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ORIGINAL SCIENTIFIC PAPER

Acute Effects of Olfactory Stimulation on 50-m Sprint Swimming Performance in Competitive Swimmers

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Abstract

Aromatherapy has been proposed as a non-pharmacological strategy capable of modulating psychophysiological responses that may influence athletic performance; however, evidence regarding its acute effects on swimming performance remains limited. The aim of this study was to examine the acute effects of different olfactory essential oils on 50-m sprint swimming performance in competitive swimmers. Twenty-one competitive sprint swimmers (8 males/13 females; age: 21.9 ± 2.0 years) completed four experimental conditions separated by four days: control (CON); activation essential oil (ACT); relaxation essential oil (REL); and placebo (PLA). Following a standardized warm-up, participants were exposed to the respective olfactory stimulus and subsequently performed a maximal 50-m sprint swim. Sprint time was recorded using a partially randomized within-subject crossover design. No statistically significant overall effect of condition on sprint performance was observed [$F(3,57) = 2.762$, $p = 0.062$]. A small reduction in sprint time (~1.2 %) was observed under the relaxation condition, which could be practically relevant in competitive sprint swimming settings. Acute olfactory exposure to a relaxation essential oil following warm-up was associated with a small numerical reduction in sprint swimming time. Although the overall effect was not statistically significant, these exploratory findings suggest that olfactory stimulation may influence short-duration swimming performance under specific conditions and should be interpreted cautiously. Further research is warranted to confirm these effects and clarify the underlying mechanisms.

Keywords: swimming performance · aromatherapy · sprint swimming · essential oils · olfactory stimulation

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Introduction

Aromatherapy is an alternative therapeutic approach that utilizes essential oils derived from plants to promote physical and mental well-being (Ramsey et al., 2020). Essential oils, extracted from various plant parts such as flowers, fruits and roots, contain complex chemical compounds including terpenoids, phenols, and ketones, which are responsible for their therapeutic effects (Patel, 2015; Sharmeen et al., 2021; Vora et al., 2024). These oils can be absorbed through the skin or inhaled, allowing their active compounds to influence physiological and psychological functions (Herman & Herman, 2015).

Recent evidence suggests that essential oils and aromatherapy are increasingly being explored as complementary non-pharmacological strategies for enhancing sports performance and post-exercise recovery (Ivanova et al., 2025). Studies suggest that essential oils like eucalyptus and mint (Mao et al., 2021) can improve respiratory function and oxygen flow, which are critical for endurance sports, while lavender (Kim et al., 2021; Yoo & Park, 2023) and bergamot (Perna et al., 2019) help reduce stress and anxiety, enhancing mental focus. However, most available studies have focused on general exercise performance, recovery, or endurance-related outcomes, while evidence specifically examining acute effects on short-duration sprint swimming performance remains limited.

Swimming, in particular, poses unique challenges due to prolonged exposure to chlorine and the humid pool environment, which may affect respiratory function and skin integrity. There is limited evidence for humans, but studies conducted on rats have shown that citrus essential oils with anti-inflammatory, analgesic, and stimulating properties could be particularly beneficial for rats by enhancing recovery and in respiratory function, reducing muscle pain, and improving performance in swimming trials (Tian et al., 2022). Although these findings provide preliminary mechanistic insights, their direct applicability to human athletic performance remains uncertain and requires further investigation.

Athletes incorporate essential oils into their routines to enhance post-exercise recovery, reduce stress, and improve concentration. For instance, studies have shown that a variety of essential oils such as lavender and rosemary appear to aid in recovery from fatigue and muscle spasms, while peppermint(Miranda Neto et al., 2023), orange and lemon oils enhance physical performance and mental focus (Fonseca, 2023; Sivaphongthongchai et al., 2023).

Despite the potentially beneficial properties of essential oils in sport settings, the available literature remains heterogeneous regarding study design, sport modality, and performance outcomes. In particular, evidence specifically related to sprint swimming performance is currently limited. In sprint swimming events such as the 50-m freestyle, performance is highly dependent on optimal psychophysiological arousal, reaction time, motor coordination, and the efficient execution of short-duration, high-intensity movements. Acute psychological factors such as anxiety, excessive arousal, and attentional disruption may negatively influence sprint performance. Therefore, olfactory stimulation through essential oils may represent a potential non-pharmacological strategy capable of modulating arousal state and attentional focus immediately prior to competition.

