Al-Rafidain J Med Sci. 2026;11(2):256-261.
DOI: https://doi.org/10.54133/ajms.v11i2.3243

AJMS

Research Article

Online ISSN (3219-2789)

The Effects of Red Ginger (Zingiber officinale var. rubrum) Essential Oil-Based Massage and Aromatherapy on Oxidative Stress and Inflammatory Biomarkers Related to Athlete Recovery

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Received: 5 July 2026; Revised: 26 August 2026; Accepted: 1 September 2026

Abstract

Background: Recovery techniques are essential in sports science for mitigating oxidative damage and inflammation resulting from exercise. To effectively mitigate oxidative stress and inflammation, it is crucial for the body to acquire vital elements that augment the benefits of massage therapy, such as red ginger essential oil. ***Objective***: To assess and analyze the impact of massage treatments and aromatherapy with red ginger essential oil (*Zingiber officinale* var. rubrum) on antioxidants and inflammatory biomarkers in athletes. ***Methods***: Twenty male cricketers aged 20-22 were allocated into two groups for the study; group 1 received massage and aromatherapy with a massage oil after training, while group 2 athletes received massage and aromatherapy with red ginger essential oil. Blood tests for catalase and interleukin-8 provided data. ***Results***: The research results reveal a notable disparity in catalase levels across groups 1 and 2, with group 2 having an average higher level (12.59±0.22 *vs*. 11.31±0.94 U/ml; $p<0.0001$). Group 2 had a significantly lower average level of interleukin-8 (6.19±2.49 *vs*. 16.38±6.05 pg/ml; $p=0.035$), indicating a significant difference in levels between groups 1 and 2. ***Conclusions***: The application of red ginger essential oil to augment the efficacy of massage therapy and aromatherapy aims to eradicate free radicals and inflammation in athletes, evidenced by heightened catalase antioxidant activity and diminished interleukin-8 inflammatory activity.

Keywords: Aromatherapy; Catalase; Interleukin-8; Massage; Red ginger.

تأثيرات التدليك بالزنجبيل الأحمر والعلاج بالزيوت العطرية على الإجهاد التأكسدي والمؤشرات الالتهابية المرتبطة بتعافي الرياضيين

الخلاصة

الخلفية: تقنيات التعافي ضرورية في علم الرياضة للتخفيف من التلف التأكسدي والالتهابات الناتجة عن التمرين. للتخفيف من الإجهاد التأكسدي والالتهاب بفعالية، من الضروري أن يكتسب الجسم العناصر الحيوية التي تعزز فوائد العلاج بالتدليك، مثل زيت الزنجبيل الأحمر العطري. **الهدف**: تقييم وتحليل تأثير علاجات التدليك والعلاج بزيت الزنجبيل الأحمر العطري على مضادات الأكسدة والمؤشرات الالتهابية لدى الرياضيين. **الطرائق**: تم تقسيم عشرين لاعب كريكيت ذكور تتراوح أعمارهم بين 20 و22 عاما إلى مجموعتين للدراسة؛ تلقت المجموعة الأولى تدليكا وعلاجا بزيت التدليك بعد التدريب، بينما تلقى الرياضيون من المجموعة الثانية التدليك والعلاج بزيت الزنجبيل الأحمر. وفرت تحاليل الدم للكاتالاز والإنترلوكين-8 بيانات الدراسة. **النتائج**: تكشف نتائج البحث عن تفاوت ملحوظ في مستويات الكاتالاز عبر المجموعتين 1 و2، حيث كان لدى المجموعة 2 متوسط مستوى أعلى (12.59±0.22 مقابل 11.31±0.94 U/ml؛ $p<0.0001$). كان لدى المجموعة 2 مستوى متوسط أقل بشكل ملحوظ من الإنترلوكين-8 (6.19±2.49 مقابل 16.38±6.05 pg/ml؛ $p=0.035$)، مما يشير إلى فرق كبير في المستويات بين المجموعتين 1 و2. **الاستنتاجات**: يؤدي استخدام زيت الزنجبيل الأحمر العطري لتعزيز فعالية العلاج بالتدليك والعلاج بالزيوت العطرية إلى القضاء على الجذور الحرة والالتهابات لدى الرياضيين، كما يتضح من زيادة نشاط مضادات الأكسدة للكاتالاز وانخفاض النشاط الالتهابي للإنترلوكين-8.

