronellol, geraniol, quercetin, and kaempferol in *RD* provides anti-inflammatory, anxiolytic, and adaptogenic properties (23). Today, the historical use of *RD* can inspire phytotherapy-based recovery interventions in sports. For instance, rose aromatherapy might serve as a non-invasive adjunct to enhance parasympathetic reactivation post-exercise, while rosewater-infused recovery drinks could aid rehydration and mood regulation (24). Bridging ancient wisdom with current evidence not only respects cultural knowledge systems but also opens avenues for low-risk, accessible, and natural recovery strategies in exercise physiology (25-27).

Phytochemistry and pharmacodynamics of Rosa damascena

Key bioactive compounds

RD is renowned for its rich phytochemical profile, which underpins its diverse pharmacological activities. The essential oil derived from its petals is particularly rich in monoterpenes, with citronellol and geraniol being the predominant constituents. Citronellol, accounting for approximately 14.88-47.43% of the essential oil, and geraniol, comprising about 5.5-18%, are primarily responsible for the plant's characteristic aroma and several therapeutic properties (28). In addition to monoterpenes, *RD* contains a variety of flavonoids, including quercetin, kaempferol, and their glycosides. These flavonoids contribute significantly to the plant's anti-oxidant activity, scavenging free radicals and protecting cells from oxidative stress. The presence of anthocyanins, particularly cyanidin-3,5-diglucoside, further enhances its anti-oxidant capacity (29). Other notable constituents include phenylethyl alcohol, which imparts a pleasant fragrance and exhibits antimicrobial properties, and nonadecane, a hydrocarbon that contributes to the stability of the essential oil. The synergistic interaction among these compounds is believed to potentiate the overall therapeutic efficacy of *RD* (30). A comprehensive list of bioactive compounds identified in *RD*, along with their proposed biological targets and supporting evidence, is provided in Table 1.

Mechanisms of action: Neuroactive, Anti-inflammatory, anti-oxidant

The pharmacodynamic properties of *RD* are multifaceted, encompassing neuroactive, anti-inflammatory, and anti-oxidant mechanisms. The neuroactive effects are primarily attributed to its monoterpene constituents. Geraniol and citronellol have been shown to modulate the central nervous system by interacting with gamma-aminobutyric acid (GABA) receptors, leading to anxiolytic and sedative effects. These interactions may underlie the traditional use of *RD* to alleviate stress and promote relaxation (31). The anti-inflammatory properties are mediated by inhibiting pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). Studies have demonstrated that extracts of *RD* can suppress the expression of these cytokines, thereby reducing inflammation. This effect is particularly relevant in the context of exercise-induced inflammation, where modulation of the inflammatory response can aid in recovery and performance (32). Anti-oxidant activity is another critical aspect of *RD* pharmacodynamics. The flavonoids and anthocyanins present in the plant scavenge reactive oxygen species (ROS), mitigating oxidative stress. This anti-oxidant effect not only protects against cellular damage but also supports the body's natural defense mechanisms, which are essential for athletes undergoing intense physical training (33).

Pharmacokinetics and bioavailability in humans

Understanding the pharmacokinetics and bioavailability of *RD*'s bioactive compounds is crucial for optimizing its therapeutic applications. Monoterpenes like citronellol and geraniol are lipophilic and can be absorbed through the gastrointestinal tract. However, their bioavailability is influenced by factors such as metabolism and the presence of other dietary components. After oral administration, these compounds undergo first-pass hepatic metabolism, where they are conjugated and subsequently excreted. The half-lives of monoterpenes vary, but studies suggest they

Table 1. Bioactive constituents of *Rosa damascena* and their putative mechanisms of action

Compound	Biological class	Proposed mechanism	Source of evidence
Citronellol	Terpene	Anti-inflammatory via NF-κB inhibition	*In vitro*
Geraniol	Monoterpenoid	Antioxidant and neuroprotective effects	Animal model
Kaempferol	Flavonoid	HPA axis modulation, cytokine suppression	Clinical trial
Quercetin	Flavonoid	Reduces oxidative stress and inflammation	*In vivo*
Eugenol	Phenolic compound	Modulates the immune response and reduces DOMS	*In vitro*

This table summarizes major bioactive compounds identified in *Rosa damascena* (RD), their biological class, proposed mechanism of action, and the type of supporting evidence
HPA: Hypothalamic–pituitary–adrenal axis; DOMS: Delayed onset muscle soreness; *In vitro*: Studies conducted in cell culture; *In vivo*: Studies conducted in animal models

are rapidly metabolized and eliminated from the body. Enhancing their bioavailability may involve the use of delivery systems such as nanoemulsions or encapsulation techniques, which can protect the compounds from degradation and improve absorption (34). Flavonoids, on the other hand, exhibit variable bioavailability due to their complex structures and interactions with gut microbiota. The glycosylated forms of flavonoids are hydrolyzed in the intestine, and the aglycones are absorbed and metabolized. The resultant metabolites may retain biological activity, contributing to the overall therapeutic effects of *RD* (35).

Safety profile and toxicology

Safety assessments of *RD* have been conducted to evaluate its potential toxicity. Acute and sub-chronic toxicity studies in rodents have shown that high doses of *RD* extracts do not produce significant adverse effects. For instance, the median lethal dose (LD50) of the hydroalcoholic extract in rats has been reported to be greater than 5 g/kg, indicating a high margin of safety (36). In human studies, the administration of *RD* extracts has been generally well-tolerated. Clinical trials using rose oil or extracts for various therapeutic purposes have not reported serious adverse events, further supporting its safety profile (37).

While *RD* is considered safe, potential adverse events and drug interactions should be considered. Mild side effects such as gastrointestinal discomfort or allergic reactions have been reported in rare cases. Additionally, due to its sedative properties, *RD* may potentiate the effects of central nervous system depressants, and caution is advised when used concomitantly with such medications (38).

Determining safe and effective dosage ranges for athletes is essential for maximizing benefits while minimizing risks. Based on available studies, doses of *RD* extract ranging from 500 mg to 1 g per day have been used without adverse effects. However, individual responses may vary, and it is recommended that athletes consult healthcare professionals before incorporating *RD* into their regimen (39).

Neuropsychological and mood-enhancing effects

Effects on mood, anxiety, and depression

The neuropsychological implications of *RD* are receiving growing attention, particularly in the context of exercise recovery and mental well-being among athletes. Chronic psychological stress, anxiety, and depressive symptoms are prevalent challenges in competitive sports, often exacerbated by overtraining, performance pressure, and injury (40). Bioactive compounds in *RD*, notably citronellol, geraniol, and flavonoids, have demonstrated significant mood-modulating properties through various neurochemical pathways. Several clinical and preclinical studies have identified anxiolytic and antidepressant-like effects of *RD*. These are believed to be mediated by interaction with the serotonergic and GABAergic systems. In animal models, inhalation or administration of rose essential oil has led to increased serotonin (5-HT) levels and GABA receptor modulation, contributing to reduced anxiety-like behavior and enhanced mood stabilization (41, 42). A double-blind randomized controlled trial in humans reported that oral intake of *RD* extract significantly reduced scores on the Beck Depression Inventory and Hamilton Anxiety Rating Scale in participants with mild-to-moderate depressive symptoms (43). Furthermore, *RD* may provide neuroprotective benefits by suppressing oxidative stress in the central nervous system (CNS), a recognized contributor to depression pathophysiology. The anti-oxidant constituents, particularly quercetin and kaempferol, attenuate neuroinflammation and neuronal apoptosis, preserving hippocampal function and resilience under chronic stress conditions (44). In the context of exercise physiology, mood enhancement is not only vital for psychological well-being but also impacts adherence to training, motivation, and recovery. Supplementation with *RD* in athletes may serve as a natural adjunct to alleviate exercise-induced psychological fatigue and emotional dysregulation, especially in high-stress competition periods or recovery phases.