Specifically, the purpose of this study is to investigate the potential impact of aromatherapy, particularly the olfactory effects of different types of essential oils, on the performance of competitive swimmers in short-distance sprint events, with a focus on the 50-meter freestyle swim. It was hypothesized that olfactory exposure to essential oils, particularly relaxation-oriented aromas, would acutely improve 50-m sprint swimming performance compared with the control and placebo conditions.

Method

Subjects

Twenty-one (N = 21) competitive sprint swimmers (8 males/13 females; age: 21.9 ± 2.0 years) actively participating in regional and national-level sprint swimming competitions fulfilled the inclusion and exclusion criteria and participated in this study. (Figure 1).

Inclusion criteria included participants aged >18 years with an active athletic membership (registered with a sports club and federation). Exclusion criteria included a history of overtraining syndrome, having a muscle injury in the last 6 months, allergies to massage oil any acute or chronic condition that would limit the ability of the volunteer to participate in the study and refusal to give written informed consent.

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the University of Thessaly (GR16/5-4-2023). All participants gave their written informed consent prior to study participation.

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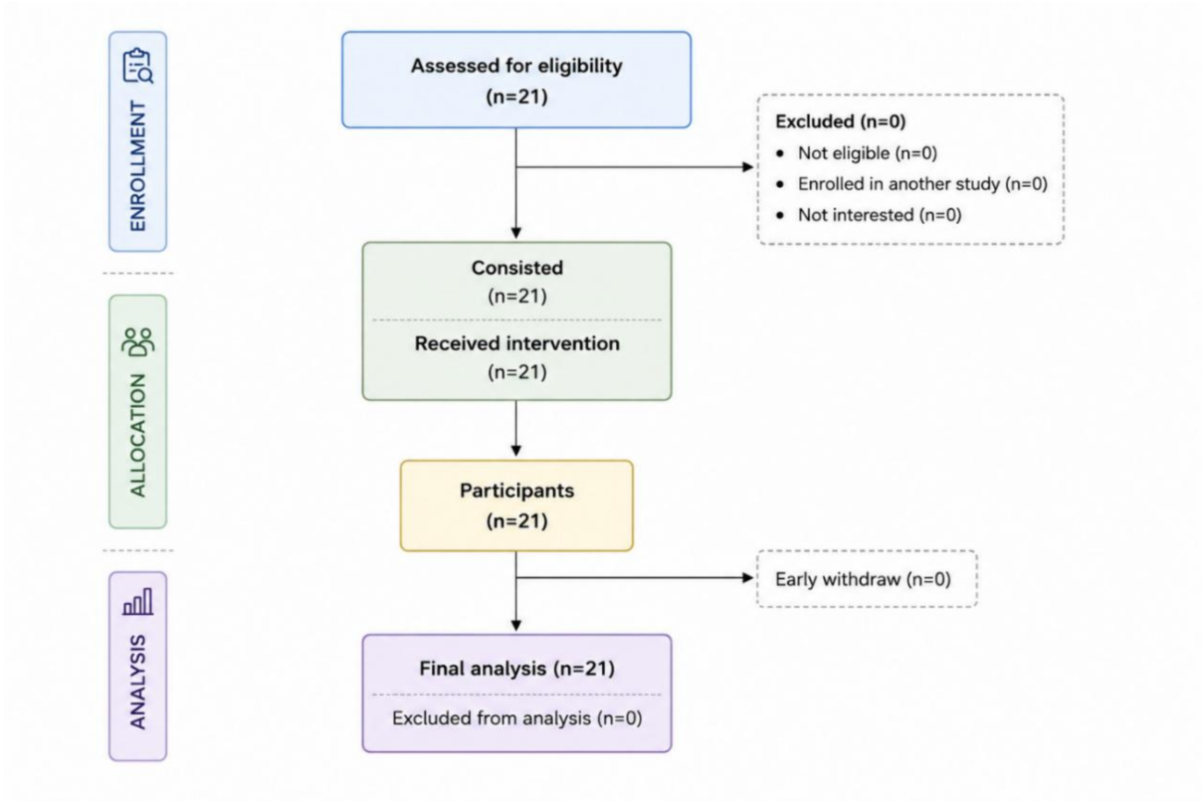

Figure 1. Consort Diagram of the present study summarizing recruitment, enrollment and dropout rates. Twenty-one participants (N=21) completed the study.