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Article citation: Harahap NS, Sinaga FA, Pane YS, Gultom S, Sibuea FM. The Effects of Red Ginger (Zingiber officinale var. rubrum) Essential Oil-Based Massage and Aromatherapy on Oxidative Stress and Inflammatory Biomarkers Related to Athlete Recovery. *Al-Rafidain J Med Sci*. 2026;11(2):256-261. doi: https://doi.org/10.54133/ajms.v11i2.3243

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INTRODUCTION

Multiple elements, including physical condition, technique, and strategy, affect athletic performance. Physical training primarily emphasizes the comprehensive development of an athlete's physical condition and constitutes a fundamental part of the training process aimed at attaining optimal performance. Athletes pur-sang excellence must participate in intensive training and continuous, repetitive practice. This scenario leads to a 10–20 fold increase in oxygen consumption compared to resting states, resulting in mitochondrial metabolism, xanthine oxidation, and leukocyte activation, which can trigger the production of reactive oxygen species (ROS) [1,2]. The increased production of reactive oxygen species (ROS) correlates with an intensified systemic inflammatory response, which aggravates fatigue, delayed onset muscle soreness (DOMS), and vulnerability to musculoskeletal injuries, ultimately impairing sports performance. Physiological levels of reactive oxygen species (ROS) facilitate signaling for exercise adaptation; nevertheless, excessive ROS production may result in oxidative stress. Oxidative stress refers to an imbalance between the synthesis of reactive oxygen species (ROS) and endogenous antioxidants, resulting in an excess of oxidants that disrupts signaling and redox regulation and causes molecular damage [3]. Oxidative stress can adversely affect cell membranes, proteins, lipids, and the DNA of muscle cells [4-6]. Oxidative stress induces inflammation marked by the release of inflammatory