Sleep quality and circadian modulation in athletes

Adequate sleep quality and circadian alignment are essential components of recovery and optimal performance in athletic populations. Disruptions in sleep architecture and circadian rhythms can negatively impact muscular repair, hormonal balance, and cognitive function. Emerging evidence suggests that *RD* may favorably influence sleep quality through multiple mechanisms, including central nervous system modulation and melatonin pathway interaction. Experimental studies in rodents have shown that rose oil inhalation leads to significant increases in non-REM sleep duration and total sleep time, likely via up-regulation of GABAergic signaling and attenuation of hypothalamic-pituitary-adrenal (HPA) axis activity (45). These effects translate into improved sleep initiation and maintenance, which are particularly relevant for athletes undergoing high-intensity training that may disrupt natural sleep cycles. Clinical data further corroborate these findings. In a randomized, crossover trial, participants who received *RD* aromatherapy prior to bedtime demonstrated significantly improved Pittsburgh Sleep Quality Index (PSQI) scores and reported enhanced subjective sleep satisfaction (46). The calming and sedative effects appear to be dose-dependent and are most effective when administered consistently over time. Athletes experiencing delayed sleep phase syndrome (DSPS), jet lag from travel, or performance-related insomnia may particularly benefit from *RD* interventions. Its influence on melatonin secretion and core body temperature regulation could help re-entrain circadian rhythms, especially when combined with light therapy and structured sleep hygiene protocols (47).

Cognitive function and mental clarity during training

Cognitive performance, comprising attention, working memory, decision-making, and executive function, is integral to both tactical sports and endurance disciplines. Mental fatigue, often induced by prolonged exertion or inadequate recovery, can impair motor coordination, reaction time, and competitive outcomes. Botanical agents that support cognitive clarity without central nervous system overstimulation are of high interest, particularly in natural sports nutrition. Preclinical investigations suggest that *RD* enhances cognitive function via cholinergic system modulation and oxidative stress reduction in neural tissues. A study on scopolamine-induced memory impairment in rats showed that treatment with *RD* extract significantly improved performance in maze navigation and object recognition tasks, suggesting its nootropic potential (48). Flavonoids such as quercetin and kaempferol found in *RD* exhibit neurovascular protective effects, enhancing

cerebral blood flow and promoting synaptic plasticity. These mechanisms support sustained attention and reduced cognitive load during mentally demanding athletic tasks. Moreover, the aromatherapeutic properties of rose oil have been shown to improve reaction time, vigilance, and EEG-based markers of alertness without inducing overstimulation—a key advantage over caffeine or synthetic stimulants (49). In sports like fencing, tennis, or martial arts, where split-second decisions determine outcomes, enhancing cognitive resilience is crucial. Incorporating *RD* through supplementation, aromatherapy, or functional foods may offer an evidence-based strategy to sustain mental clarity, especially in training camps and competition weeks where cognitive fatigue is common.

Anti-inflammatory, anti-oxidant, and immunomodulatory roles

Effects on IL-6, TNF-α, CRP, and immune response

Inflammation plays a pivotal role in both acute and chronic phases of exercise adaptation. However, excessive or unresolved inflammation may impede recovery, induce fatigue, and contribute to overtraining syndrome in athletes. Among pro-inflammatory cytokines, interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and C-reactive protein (CRP) are widely recognized biomarkers that reflect systemic and muscular inflammatory responses (50). *RD* exhibits potent anti-inflammatory effects, mediated by its essential oils (notably citronellol and geraniol) and polyphenolic constituents, including quercetin, kaempferol, and gallic acid. These phytochemicals can down-regulate pro-inflammatory cytokines and modulate immune cell signaling pathways. *In vitro* studies have demonstrated significant inhibition of IL-6 and TNF-α expression in lipopolysaccharide (LPS)-stimulated macrophages treated with *RD* extracts (51). Animal models of inflammation also showed a marked reduction in serum CRP and in inflammatory cell infiltration upon administration of *RD* oil or its hydroalcoholic extract (52). In human contexts, limited but promising data suggest immunomodulatory benefits. A pilot clinical trial involving individuals with inflammatory disorders demonstrated significant decreases in CRP and IL-6 after daily ingestion of *RD* capsules for four weeks (53). These findings position the plant as a potential adjunctive therapy for managing low-grade systemic inflammation in physically active populations. For athletes engaged in repetitive high-intensity training, the regular use of *RD* in nutritional or therapeutic protocols may attenuate transient immunosuppression and enhance resilience against infection and systemic inflammation. These properties align with broader trends in immunonutrition and plant-based anti-inflammatory supplementation in sports medicine.

Exercise-induced inflammation, DOMS, and muscle recovery

Delayed onset muscle soreness (DOMS) is a common consequence of eccentric or novel exercise. It is characterized by localized inflammation, stiffness, and pain that can impair subsequent performance and training continuity. The inflammatory cascade triggered by muscle microtrauma involves up-regulation of cytokines (e.g., IL-1β, IL-6, and TNF-α), neutrophil infiltration, and oxidative stress (54). Botanical agents with both anti-inflammatory and analgesic properties have garnered attention as alternatives to nonsteroidal anti-inflammatory drugs (NSAIDs), which can blunt adaptive responses to exercise. *RD*, through its bioactive constituents, exhibits antinociceptive effects comparable to conventional analgesics but without the gastrointestinal or renal side effects commonly associated with NSAIDs (55). Preclinical research supports this: rats administered rose extract post-exercise showed significantly reduced muscle edema, leukocyte infiltration, and behavioral indicators of discomfort (56). Topical application of *RD* essential oil has also been shown to enhance recovery in human subjects. In a randomized controlled study involving resistance-trained males, localized aromatherapy massage using rose oil resulted in lower post-exercise creatine kinase (CK) levels and reduced subjective pain scores at 24- and 48-hours post-training (57). The combined anti-oxidant and anti-inflammatory actions of *RD* appear to mitigate the extent and duration of muscle damage, enhance blood flow, and accelerate tissue repair. These effects are particularly relevant for athletes engaged in high-frequency training cycles where minimizing downtime and optimizing recovery are critical. The proposed mechanisms by which *RD* exerts its restorative effects during post-exercise recovery are illustrated in Figure 1. This schematic outlines the plant's interactions with neuropsychological, anti-inflammatory, and