Study Design

Participants were assigned to four experimental conditions, each separated by four days. The control condition (CON) was always performed first and served as a baseline measurement, during which participants completed a standardized warm-up (600-m freestyle swim at low intensity), followed by a 5-min passive rest period and a timed 50-m maximal sprint swim without any intervention.

Following the control condition, participants completed three additional experimental sessions in a randomized order: a) Activation condition (ACT), b) Relaxation condition (REL), and c) Placebo condition (PLA). In all experimental conditions, participants first completed the standardized warm-up and were then exposed to the respective olfactory stimulus for 10 minutes prior to performing the 50-m maximal sprint swim.

The order of the ACT, REL and PLA conditions was randomized for each participant, while the researcher responsible for data analysis was blinded to the assigned condition. All measurements were conducted in the same indoor swimming pool under controlled environmental conditions (water temperature: 25°C), and all testing sessions were performed at the same time of day to minimize potential circadian or training-related effects (Figure 2). Each experimental session was separated by a 4-day interval to minimize potential carry-over, fatigue, or training adaptation effects. Participants were instructed to avoid strenuous exercise, alcohol consumption, caffeine intake, and the use of strong fragrances or perfumes prior to each experimental session in order to minimize potential influences on physiological responses and olfactory perception. Due to the perceptible nature of the olfactory stimuli, complete participant blinding was not feasible, and participants may have been able to distinguish between the experimental conditions based on odor characteristics. However, participants were not informed regarding the intended effects or expected outcomes of each condition in an effort to minimize expectancy-related influences on performance. The control condition was intentionally performed first in all participants to establish a stable baseline measurement and avoid potential carry-over effects from prior olfactory exposure. However, this approach may also introduce potential order, familiarization, or learning effects that could have influenced subsequent performance trials. The subsequent experimental conditions (ACT, REL and PLA) were randomized in order.

Procedure

All measurements were performed in an indoor 25-m swimming pool under standardized conditions. Participants wore swimming goggles and swimming cap for their warm-up and also for their timed 50-m max sprint swimming trial. They wore swimwear and kept the same outfit for all testing sessions (Figure 2).