mediators, including interleukin 8 (IL-8), recognized as an inflammatory biomarker [7,8]. This condition is a significant factor influencing the quality of an athlete's recuperation. However, athletes often overlook the elements of oxidative stress and inflammation that result from rigorous and sustained training. The body possesses an intrinsic antioxidant defense system to regulate reactive oxygen species (ROS), one component of which is the enzyme catalase. Catalase is an antioxidant that catalyzes the decomposition of hydrogen peroxide (H_2O_2) into water and oxygen, thus averting further oxidative damage. The reduction in catalase activity following high-intensity exercise signifies a disparity between free radical generation and the body's antioxidant capability. The rise in catalase following the intervention indicates an improvement in the body's antioxidant defense mechanism against post-exercise reactive oxygen species buildup [9]. High-intensity exercise induces oxidative stress and elevates the body's inflammatory response due to muscle injury. Inflammation is a physiologic response resulting from tissue damage induced by intense physical exertion [10]. Fatigue and myalgia indicate an inflammatory response, leading to diminished muscular strength and thus worse sports performance [11,12]. Prior studies indicate that intense physical activity enhances the synthesis of inflammatory cytokines [13]. Interleukin-8 (IL-8) is a pro-inflammatory cytokine and chemokine secreted in response to muscle microdamage. IL-8 is a cytokine involved in leukocyte activation, neutrophil motility, and muscle tissue inflammation following treatment. The athletes' increased IL-8 levels are associated with neutrophil infiltration into the tissue, resulting in inflammation and amplifying the body's response to inflammatory stimuli [14]. Although IL-8 plays a physiological role in angiogenesis and muscle remodeling, elevated levels can extend inflammation, exacerbate delayed-onset muscle soreness (DOMS), and impede athletic recovery. Recovery techniques are essential in sports science for mitigating oxidative damage and inflammation resulting from exercise. Massage therapy is a commonly employed healing technique. Massage is the mechanical manipulation of soft tissues with rhythmic pressure, intended to yield physiological effects such as improved blood circulation, enhanced lymphatic flow, stimulation of the neurological system, and increased muscular relaxation [15,16]. Massage is known to alter inflammatory pathways and enhance circulatory function; hence, it facilitates post-exercise recovery. To effectively mitigate oxidative stress and inflammation, it is crucial for the body to acquire vital elements that augment the benefits of massage therapy, such as red ginger essential oil. Massage is frequently integrated with aromatherapy, utilizing herbal essential oils. Aromatherapy functions by the transdermal absorption of active substances and the stimulation of the olfactory system, which is linked to the limbic system, thereby yielding relaxing, analgesic, and anti-inflammatory benefits [17,18]. Red ginger is an herbal plant with potential as a natural rehabilitation agent. Red ginger is recognized for its bioactive constituents, including gingerol, shogaol, zingerone, zingiberene, flavonoids, and other phenolic compounds, which exhibit potent antioxidant and anti-inflammatory properties. The red ginger plant was selected due to its accessibility as a widely cultivated herbal species in home gardens, facilitating the production of phytopharmaceuticals rooted in local culture [19,20]. The biological efficacy of ginger arises from the presence of both volatile and non-volatile molecules. The volatile constituents in ginger are essential oils characterized by a unique fragrance, comprising sesquiterpenes and monoterpenoids. In contrast, the non-volatile constituents impart ginger's pungent flavor, comprising gingerol, shogaol, zingerone, and paradol [21]. The chemicals gingerol and shogaol in red ginger essential oil are recognized for their ability to inhibit inflammatory pathways, including nuclear factor-kappa B (NF-κB), reduce the synthesis of prostaglandins and leukotrienes, and bolster the body's antioxidant defense mechanisms. The effects of red ginger essential oil suggest its potential utility as a sports recovery method to mitigate inflammation and oxidative stress following exercise. Prior studies indicated that massage with red ginger essential oil may alleviate pain, promote relaxation, and boost many physiological parameters following intense exercise. Investigations into the impact of the synergistic use of massage and aromatherapy with red ginger essential oil on particular biomarkers of oxidative stress and inflammation, including catalase and interleukin-8 levels in athletes, remain notably scarce [22].

METHODS

Study design and setting

This study used a two-group posttest-only control design. The study was carried out at the multipurpose field and the training facilities of Universitas Negeri Medan, Indonesia, from July to September 2025. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants before enrollment.

Participants

The research participants comprised 20 male cricket sportsmen, aged 20 to 22 years, who were non-smokers and consented to participate in the study by signing a consent form. The research participants were randomly assigned to two groups: Group 1 consisted of athletes who received massage therapy and aromatherapy with a massage oil devoid of red ginger essential oil post-training; Group 2 comprised athletes who received massage therapy and aromatherapy with a massage oil containing red ginger essential oil post-training.

Anthropometric measurements

The anthropometric parameters of the research participants include age (years), weight (kg), height (cm), Body Mass Index (BMI) (kg/m²), systolic blood

pressure (mmHg), and diastolic blood pressure (mmHg).

Physical activity

The physical activity program, massage therapy, and aromatherapy are implemented at the Universitas Negeri Medan Multipurpose Field over a period of 4 weeks, occurring 3 times weekly, with each physical exercise session lasting 60 minutes from 07:00 to 08:00 WIB. Following physical activity, massage therapy and inhalation aromatherapy are administered concurrently for 30 minutes between 08:00 and 10:00 WIB.