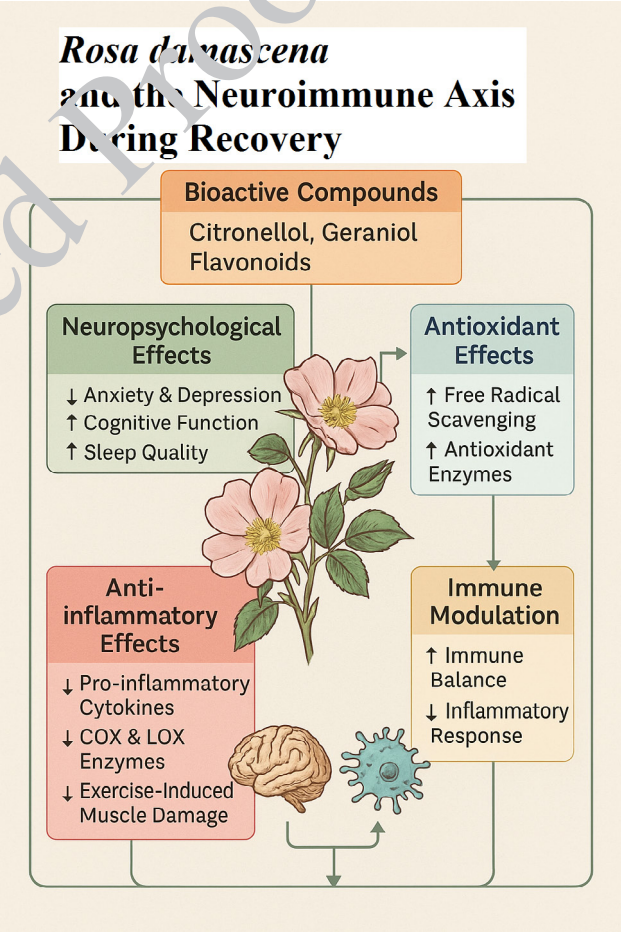

Figure 1. A Proposed mechanistic framework illustrating the role of *Rosa damascena* in recovery following exercise
This schematic integrates evidence from preclinical and clinical studies to demonstrate how bioactive compounds in RD (e.g., citronellol, geraniol, flavonoids) interact with the central nervous, endocrine, and immune systems to promote recovery. Key mechanisms include neuropsychological effects (↓ anxiety and depression, ↑ cognitive function, ↑ sleep quality), antioxidant effects (↑ free radical scavenging, ↑ antioxidant enzymes), anti-inflammatory effects (↓ pro-inflammatory cytokines, ↓ COX and LOX enzyme activity, ↓ exercise-induced muscle damage), and immune modulation (↑ immune balance, ↓ inflammatory response)
RD: *Rosa damascena*; HPA: Hypothalamic–pituitary–adrenal axis; COX: Cyclooxygenase; LOX: Lipoxygenase

HPA axis pathways, providing an integrative model for its translational potential in exercise recovery settings. This conceptual model demonstrates how bioactive constituents of *RD* interact with the central nervous, endocrine (HPA axis), and immune systems to promote recovery and reduce inflammation following physical exertion. The figure integrates findings from preclinical and clinical studies to propose a consolidated framework for its use in recovery paradigms.

Oxidative stress and redox homeostasis in athletes

Intense and prolonged physical activity is associated with a substantial increase in ROS, which can overwhelm endogenous anti-oxidant defenses and lead to oxidative damage to lipids, proteins, and DNA (58). While moderate ROS production is essential for cellular signaling and adaptive responses, excessive oxidative stress contributes to fatigue, muscle injury, and impaired recovery. *RD* is rich in polyphenolic anti-oxidants, including gallic acid, quercetin, and vitamin C analogs, all of which contribute to its strong radical-scavenging capacity. In DPPH and ABTS assays, *RD* extracts have demonstrated anti-oxidant activities comparable to standard compounds such as ascorbic acid and Trolox (59). Furthermore, studies on exercise-induced oxidative stress models in rodents have shown that supplementation with *RD* reduces malondialdehyde (MDA) levels and restores superoxide dismutase (SOD) and catalase (CAT) activity (60). From a physiological perspective, maintaining redox balance is essential not only for recovery but also for immune regulation and mitochondrial function. Incorporating *RD* into pre- or post-exercise nutrition plans, whether as tea infusions, extracts, or encapsulated supplements, may support endogenous anti-oxidant defenses, particularly in endurance athletes or those exposed to oxidative environments (e.g., altitude, pollution). Additionally, some emerging studies suggest potential mitochondrial biogenic effect via the up-regulation of PGC-1α, though these findings remain preliminary and require further validation in athletic cohorts (61). Overall, the plant's dual role as an anti-oxidant and anti-inflammatory agent makes it uniquely suited for integrated recovery strategies in modern sports physiology.

Cardiometabolic health and performance factors

The integration of *RD* into exercise physiology and sports nutrition holds significant potential to optimize cardiometabolic health and performance. Given the interconnectedness of metabolic function, cardiovascular dynamics, and athletic output, the polyphenolic, flavonoid-rich, and bioactive matrix of *RD* offers promising adjunctive benefits. This section explores three key domains in which *RD* may exert mechanistic and functional influence: cardiovascular regulation, glucose-insulin homeostasis, and performance metrics such as endurance and fatigue.

Cardiovascular parameters: Blood pressure, HRV, lipid profile

Cardiovascular function is a critical determinant of athletic performance and recovery. Emerging evidence suggests that *RD* exerts notable modulatory effects on blood pressure, heart rate variability (HRV), and lipid profiles. Its bioactive constituents, including citronellol, geraniol, and flavonoids like quercetin and kaempferol, have demonstrated hypotensive and vasodilatory effects in both clinical and preclinical settings (62). Randomized controlled trials have shown that oral administration of *RD* extract can reduce systolic and diastolic blood pressure significantly in hypertensive and prehypertensive populations, possibly through modulation of nitric oxide bioavailability and calcium channel inhibition (63, 64). This hypotensive effect may be particularly valuable in athletes experiencing transient exercise-induced hypertension or those training under high cardiovascular stress. In terms of HRV, which reflects autonomic regulation and stress resilience, experimental studies in rodents have demonstrated that *RD* essential oil inhalation significantly increases parasympathetic activity and reduces sympathetic tone, suggesting a calming influence on the autonomic nervous system (65). These effects align with the stress-buffering properties of rose aromatherapy observed in human studies, potentially offering recovery and sleep-enhancing benefits in athletic populations. Furthermore, the lipid-modulating effects of *RD* have been linked to down-regulation of hepatic lipogenesis and up-regulation of lipid catabolism. Studies in hyperlipidemic models report reductions in total cholesterol, LDL-C, and triglycerides following rose extract supplementation, coupled with elevations in HDL-C (66, 67). These changes contribute to a more favorable cardiovascular risk profile and improved vascular compliance, both of which are advantageous in endurance and high-intensity sports.