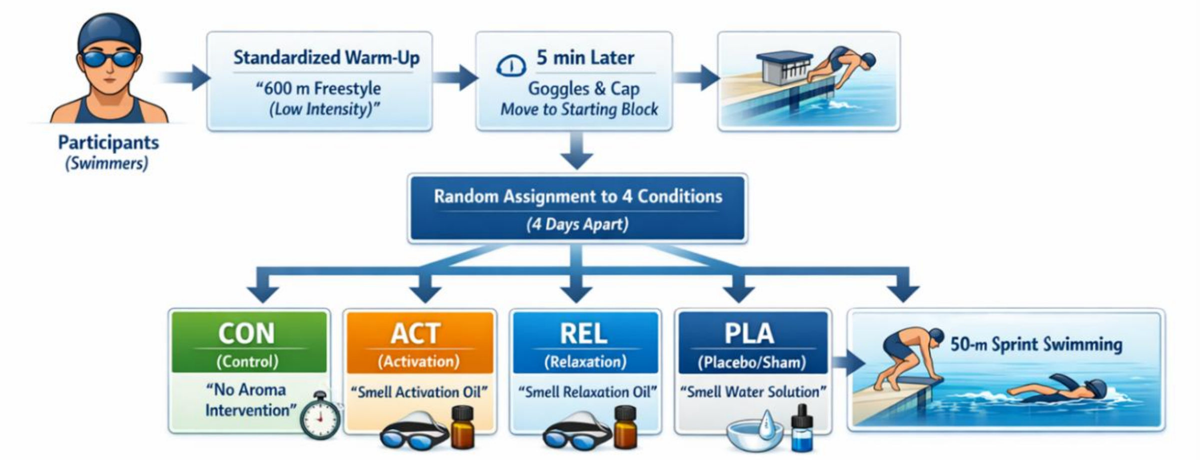

Figure 2. Study Flow Chart.
Participants were randomized and participated in 4 different trial sessions over four sessions, each separated by four days, with the control condition (CON) always performed first. (CON) = control protocol, no intervention and 50-m maximum swimming sprint; (ACT) = wearing a mask containing the activation essential oil for 10 minutes and 50-m maximum swimming sprint; (REL) = wearing a mask containing the relaxation essential oil for 10 minutes and 50-m maximum swimming sprint; (PLA) = wearing a mask containing the water-based placebo solution for 10 minutes and 50-m maximum swimming sprint.

In all experimental conditions, participants first completed a standardized warm-up session. Following the warm-up, participants sat quietly in a resting position and wore a mask containing either the activation essential oil (ACT), relaxation essential oil (REL), or the "sham" water-based solution (PLA) for 10 minutes. The mask was positioned directly over the nose and mouth according to its standard fit and was applied in the same manner across all experimental sessions. Exposure duration was standardized and controlled using a stopwatch. However, precise quantification of inhaled olfactory intensity and detailed concentration-related information regarding the aromatic formulations were not fully available from the manufacturer, and olfactory intensity perception was not objectively standardized between participants. Immediately after the olfactory exposure, participants proceeded to the starting block and performed a 50-m maximal sprint swimming trial.
Sprint swimming time was recorded when the athletes reached the 50-m finish line by one experienced researcher blinded to the experimental condition that the participants attended. Specifically, sprint performance time was recorded using a handheld stopwatch operated by the same experienced investigator across all trials. Following completion of the sprint swimming trial, participants performed a standardized cool-down procedure consisting of a 200-m low-intensity freestyle swim followed by static stretching exercises targeting the main muscle groups involved (back, shoulders, and legs), with each stretch held for 20–30 seconds.

Essential Oils
Activation Essential Oil (ACT)

The activation essential oil consisted of a commercially available custom-made aromatic mixture prepared by a Greek producer in collaboration with external specialists in aromatherapy and natural product formulation. According to the available product information, the formulation included carrier substances (olive oil, avocado oil, sesame oil, natural wax, propolis oil, and cocoa butter) combined with essential oils including cinnamon, oregano, sage, lemon, eucalyptus, nutmeg, orange, and spearmint. However, detailed compositional analysis, percentages of active compounds, and standardized ISO/pharmacological certification data were not available from the manufacturer.

Relaxation Essential Oil (REL)

The relaxation condition involved a vanilla-based aromatic formulation specifically prepared for olfactory exposure purposes by a Greek producer in collaboration with external specialists in

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aromatherapy and natural product formulation. According to the available product information, the formulation primarily contained vanilla extract; however, detailed compositional analysis, percentages of major active compounds, and standardized ISO/pharmacological specification data were not available from the manufacturer.

Placebo (PLA)

The placebo condition consisted of a water-based solution without added aromatic compounds. The solution was used to mimic the intervention procedure while minimizing exposure to active olfactory stimuli.
Both products (ACT and REL) were commercially available formulations obtained from local retail suppliers and used exclusively for olfactory exposure purposes.

Sprinting Capacity - Speed

Time to complete the 50-m distance was recorded using a standard official handheld stopwatch (FINIS Stopwatch 3x300 Yellow, Product ID: 1.30.040) operated by the same experienced investigator across all trials. Although electronic timing systems with touchpad technology provide higher measurement precision in competitive swimming, the same investigator and identical testing procedures were consistently used throughout all experimental sessions in order to minimize inter-trial variability and potential measurement error.