Massage and aromatherapy

The individual is positioned supine on the massage table in a heated environment (27°C). This study employs the massage techniques of effleurage, tapotement, and petrissage, which can stimulate, soften, and relax muscles. The massage targets the back, hamstrings, and calves. Massage treatment is conducted by a certified professional referred to as a "masseur." Inhaling the essential oils of red ginger mixed with hot water is the most effective way to use aromatherapy. The athlete inhales essential oil steam directly through the nose during the massage. Throughout the trial, participants were instructed to refrain from consuming antioxidant compounds, including vitamin C and vitamin E, and to avoid any physical activities outside of the designated training regimen. Data were acquired from blood testing, specifically the analysis of catalase levels and interleukin-8.

Blood analysis

The blood sample for analysis was obtained from the athlete's cubital vein, collected in a BD Vacutainer K2E (EDTA) tube, centrifuged at 1700 rpm for 10 minutes, and subsequently transferred into a 1.5 mL Eppendorf tube. Briefly, 10 µL of each sample or positive control was added to a 96-well plate. The catalase reaction was initiated by adding 90 µL of freshly prepared 50 µM H_2O_2 substrate and incubated for 30 min at room temperature. A hydrogen peroxide standard curve was prepared according to the manufacturer's instructions. Subsequently, 100 µL of Detection Reagent (Assay Buffer, Dye Reagent, and HRP Enzyme) was added to each well, followed by incubation for 10 min. Absorbance was measured at 570 nm using a microplate reader. Serum IL-8 levels were measured using a quantitative sandwich ELISA (Human Interleukin-8 ELISA Kit, Catalogue No. MBS703104) according to the manufacturer's instructions. Briefly, samples and standards were added to antibody-coated microplate wells, followed by incubation with a biotin-conjugated anti-IL-8 antibody and HRP-conjugated avidin. After substrate addition and reaction termination, absorbance was measured using a microplate reader, and IL-8 concentrations were calculated from the standard curve.

Ethical Considerations

The research concerning human utilization has adhered to all pertinent national regulations and institutional policies, complied with the principles of the Declaration of Helsinki, and received approval from the Ethics Committee for the Implementation of Health Research, Faculty of Medicine, University of North Sumatra, Indonesia (approval No. 858/KEPK/USU/2025).

Statistical methods

Data were analyzed using SPSS version 22.0, with statistical significance set at $p < 0.05$. Data normality was assessed using the Kolmogorov–Smirnov test and homogeneity using Levene's test. Normally distributed data were analyzed with the independent t-test, whereas non-normally distributed data were analyzed using the Mann–Whitney U test to compare differences between the two groups.

RESULTS

Table 1 indicates that the two research subject groups, group 1 and group 2, exhibit comparable physiological features in terms of age, weight, height, BMI, systolic blood pressure, and diastolic blood pressure. This signifies the absence of substantial differences ($p > 0.05$), indicating that all research subjects are homogeneous.

Table 1: Characteristics of the participants (n=10 in each group)

Variable	Group	*Result*	*p-value*
Age (years)	group 1	20.5±0.483	0.501
	group 2	20.4±0.483	
Body weight (kg)	group 1	59.1±0.699	0.20
	group 2	57.1±2.799	
Height (cm)	group 1	163.2±5.147	0.101
	group 2	161.2±1.578	
Body Mass Index (kg/m^2)	group 1	20±2.71	0.406
	group 2	21.9±1.16	
Systolic blood pressure (mmHg)	group 1	118±0.0	0.283
	group 2	118±0.0	
Diastolic blood pressure (mmHg)	group 1	80±0.0	0.555
	group 2	79±0.0	

Values are presented as mean±SD. Note: The data are homogeneous ($p>0.05$).

Table 2 displays the study's findings, which indicate that group 2 had a higher average catalase level than group 1, with a p-value of <0.0001 from an independent t-test (12.59 U/ml ± 0.22 *vs*. 11.31 U/ml ± 0.94). Catalase levels were significantly higher in group 2 than in group 1, according to the results. Group 2 had a lower average interleukin-8 level than group 1, with a p-value of 0.035 (p<0.05) from an independent t-test (6.19 pg/ml ± 2.49 *vs*. 16.38 pg/ml ± 6.05). This result shows that compared to group 1, levels of interleukin-8 were much lower in group 2.