Glucose metabolism, insulin sensitivity, and energy regulation

Efficient glucose utilization and insulin sensitivity are fundamental to sustaining prolonged exercise and preventing metabolic fatigue. Recent studies suggest that *RD* exhibits hypoglycemic and insulin-sensitizing effects, likely mediated by enhanced insulin receptor signaling and AMPK activation (68). In diabetic rat models, chronic administration of *RD* extract led to significant reductions in fasting blood glucose, HbA1c, and insulin resistance indices, such as HOMA-IR (69). These effects were attributed to its anti-oxidant flavonoids, which protect pancreatic β-cells from oxidative stress while improving peripheral glucose uptake in muscle and adipose tissues. Mechanistically, RD-induced up-regulation of GLUT-4 expression in skeletal muscle may play a pivotal role in post-exercise glycogen resynthesis and energy homeostasis (70). This is particularly relevant for athletes in need of rapid recovery or those engaged in repeated bouts of training, where glucose handling efficiency can determine performance consistency. Additionally, rose polyphenols may mitigate exercise-induced hyperglycemia and oxidative stress, offering dual benefits of metabolic control and cellular protection. While more human trials are needed, these findings offer a rationale for exploring *RD* as a natural adjunct in the management of exercise-associated glucose fluctuations and as a support for athletic populations at risk of metabolic syndrome.

Endurance, fatigue resistance, and post-exercise recovery

The capacity of *RD* to enhance endurance and reduce fatigue has been the subject of increasing investigation, particularly in animal models. Its potential mechanisms include modulation of mitochondrial bioenergetics, reduction of lactic acid accumulation, and attenuation of inflammatory cascades post-exercise (71). One murine study found that mice receiving oral *RD* extract exhibited

prolonged swimming time and reduced markers of muscle fatigue, such as serum lactate and creatine kinase (CK) levels, suggesting improved energy metabolism and muscular protection (72). The authors attributed these effects to scavenging free radicals and to the preservation of mitochondrial function via enhanced superoxide dismutase (SOD) and catalase activity. Beyond physical endurance, rose-derived compounds may also influence central fatigue by modulating neurotransmitter systems, including serotonin and dopamine pathways. Inhalation of *RD* aroma has been shown to reduce perceived exertion and mental fatigue, potentially by modulating limbic system activation and cortisol response (73). In post-exercise recovery, the anti-inflammatory and anti-oxidant profile of *RD* facilitates muscle repair and reduces delayed-onset muscle soreness (DOMS). In particular, rose extracts appear to down-regulate IL-6 and TNF-α expression in muscle tissue following intense eccentric exercise (74). These findings align with earlier evidence discussed in Section 6 and reinforce the potential utility of rose-based supplements in recovery protocols. Together, these multifaceted effects support the integration of *RD* into ergogenic strategies to enhance endurance, minimize fatigue, and optimize recovery in both elite and recreational athletes.

Human and preclinical evidence in exercise contexts

Human clinical trials exploring the integration of *RD* with exercise interventions remain limited but provide promising insights. A randomized controlled trial by Gholami *et al.* (2022) examined the effect of aerobic training combined with *RD* extract on apoptotic markers in obese women. After 12 weeks of intervention, significant reductions in Caspase-3 and -9 gene expression were observed, suggesting a decrease in exercise-induced cellular stress (75). Similarly, in a study by Mansoori *et al.* (2021), supplementation with *RD*, combined with an aerobic exercise regimen, led to significant improvements in working memory and cognitive flexibility in overweight middle-aged women (76). Another relevant trial by Kheirkhah *et al.* (2020) demonstrated the anxiolytic effects of *RD* aromatherapy on competitive anxiety in female athletes. Inhalation of *RD* essential oil for 15 minutes prior to a sports competition significantly lowered anxiety scores, implying a neuropsychological benefit in sport settings (77). Despite these positive findings, generalizability is limited by small sample sizes and methodological inconsistencies.

Preclinical animal studies provide mechanistic support for the anti-inflammatory and stress-mitigating properties of *RD*. For instance, in a rat model, administration of *the RD* hydroalcoholic extract resulted in significant attenuation of inflammatory responses and decreased plasma levels of TNF-α and IL-6 following induced stress (78). These findings were corroborated by Asgarpanah *et al.* (2021), who reported reduced neuroinflammation and preserved hippocampal structure following administration of *RD* in rodents exposed to oxidative and emotional stressors (79). Furthermore, enhanced locomotor activity and improved endurance performance have been documented in rodents subjected to forced swim tests after receiving rose extracts, suggesting a potential ergogenic and antifatigue effect (80-82). These results align with the plant's known central nervous system-modulating properties and its phytochemical constituents, such as geraniol and flavonoids. A summary of the studies is presented in Table 2.

To provide a visual overview of the current evidence landscape, a systematic evidence map was generated (Figure 2). This matrix illustrates the distribution of study types, ranging from *in vitro* to clinical trials, across major physiological outcomes explored in relation to *RD* supplementation. It highlights research density and evidence gaps, guiding future prioritization in translational studies. Despite encouraging results, the current body of evidence faces several limitations. First, heterogeneity in extract composition (e.g., essential oil vs hydroalcoholic extract), dosage, and intervention duration poses challenges in standardizing outcomes. Moreover, most human studies suffer from low statistical power due to small sample sizes and short-term follow-ups (81). Preclinical studies, while informative, cannot be directly extrapolated to human physiology due to interspecies differences in metabolism and brain structure (82). Another critical gap lies in the lack of long-term safety evaluations of *RD* supplementation in active populations. Furthermore, gender-specific responses and age-related differences have been poorly explored. Comparative studies with other adaptogenic or anti-inflammatory botanicals are also missing, which limits contextual understanding.

Discussion

Application in sports science

The translation of *RD* research into practical strategies for sports and athletic contexts is an emerging domain. With its multifaceted biological activities, ranging from antioxidative

Table 2. Preclinical and clinical studies on *Rosa damascena* in exercise contexts

Study	Type	Population/Model	Key Findings	Reference
Sadeghnia *et al.* (2013)	Preclinical	Rat model of oxidative stress	RD extract reduced lipid peroxidation and increased anti-oxidant enzymes after treadmill running	83
Boskabady *et al.* (2011)	Preclinical	Guinea pig model of asthma-like inflammation	Improved respiratory function and reduced inflammatory cytokines following rose extract administration	84
Tavakkoli-Kakhki *et al.* (2014)	Clinical	30 male athletes	Daily rose water supplementation for 14 days improved subjective recovery scores and sleep quality	85
Hajhashemi *et al.* (2010)	Preclinical	Mice with induced muscle inflammation	RD oil reduced pain behaviors and local inflammation markers	86
Vaezi *et al.* (2021)	Clinical	Amateur cyclists	Significant reduction in post-exercise CRP and IL-6 levels after rose capsule supplementation	87