Statistical Analysis

The statistical analysis was performed using IBM SPSS Statistics version 29 (SPSS Inc., Chicago, U.S.A.). Data were checked for normal distribution (Shapiro-Wilk test) and average data are presented as mean ± SD. An independent T-test was used to examine if there were significant differences in basic characteristics. A General Linear Model with Repeated Measures ANOVA (GLM) was used to examine differences between experimental conditions. The assumption of sphericity was assessed using Mauchly's test, and when violated, Greenhouse-Geisser corrections were applied. A Bonferroni post-hoc test was performed to assess individual differences. To assess normality, the Shapiro-Wilk test was used alongside graphical representations, including the Normal Q-Q plot, Detrended Normal Q-Q plot, and Box Plot. The significance level was set at 5%. Beyond significance testing (p-value), effect size was also considered to evaluate the magnitude of the effect. Partial eta squared (partial η^2) was used as the effect size metric for the repeated-measures ANOVA analyses.

Power Analysis

Sample size calculations were conducted using G*Power 3.1.(Faul et al., 2007) The post-hoc "GLM": Repeated measures, within factors method was used to calculate the power analysis. The resulting minimum required sample size to achieve 98% power was 21 for 1 sided group errors 5% [(Effect size = 0.3814123, Critical F = 2.7580783, Ndf 3, Ddf 60, Power (1-β err prob) = 0.9881439 (98% power)].

Results

Twenty-one competitive swimmers completed all experimental conditions and were included in the final analysis. Baseline anthropometric and training characteristics are presented in Table 1.

Table 1. Baseline Characteristics.

Parameters	Values
N=21	8M/13F
Age (years)	21.9±2.0
Body Height (cm)	1.73±0.09
Body Weight (kg)	70.75±11.36
Training Experience (years)	11.1±5.0
BMI (kg/m²)	23.64±4.5

Note: Data are presented as Mean ± SD. Significance level $p \le 0.05$. BMI: Body Mass Index.

The effects of the four experimental conditions on 50-m sprint swimming performance are presented in Table 2 and illustrated in Figure 3. No statistically significant overall effect of condition was observed, $F(3, 57) = 2.762$, $p = 0.062$, partial $\eta^2 = 0.127$. Although the overall effect was not statistically significant, exploratory Bonferroni-adjusted pairwise comparisons indicated lower sprint times in the relaxation essential oil condition (REL) compared with the control condition (CON), corresponding to a mean reduction of 1.19 % ($p = 0.030$). No statistically significant differences were observed between the activation essential oil (ACT) or placebo (PLA) conditions and CON ($p > 0.05$). These exploratory findings should be interpreted cautiously given the non-significant overall effect.

Table 2. Comparative Effects of Different Essential Oils on Sprint Performance (50-m Swim).

Variables	CON (95% CI)	ACT (95% CI)	REL (95% CI)	PLA (95% CI)	p value* (Partial η^2)
N	**21**	**21**	**21**	**21**	**-**
50-m Swim (sprint)	31.68±3.77 (30.1 to 33.3)	31.68±3.74 (30.1 to 33.3)	31.30±3.73** (29.7 to 32.9)	31.75±3.79 (30.1 to 33.4)	0.062* (0.127) **(-1.19% ± 1.0)**

Note: Data are presented as Mean ± SD. Significance level $p \leq 0.05$. CON: control; ACT: activation essential oil; REL: relaxation essential oil; PLA: placebo solution. The reported p value refers to the overall effect of condition [F (3, 57), with partial η^2 indicating effect size] **Exploratory pairwise comparison between CON and REL (Bonferroni-adjusted $p = 0.030$); findings should be interpreted cautiously due to the non-significant omnibus ANOVA effect.