Table 2: Differences in catalase and interleukin-8 levels (n=10 in each group)

Variable	Group 1	Group 2	p-value
Catalase (U/ml)	11.31±0.94	12.59±0.22	<0.0001
Interleukin-8 (pg/ml)	16.38±6.05	6.19±2.49	0.035

Results are presented as mean±SD. Note: The difference is statistically significant (p< 0.05).

DISCUSSION

This study's findings suggest that massage and aromatherapy with red ginger essential oil may influence post-exercise oxidative stress and inflammation, as seen by alterations in catalase and interleukin-8 (IL-8) levels. High-intensity exercise can elevate the formation of reactive oxygen species (ROS) and the release of pro-inflammatory cytokines. In athletes, this response is crucial to the adaptation process; nevertheless, if excessive, it may impede recovery, exacerbate delayed onset muscle soreness (DOMS), diminish performance, and elevate the risk of recurrent injuries. The catalase levels in group 2 were higher than those in group 1, suggesting that the antioxidant activity of red ginger essential oil, which is utilized as a massage oil and in aromatherapy, has a substantial impact on the reduction of ROS production in athletes as a result of training. The rise in catalase activity indicates an enhancement in the antioxidant defense system and the body's capacity to combat oxidative stress following exercise. Catalase is an antioxidant that reduces hydrogen peroxide to water and oxygen without the need for an electron donor [23]. Consequently, catalase is a critical biomarker for the assessment of physiological adaptation and recovery as a result of physical exercise. The optimal capacity for endogenous antioxidant defense is indicated by the increase in catalase activity, which can assist in reducing damage to muscle cell membranes, lowering lipid peroxidation, accelerating recovery, preserving mitochondrial function, and decreasing the risk of inflammation and muscle fatigue [24]. The anti-inflammatory activity of red ginger essential oil as a massage and aromatherapy oil has a considerable effect on preventing inflammation in athletes due to training, as evidenced by the fact that the level of interleukin-8 in group 2 was lower than in group 1. The intervention's reduction in IL-8 suggests that red ginger essential oil suppresses the post-exercise inflammatory response [25]. Interleukin 8 (IL-8) is temporarily elevated as an inflammatory response as a result of high-intensity or protracted exercise. Nevertheless, consistent physical activity can also improve the overall anti-inflammatory response, potentially diminishing chronic inflammation that is linked to elevated IL-8 levels. IL-8, also referred to as chemokine CXCL8, is a cytokine that is crucial for the immune and inflammatory response. It attracts immune cells, including neutrophils, to the site of inflammation and tissue remodeling. In group 1, an increase in IL-8 was observed as a response to oxidative stress and cellular damage as a result of high-intensity and protracted physical exercise [26,27]. Red ginger essential oil comprises bioactive constituents, including gingerol, shogaol, zingerone, zingiberene, and an array of monoterpenes and sesquiterpenes. These chemicals are documented to exhibit antioxidant action via the activation of the Nrf2 (nuclear factor-erythroid-2-related factor 2) pathway, resulting in an enhancement of antioxidant defense mechanisms, including catalase. Red ginger essential oil exhibits anti-inflammatory properties through the activation of nuclear factor kappa-B (NF-κB) and the inhibition of inflammatory pathways, leading to a reduction in pro-inflammatory mediators such as IL-8 [28,29]. The discomfort associated with inflammation arises from the heightened oxygenation of arachidonic acid, which is processed by the enzyme cyclooxygenase-2 (COX-2), leading to the synthesis of prostaglandins and leukotrienes [30]. Massage therapy is a rehabilitative technique employed in sports science due to its capacity to mitigate inflammation, expedite recovery, and diminish pain associated with muscle injuries. The method of massage therapy entails modifying the signaling pathways associated with inflammation, diminishing nerve sensitization, and possibly activating advantageous immunostimulatory pathways. The amalgamation of massage with red ginger essential oil presents the potential for a synergistic effect. Massage facilitates topical absorption and enhances local blood flow, whereas the volatile constituents of essential oils can penetrate the skin and engage the olfactory system. Aromatherapy via inhalation influences the limbic system, namely regions linked to stress, emotions, and relaxation, whereas topical application enables essential oil constituents to engage with peripheral tissues [31]. The antioxidant and anti-inflammatory properties of red ginger essential oil serve as a defense against reactive oxygen species (ROS). Antioxidant substances can safeguard lipid membranes from damage and suppress the production of the COX-2 enzyme, thereby obstructing the manufacturing of pain mediators such as prostaglandins [32]. Antioxidants are crucial agents that can neutralize free radicals and reactive oxygen species (ROS). Despite the human body's inherent defense mechanisms against oxidation, the application of antioxidant-rich substances, such as red ginger essential oil in massage treatment, can augment these antioxidant defenses [33]. Essential oils penetrate the body via two routes: inhalation through the olfactory system and absorption through the dermal surface. Regular and repetitive massage therapy enhances the absorption of essential oils and activates the limbic system [34]. The scent of essential oils inhaled during the massage is