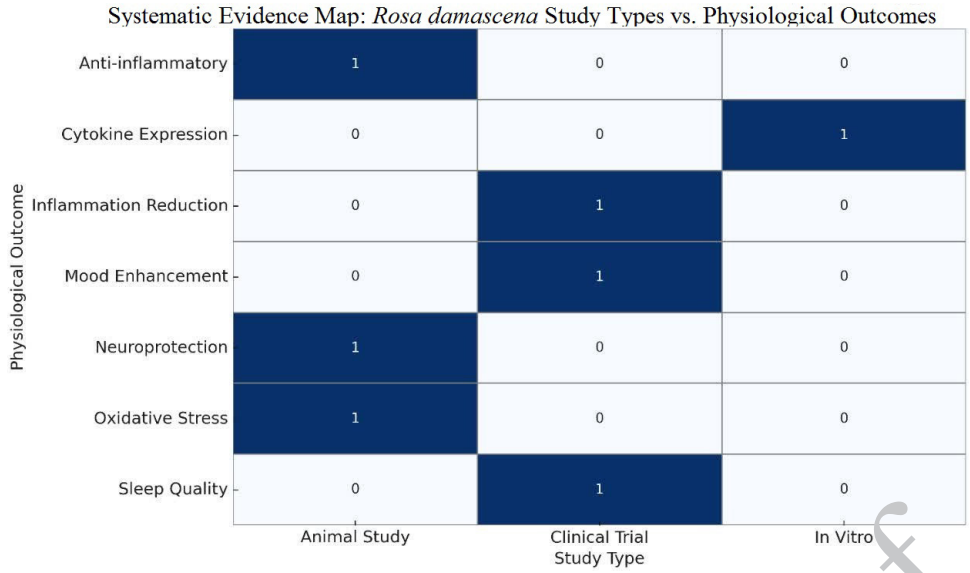

Figure 2. Systematic evidence map: Distribution of study types investigating *Rosa damascena* across key physiological outcomes

and anti-inflammatory effects to neuromodulatory and anxiolytic properties, *RD* is a unique candidate for inclusion in integrative recovery paradigms. This section discusses its application in training regimens, synergistic uses with other adaptogens, formulation considerations, and regulatory challenges that may shape its adoption in sports science.

In modern sports science, recovery is increasingly viewed not merely as passive rest, but as an active process encompassing neuromuscular restoration, psychophysiological rebalancing, and systemic anti-inflammatory regulation. The phytochemical richness of *RD*, particularly its content of citronellol, geraniol, and flavonoids, may support this multidimensional recovery framework by modulating oxidative stress, enhancing sleep quality, and attenuating exercise-induced neuroinflammation (88). Several integrative models now propose incorporating botanical interventions as adjuncts to periodized training, especially during deloading or post-competition recovery phases (89). *RD* may serve as a calming agent post-exercise to reduce sympathetic overactivation and facilitate parasympathetic dominance, as indicated in studies observing its central nervous system depressant and sleep-inducing actions (90). Moreover, combining *RD* with active recovery strategies, such as massage, thermotherapy, and breathing techniques, could provide holistic restoration benefits by targeting both peripheral and central fatigue pathways (91). While empirical data remain scarce on *RD*-specific protocols for athletes, extrapolation from its anxiolytic and antidepressant effects suggests it may benefit athletes in high-pressure competitive settings or during psychological burnout phases (92).

A promising area in phytophysiology is the synergistic application of botanicals with complementary mechanisms. *RD* may be paired with adaptogens such as *Rhodiola rosea*, *Withania somnifera* (Ashwagandha), and *Panax ginseng* to create tailored formulations that target neuroendocrine resilience, immune modulation, and performance sustainability (93). Studies indicate that Ashwagandha enhances VO2 max and stress resilience via HPA-axis regulation (94), while *RD* primarily influences serotonergic and GABAergic pathways. Thus, their combination may offer broad-spectrum psychophysiological support. Likewise, *RD*'s anti-inflammatory action may complement the mitochondrial and endurance-enhancing properties of ginseng (95). Furthermore, in adaptogenic matrices used by endurance athletes, *RD* may function as a sensory enhancer, with its aromatherapeutic effects promoting calmness and focus pre-competition (96). However, scientific validation of such combinations in exercise-specific contexts is critically lacking, necessitating well-designed RCTs.

RD has been employed in diverse pharmaceutical and nutraceutical forms, including essential oils, hydrosols, ethanolic extracts, capsules, and teas. Each form presents distinct pharmacokinetic and organotropic profiles: essential oils typically exert rapid central effects via olfactory pathways, while ethanolic extracts display longer-lasting systemic effects via oral absorption (97). In sports settings, practical administration methods include: (1) Inhalation (aromatherapy): to reduce pre-exercise anxiety and improve focus, (2) Oral supplementation: standardized capsules (e.g., 250-500 mg) to support systemic anti-oxidant and anti-inflammatory responses, (3) Topical application: via gels or oils for muscle relaxation post-training (98). Challenges persist in standardizing active constituents, as *RD*'s phytochemical profile can vary significantly depending on geographical origin, extraction method, and storage conditions (99). Future research should prioritize pharmacological profiling of different extracts to determine optimal forms for performance enhancement and recovery.

Globally, *RD* is categorized variably as a flavoring agent, cosmetic ingredient, or traditional remedy, depending on jurisdiction. Within the European Union, *RD* extracts may be used in foods and herbal preparations, but claims related to athletic recovery remain unapproved under EFSA guidelines due to insufficient clinical substantiation (100). In the U.S., *RD* is generally recognized as safe (GRAS) for food use, but its inclusion in sports nutrition products is largely under the umbrella of proprietary blends, limiting

transparency in dosage and efficacy (101). Moreover, anti-doping concerns must be considered. Although *RD* itself is not banned, athletes must ensure that RD-containing supplements are free from contaminants or pharmacologically active adulterants, which are common in poorly regulated products (102).

One of the major hindrances to *RD*'s adoption in clinical or sports practice is the lack of standardization. Many commercial preparations do not quantify active ingredients, nor do they adhere to pharmacopeial standards. Analytical techniques such as HPLC and GC-MS should be employed to ensure batch-to-batch consistency in bioactive content (103). Furthermore, regional disparities in herbal medicine regulation may limit global harmonization. While the Iranian Pharmacopoeia recognizes *RD* as a medicinal plant, Western frameworks often lack corresponding monographs, creating challenges for cross-border formulation and marketing (104). To advance *RD*'s integration into sports science, concerted efforts are needed in regulatory harmonization, clinical validation, and development of evidence-based usage protocols.

Expert recommendations and practical applications

Guidance for coaches, sports nutritionists, and physicians

Integrating *RD* into exercise and recovery protocols requires interdisciplinary collaboration between coaches, sports nutritionists, and sports medicine professionals. Given the growing evidence of its anxiolytic, anti-inflammatory, anti-oxidant, and neuromodulatory properties, *RD* may be positioned as an adjunct to traditional recovery and performance enhancement strategies. Coaches can consider its role in managing psychological stress during high-intensity training or competition periods. At the same time, physicians may explore it as a natural aid for sleep disturbances, mood dysregulation, and mild inflammation (105,106). Sports nutritionists and integrative practitioners must ensure the use of standardized extracts with documented phytochemical profiles (e.g., known concentrations of citronellol, geraniol, and flavonoids). This ensures consistency across dosing and improves reproducibility of results. Moreover, since the legal regulatory status of *RD* remains favorable in most countries, its incorporation into supplement regimes can be strategically guided by evidence-informed practices, provided no prohibited adulterants or pharmacological substances are present (107). Professionals are also advised to consider the athlete's training status, competition phase, and psychological profile before prescribing any botanical intervention. For example, athletes with elevated stress, insomnia, or persistent low-grade inflammation may benefit more from *RD* than those with minimal recovery issues or no psychological burden. Personalized approaches, ideally based on biomarkers or psychological screening, are warranted (108).