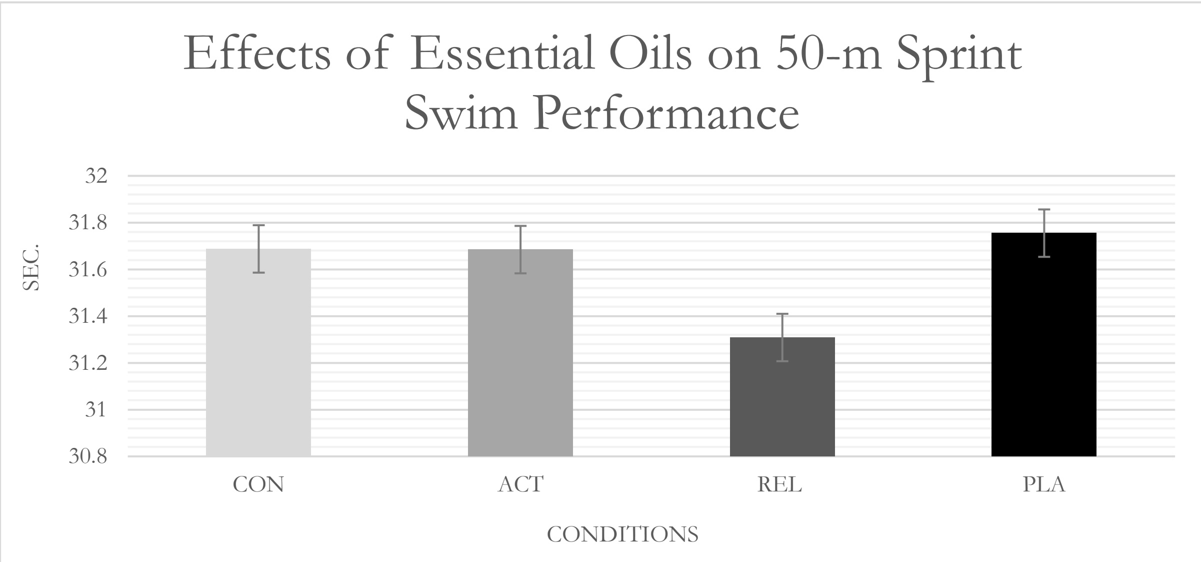

Figure 3. Effects of Essential Oils on 50-m Sprint Swim Performance.
Note: CON: control protocol; ACT: activation essential oil protocol; REL: relaxation essential oil protocol; PLA: placebo protocol; SEC.: Seconds.

Discussion

To the best of our knowledge, this is the first study to assess the effects of different essential oils with olfactory use on the performance of competitive swimmers, employing an objective measurement method (timing of 50-m freestyle swim). A group of competitive sprint swimmers was selected, as this population is exposed to high physical and psychological demands that may modulate responsiveness to acute psychophysiological interventions.

Although no statistically significant overall effect was observed, the magnitude of performance improvement was small; however, even minimal reductions in sprint time may be considered practically meaningful in competitive swimming, where race outcomes are frequently determined by fractions of a second. Therefore, the observed improvement in the relaxation condition could be of potential practical interest in sprint swimming contexts; however, these findings should be interpreted cautiously given the absence of a statistically significant overall condition effect (Table 2, Figure 3). Furthermore, in contrast to our initial hypothesis, the activation essential oil did not produce the expected results. Specifically, no meaningful difference in sprint time was observed between the activation essential oil and the control condition, with no decrease or increase observed. In a similar study by Korolkov et al., the effect of three essential oil mixtures (activating, relaxing, placebo) on the functional condition of young mini golf players was examined, and the results showed that the aromas reduced the excitation of the autonomic nervous system, with inhalation of the activating aroma having the greatest impact on athletic

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performance (Korolkov et al., 2018). These findings differ from the present study, which observed a favorable effect following the relaxation essential oil condition. Differences in sport modality, task demands, and outcome measures may partly explain this discrepancy.

It appears that the intrusion of relaxation essential oil (vanilla planifolia-based) through olfaction may lead to a reduction in anxiety and sleepless tension, improvement in concentration, as well as a decrease in feelings of fatigue and apnea (Edraki et al., 2013; Maya-Enero et al., 2022).

The following mechanistic interpretations should be considered hypothetical and exploratory, as no psychophysiological or neurobiological markers were directly assessed in the present study. Vanilla-based essential oils contain bioactive aromatic compounds, predominantly vanillin, a phenolic aldehyde with evidence for neuromodulatory effects beyond simple scent perception. Preclinical evidence suggests that vanillin may influence monoamine neurotransmitter systems in preclinical models of stress and depression, suggesting a potential neuromodulatory role. However, extrapolation of these mechanisms to acute human athletic performance should be made with caution (Xu et al., 2015).