detected by the olfactory nerves in the nose and subsequently relayed to the brain's limbic system. This signal prompts the brain to release β-endorphins, linking the neurological system with other bodily systems and inducing a sensation of comfort [35]. The inhalation approach of aromatherapy is more rapid, convenient, and secure. The benefit of employing aromatherapy via inhalation, as opposed to oral treatment, is that it does not impact the digestive system, particularly when the focus is on the respiratory tract or lungs [36]. The olfactory nerve is the sole cranial nerve directly activated by external stimuli and transmits signals to the cerebral cortex, resulting in a pronounced stimulatory impact. Aromatherapy via inhalation of red ginger essential oil evaporates and interacts with the cilia of the nasal mucosa, influencing the limbic system and hypothalamus, resulting in a calming impact on the nervous system. Aromatherapy, especially utilizing red ginger essential oil, may assist athletes in achieving relaxation and tranquility prior to or following training or tournaments [37]. The findings of this study align with the research conducted by Harahap *et al*. (2017), which asserts that massage is more efficacious in alleviating muscle discomfort than the absence of massage in athletes (38). The study conducted by Harahap et al. (2023) found that massage with orange essential oil effectively speeds up healing [39]. Massage therapy mitigates inflammation, promotes rapid recovery, and alleviates muscle discomfort [40]. The findings of this study endorse the application of massage with red ginger aromatherapy as a viable non-pharmacological method to expedite the recovery phase following intensive training or as an adjunctive recovery strategy. This information is crucial for athletes' recovery techniques, as oxidative stress and inflammation are primary factors contributing to delayed onset muscle soreness (DOMS), tiredness, and the risk of musculoskeletal injuries.

Study Limitations

This study has several limitations. First, the relatively small sample size may limit the generalizability of the findings. Second, only two biomarkers (catalase and IL-8) were evaluated, whereas other oxidative stress and inflammatory markers were not assessed.

Conclusion

Red ginger essential oil massage and aromatherapy may enhance athlete recovery by increasing antioxidant defense (catalase) and reducing inflammation (IL-8). As an adjunct recovery therapy, this intervention has the potential to improve post-exercise recovery and athletic performance. These findings support the development of red ginger essential oil as a promising local herbal-based strategy for sports recovery.

ACKNOWLEDGMENTS

The authors thank all people who assist in conducting the study.

Conflict of interests

The authors declared no conflict of interest.

Funding source

Financial support for this project is sourced from a grant allocated by the DPPM Research Program Fund for the 2025 Fiscal Year, specifically under the Fundamental-Regular Research Program of the Directorate of Research and Community Service (DPPM), reference No. 008/UN33.8/DPPM/PL/2025.

Data sharing statement

The data that supports the findings of this study are available from the corresponding author upon a reasonable request.

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