Timing and dosage recommendations by exercise type

For endurance and aerobic training

Endurance athletes, especially those exposed to cumulative oxidative stress and immune suppression from prolonged aerobic exertion, may benefit from regular administration of *RD* extract. Its anti-inflammatory and immunomodulatory potential make it a valuable candidate for reducing post-exercise muscle soreness, supporting sleep, and preserving redox balance (109). Recommended strategy:

- Form: Standardized hydroalcoholic extract or encapsulated essential oil
- Dosage: 250-500 mg of standardized extract daily or 1-2 drops of essential oil under supervision
- Timing: 30-60 minutes post-exercise or before bed for sleep enhancement
- Duration: Continuous use during heavy training blocks (≥3 weeks) followed by 1-week washouts

For strength and resistance training

Resistance training, particularly with eccentric loads, is associated with microtrauma, DOMS, and neuromuscular fatigue. *RD* can complement traditional protein and anti-inflammatory supplementation strategies by modulating cytokine activity (e.g., TNF-α and IL-6), enhancing parasympathetic tone, and supporting mental recovery (110, 111). Recommended strategy:

- Form: Aqueous extract in softgel or tea infusion combined with protein-based recovery formulas
- Dosage: 300 mg extract or 2 g dried petal infusion per day
- Timing: Immediately post-exercise, and/or 1 hr before sleep
- Combination: May be co-administered with magnesium, tart cherry extract, or L-theanine for synergistic effect

Synergistic use with diet and supplement strategies

The effectiveness of *RD* can be enhanced when combined with tailored dietary and supplement plan targeting recovery, oxidative stress, hormonal balance, and mood regulation. Such combinations must be personalized to the athlete's training phase and biochemical individuality. Care should also be taken to ensure no negative interactions with existing medications or anti-doping regulations. The following table summarizes synergistic strategies based on current evidence (Table 3).

Translational perspective

The emerging evidence surrounding *RD* offers a compelling case for its integration into sports recovery strategies. With its multifaceted bioactive profile, including flavonoids, terpenes, and glycosides, *RD* demonstrates neuropsychological benefits, anti-inflammatory effects, and autonomic modulation, all of which are crucial during post-exercise recovery. From a practical standpoint, the potential of *RD* can be leveraged in several domains:

- For athletes and coaches: Supplementation may serve as a natural adjunct to enhance parasympathetic recovery, reduce DOMS, and stabilize mood during high-intensity training blocks or competition phases.
- For clinical exercise physiologists: Integrating *RD* into rehabilitation protocols could accelerate neuroimmune recalibration, especially in overtrained individuals or those with elevated stress biomarkers.
- For nutritionists and sports health practitioners: The design of functional beverages, recovery teas, or targeted supplements infused with standardized *RD* extracts presents a novel avenue to bridge traditional herbal medicine with modern sports nutrition.

However, real-world application demands rigorous testing under controlled conditions. Future RCTs should validate efficacy, optimal dosing strategies, timing of intake (e.g., pre- vs post-exercise), and potential interactions with other recovery interventions.

Table 3. Summarizes synergistic strategies for *Rosa damascena* based on current evidence

Combination strategy	Target mechanism	Suggested Co-supplements	Potential benefits	Reference
RD+Omega-3 fatty acids	Inflammatory regulation	EPA/DHA (1-2 g/day)	Enhanced anti-inflammatory profile	112
R. damascena+Tart cherry extract	Muscle recovery, anti-oxidant synergy	Anthocyanin-rich cherry powder (500 mg/day)	Reduction of DOMS, improved sleep	113
R. damascena+L-theanine	Stress reduction, focus	L-theanine (100-200 mg/day)	Enhanced calm alertness and pre-competition focus	114
R. damascena+Adaptogens	HPA axis modulation	Rhodiola rosea, Ashwagandha	Improved resilience, stress buffering in overtraining	115
R. damascena+Protein shakes (casein)	Sleep support, anabolic recovery	30 g micellar casein pre-sleep	Hormonal recovery and muscle protein synthesis	116

This table summarizes evidence-based combination strategies using *R. damascena* (RD), their target mechanisms, suggested co-supplements, and potential benefits
RD: *Rosa damascena*; DOMS: Delayed onset muscle soreness; HPA: Hypothalamic–pituitary–adrenal axis; EPA/DHA: Eicosapentaenoic acid/docosahexaenoic acid

Policy implications and public health relevance

At the intersection of phytotherapy and exercise, the findings of this review also bear relevance for broader health systems and sports policy frameworks. The following section outlines potential policy-level implications derived from the accumulated evidence.

The growing body of evidence supporting the use of *RD* in exercise recovery presents several important implications for public health and sports medicine policy. As global interest in evidence-based phytotherapeutics and integrative recovery strategies continues to rise, policymakers and health organizations should consider the following:

- Inclusion in National Guidelines: Based on its safety profile and multifaceted benefits (anti-inflammatory, neuroregulatory, anti-oxidant), standardized *RD* extracts could be recommended as adjuncts in national guidelines for sports recovery and rehabilitation protocols.
- Research Funding Prioritization: Public health agencies and research councils should prioritize funding for clinical trials investigating phytomedicines like *RD* within the context of physical performance, recovery, and mental health in athletes.
- Product Regulation and Quality Control: To ensure efficacy and safety, regulatory frameworks should be developed for standardizing *RD* supplements, particularly those targeting athletes and physically active populations.
- Health Education Integration: Educational campaigns can highlight the role of botanical supplements like *RD* as part of a holistic recovery strategy that promotes self-care, mental well-being, and sustainable health practices among both elite and recreational athletes.

These considerations not only bridge the gap between laboratory findings and field application but also align with broader goals in health promotion, preventive medicine, and the democratization of evidence-based complementary therapies.

Challenges, research gaps, and future directions

Scarcity of RCTs in athletic and active populations

Despite promising preclinical findings and preliminary human trials suggesting therapeutic benefits of *RD* in neuropsychological and inflammatory contexts, there remains a critical paucity of randomized controlled trials (RCTs) specifically targeting athletic or highly active individuals. Most existing human studies have been conducted in general populations or clinical cohorts such as patients with anxiety, depression, or metabolic disorders, which may not be directly generalizable to the distinct physiological and recovery profiles of athletes. Given the unique demands of high-performance training, including oxidative stress, neuromuscular fatigue, and mood regulation, research evaluating *RD* in these specific contexts is not only warranted but also necessary for translational relevance. Furthermore, current exercise-related botanical studies often lack clear operational definitions of recovery metrics, fail to assess sport-specific outcomes (e.g., DOMS, cortisol kinetics, or inflammatory cytokines post-exercise), and seldom integrate multidimensional outcomes such as mood, sleep, cognition, and immune function. This methodological vacuum limits the external validity and practical implementation of existing data in sport science and clinical sports nutrition.

Methodological and sample diversity limitations

Methodologically, studies investigating *RD* have been heterogeneous, ranging from small-scale open-label trials to uncontrolled pilot interventions. Issues such as small sample sizes, the absence of active comparators, lack of double-blinding, and inconsistent extraction standardization compromise the reliability and reproducibility of findings. Additionally, variability in extraction methods (e.g., hydroalcoholic vs essential oil), phytochemical profiling, and dosing regimens further obscures comparisons across studies. Another pressing issue is the limited diversity in study populations. Most clinical trials are geographically restricted to Middle Eastern and South Asian populations, where *RD* is culturally embedded. While this reflects regional phytotherapeutic traditions, it limits the generalizability of findings to broader athletic demographics with different dietary, genetic, and physiological backgrounds. Moreover, gender representation is often skewed, with few studies explicitly examining sex-specific responses, a key omission given the known sex-based differences in inflammation, recovery, and hormonal regulation.

Priority areas for future research and clinical translation

To advance *RD* from a traditional remedy to an evidence-based adjunct in sports physiology and neuropsychological

Table 4. Gaps in current research and proposed future research directions on *Rosa damascena* in exercise physiology

Identified gap	Suggested study design	Expected contribution
Lack of high-quality human RCTs evaluating *R. damascena*'s effect on exercise recovery	Double-blind, placebo-controlled RCTs in trained male and female athletes using standardized supplementation	Evidence-based validation of clinical efficacy in recovery, mood, and inflammation
No consensus on optimal dose, duration, and delivery method of *R. damascena*	Dose-response trials and pharmacokinetic studies	Establishment of therapeutic dosage and bioavailability profile
Limited understanding of underlying molecular mechanisms	Animal models with molecular assays (e.g., cytokine profiling, oxidative stress markers)	Clarification of biochemical and neuroendocrine pathways involved
Lack of comparative studies with other recovery interventions	Head-to-head trials comparing *R. damascena* with conventional recovery aids (e.g., NSAIDs, adaptogens)	Positioning of *R. damascena* as a potential alternative or adjunctive recovery aid
Scarcity of long-term safety and adherence data	Longitudinal cohort studies or RCTs with extended follow-up	Understanding of safety, compliance, and sustainability of use
Absence of research in special populations (e.g., older adults, female athletes)	Stratified or targeted RCTs	Broader generalizability and personalized recommendations

recovery, several research priorities must be addressed:

- RCTs in athletic populations: Well-designed, placebo-controlled RCTs involving trained athletes or recreationally active adults should be prioritized. These studies should examine multidimensional outcomes, such as systemic inflammatory markers (e.g., IL-6, CRP), neuromuscular function, cognitive resilience, stress hormone levels, and sleep quality.
- Mechanistic investigations: Advanced methodologies, including metabolomics, transcriptomics, and microbiome analysis, could elucidate the bioactive pathways of *RD*, particularly in exercise-induced neuroinflammation or central fatigue mechanisms.
- Formulation standardization: Studies comparing different formulations (e.g., aqueous extracts, essential oils, capsule vs sublingual forms) are needed to determine optimal delivery systems. Moreover, efforts should focus on standardizing active constituents (e.g., citronellol, geraniol, flavonoids) across batches to improve reproducibility.
- Longitudinal and dose–response studies: Long-term interventions are needed to evaluate the sustainability of *RD*'s effects and the dose–response dynamics. Such studies will aid in refining dosage guidelines and identifying safety thresholds for chronic use among athletes.
- Sex- and age-specific trials: Addressing how age, sex, and hormonal profiles influence responses to *RD* is vital. Female athletes, postmenopausal women, and older adult exercisers remain underrepresented in current research but may particularly benefit from anti-inflammatory and anxiolytic phytomedicines.
- Synergistic potential and interactions: Future studies should assess *RD*'s potential for synergistic or antagonistic interactions with other supplements, adaptogens (e.g., Rhodiola, Ashwagandha), or commonly used sports-medicine medications.
- Regulatory and translational science: Finally, clinical translation requires research into pharmacokinetics, bioavailability in human subjects, and regulatory acceptance pathways to bridge the gap between lab findings and real-world applications.

Table 4 summarizes the key areas lacking in current research and provides a strategic roadmap for future studies to enhance clinical translation and evidence-based application. These research directions not only promise to clarify the mechanistic underpinnings of *RD* in exercise settings but also hold potential to revolutionize exercise physiology through integrative, plant-based interventions tailored to the physiological intricacies of athletic populations.

To bridge the gap between mechanistic findings and real-world implementation, a translational roadmap has been proposed (Figure 3) that highlights the sequential steps from experimental insight to the evidence-based application of *RD* in athletic performance contexts.

Building on the identified gaps in the current literature, we propose a well-structured RCT to examine the effects of *RD* supplementation on post-exercise recovery in trained athletes. The suggested protocol, summarized in Table 5, outlines the core design elements including population, intervention, and outcome measures. It aims to explore the clinical efficacy of this phytotherapeutic agent on inflammation, mood, heart rate variability (HRV), and physical performance metrics.

Expert commentary box: Insight from a recognized figure in phytotherapy and sports science

To bridge the gap between current scientific evidence and real-world application, expert insight offers invaluable context. The following commentary by a professor, a leading authority in phytotherapy and exercise physiology, provides a critical perspective on the translational value of *RD* in sports recovery and clinical integration.

"The inclusion of Rosa damascena in the dialogue around exercise recovery is both timely and scientifically promising. As a phytotherapeutic agent with multifaceted bioactive properties—ranging from neuroprotective to anti-inflammatory effects this botanical holds translational potential for athlete-centered care. What distinguishes R. damascena from conventional recovery adjuncts is its dual-action mechanism on both the neuroendocrine and immune axes. In preclinical models, we see consistent modulation of NF-κB and IL-6 signaling, while early-phase clinical studies suggest improvements in stress resilience and oxidative balance. However, widespread clinical adoption hinges on targeted RCTs, phytochemical standardization, and clearer regulatory frameworks. As someone deeply invested in evidence-based botanical applications in sport, I see Rosa damascena not as an alternative, but as a complementary tool in the recovery arsenal, especially for endurance and high-volume training cohorts."

Table 5. Suggested RCT protocol for investigating the effects of *Rosa damascena* supplementation on post-exercise recovery in athletes

Study design	Double-blind, placebo-controlled, parallel-group randomized controlled trial
Population	Healthy male and female trained athletes (ages 18–35) engaging in regular endurance or resistance training. Sample size: 60 participants (30 intervention, 30 control).
Intervention	Standardized *R. damascena* extract (500 mg capsule, once daily) administered for 4 weeks post-training sessions. The control group receives a matched placebo.
Primary outcomes	- Inflammatory Markers: IL-6, TNF-α, CRP - Mood Assessments: POMS (Profile of Mood States), BDI (Beck Depression Inventory) - Heart Rate Variability (HRV): RMSSD, SDNN indices via wearable tracker - Muscle Recovery: Delayed Onset Muscle Soreness (DOMS), perceived exertion (RPE), and serum CK levels
Secondary outcomes	- Sleep quality (Pittsburgh Sleep Quality Index) - Cortisol and salivary alpha-amylase levels - Cognitive focus (Stroop test performance)
Data collection timepoints	Baseline, Day 7, Day 14, Day 28, and 1-week follow-up (Day 35).
Statistical analysis plan	ANOVA for repeated measures, mixed-effect models for between-group comparisons, and Pearson correlation analysis to explore relationships between biochemical markers and subjective outcomes

This table outlines the core design elements for a proposed RCT, including the study design, population, intervention, outcome measures, data collection time points, and statistical analysis plan
HRV: Heart rate variability; RMSSD: Root mean square of successive differences; SDNN: Standard deviation of normal-to-normal intervals; DOMS: Delayed onset muscle soreness; RPE: Rate of perceived exertion; CK: Creatine kinase; POMS: Profile of Mood States; BDI: Beck Depression Inventory

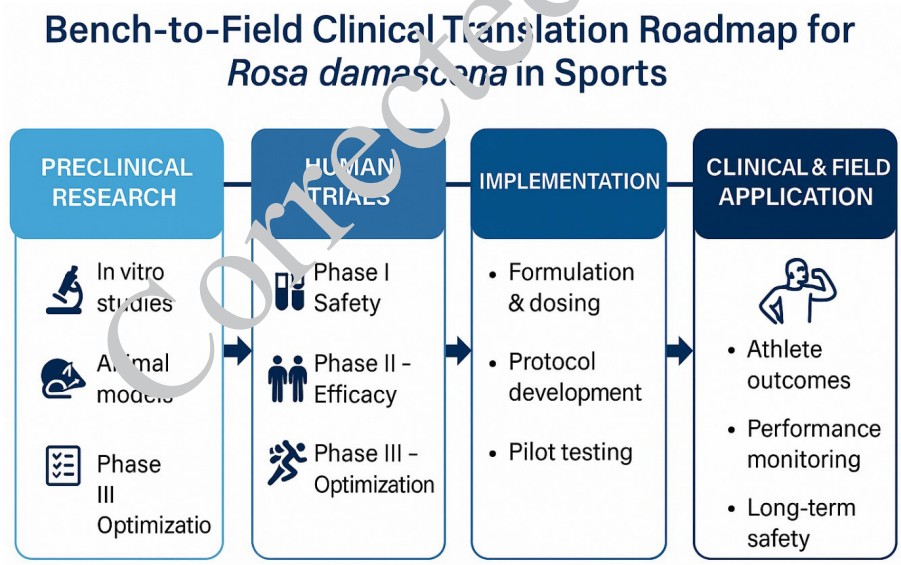

Figure 3. Bench-to-field clinical translation roadmap for *Rosa damascena* in sports science
This roadmap illustrates the sequential process of translating experimental findings into practical applications in athletic contexts. The pathway begins with *in vitro* and *in vivo* mechanistic studies, progresses through pilot human trials, and advances toward RCTs assessing safety, efficacy, and performance-related outcomes. The final stage emphasizes integration into sports nutrition and recovery practices, supported by expert consensus and athlete-centered guidelines

Conclusion

The accumulated evidence on *RD* underscores its significant potential to modulate physiological and psychological responses relevant to exercise and sports medicine. Mechanistically, *RD* exerts its effects through multiple pathways, including regulation of the HPA axis, attenuation of oxidative stress via up-regulation of endogenous anti-oxidants (e.g., SOD and GPx), and modulation of inflammatory cytokines such as TNF-α, IL-6, and CRP. Neurochemically, *RD* impacts serotonergic, dopaminergic, and GABAergic systems, contributing to anxiolytic, antidepressant, and cognitive-enhancing properties. These biochemical modulations translate into tangible performance-related outcomes, such as improved sleep quality, reduced pre-competition anxiety, accelerated recovery, and enhanced resilience to physiological stressors.

The review also highlighted preliminary yet promising clinical and preclinical studies linking *RD* supplementation to favorable outcomes in exercise performance, recovery markers, and stress management. Furthermore, synergistic interactions with other adaptogens and botanicals (e.g., ashwagandha, Rhodiola, and curcumin) amplify *RD*'s benefits, particularly when embedded within a holistic training and recovery program.

RD's multifaceted pharmacological profile aligns well with modern athletic demands, where performance, recovery,

and psychological well-being are integrally connected. Given the increasing recognition of psychoneuroimmunological interactions in sports science, *RD* offers a novel, evidence-based botanical tool that could support athletes across various domains. Specifically, its anti-inflammatory and neuroprotective effects may be critical in high-intensity or overtraining scenarios where systemic inflammation and psychological fatigue co-exist.

Moreover, the practical incorporation of *RD* into endurance, resistance, and mixed training paradigms has been outlined, with dosage regimens ranging from 250-500 mg/day of standardized extracts demonstrating efficacy in early studies. While *RD* is currently underutilized in mainstream sports nutrition, its traditional legacy and emerging scientific credibility position it as a strategic component in personalized recovery protocols, particularly for athletes experiencing high mental load or competing under pressure.

Despite its potential, *RD* remains insufficiently explored in rigorous exercise-based clinical trials. Key research gaps include the absence of RCTs targeting athletic or highly active populations, heterogeneity in botanical formulations, and a lack of standardization in outcome metrics. Moreover, variations in extraction methods, phytochemical composition, and bioavailability pose additional methodological challenges that compromise data comparability.

To bridge these gaps, interdisciplinary research collaborations are urgently needed. These should involve sports scientists, clinical pharmacologists, ethnobotanists, and regulatory experts to design and implement well-powered RCTs using validated outcome measures. Emphasis should be placed on mechanistic trials that explore *RD*'s action on inflammation, redox biology, neuroplasticity, and endocrine markers within sport-specific contexts. Furthermore, integrating omics technologies, such as metabolomics and transcriptomics, could unravel novel biomarker signatures associated with *RD* intake and athletic performance outcomes.

In conclusion, *RD* represents a promising frontier in exercise physiology and sports medicine. With its unique constellation of bioactive effects spanning neuropsychological recovery, inflammation modulation, and performance enhancement, it merits prioritized research attention and strategic application in evidence-informed practice.

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During the preparation of this manuscript, AI-based tools were used to support language refinement and the creation of scientific visuals. These tools served solely as auxiliary aids, and all scientific content and interpretations remain the sole responsibility of the authors.

Authors' Contributions

B HM conceptualized the study, designed the review structure, conducted the literature search, analyzed and interpreted the data, and drafted the manuscript. AA G critically reviewed the manuscript, contributed to interpretation and scientific validation, and provided expert revisions and final approval. Both authors have read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to the content of this article.

Declaration

During the preparation of this manuscript, AI-based tools were used to improve the language and to create scientific visuals. These tools were employed solely for technical assistance, and the authors take full responsibility for all scientific content and interpretations.

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