Additionally, complex mixtures including vanillin and other odorants (e.g. limonene, hexenol) can prevent stress-induced anxiety and cognitive alterations in mice, indicating that specific odorant combinations modulate limbic-related stress responses (Bandiera et al., 2024).

More broadly, volatile terpenes such as linalool and α-pinene have been associated with anxiolytic-like effects potentially linked to GABAergic-related pathways and olfactory mediated neural activity, further supporting a role for terpenoid constituents in modifying psychophysiological states relevant to performance contexts (Harada et al., 2018).

The olfactory system itself directly interfaces with limbic and autonomic centers involved in arousal and stress regulation, permitting odorants to influence cortical arousal independent of perceived intensity or pleasantness, and suggesting a neurophysiological basis for arousal modulation via olfactory stimuli (Yao et al., 2024). These findings support the hypothesis that olfactory stimulation may influence athletic performance through modulation of emotional state and arousal regulation.

The use of vanilla essential oil in aromatherapy has been linked to a significant reduction in anxiety levels. For instance, Bythrow et al., observed a 63% decrease in anxiety among individuals who inhaled vanilla aroma before undergoing an MRI scan (Bythrow, 2005). Additionally, vanilla has been shown to reduce stress levels(Ben Saad et al., 2017; Dhanalakshmi et al., 2016) and enhance brain concentration. Although there is no strong evidence supporting a direct impact of vanilla on sports performance, these effects may help athletes better manage physical exertion and reduce the risk of psychological fatigue, a crucial factor in competitive athletes.

From a mechanistic perspective, the observed performance improvement following the relaxation essential oil may be associated with modulation of psychophysiological arousal and attentional control. Olfactory stimulation with pleasant and familiar odors, such as vanilla, has been shown to reduce anxiety levels, enhance cognitive focus, and influence autonomic nervous system activity through direct projections to limbic structures involved in emotional regulation and motor planning(Herz, 2011; Villemure & Bushnell, 2002).

In short-duration, high-intensity swimming events, excessive arousal or pre-competition anxiety may negatively affect motor coordination, reaction time, start execution, and stroke efficiency. Therefore, a mild reduction in psychophysiological stress induced by relaxation-oriented olfactory stimuli may facilitate optimal arousal levels, thereby supporting more efficient execution of short-duration, high-intensity swimming tasks(McCormick et al., 2015; Raglin, 2001).

Nevertheless, these proposed mechanisms remain speculative within the context of the present study and require confirmation through future investigations incorporating direct psychophysiological and neurobiological assessments. The present study has several notable strengths. First, a baseline-controlled, within-subject crossover design with fixed baseline control condition was employed, allowing each participant to serve as their own control and thereby reducing inter-individual variability. The control condition was consistently performed first to establish a stable baseline, while the experimental conditions were randomized, strengthening internal validity. Second, sprint swimming performance was assessed using an objective and sport-specific outcome measure (50-m maximal swim time), enhancing the ecological validity of the findings. Third, all experimental sessions were conducted under standardized and controlled conditions, including identical warm-up procedures, timing of testing, and environmental parameters. Finally, the study addresses a novel and underexplored area by examining the acute effects of olfactory aromatherapy on competitive swimming performance, contributing new insights to the growing field of non-pharmacological performance-enhancing strategies in sport. These strengths enhance the internal validity of the study, despite the exploratory nature of some findings.

Furthermore, the present study has several limitations that should be acknowledged. First, the relatively small sample size, although adequately powered for the repeated-measures design, limits the generalizability of the findings. Second, only a single short-distance sprint event (50-m freestyle) was assessed; therefore, the results cannot be extrapolated to longer swimming distances or endurance-based performance. Therefore, the present findings should be interpreted specifically within the context of competitive sprint swimmers and may not be generalizable to recreational swimmers, elite international athletes, or endurance-based swimming populations. Third, no psychophysiological markers (e.g., anxiety levels, heart rate variability, perceived arousal) were measured, which limits the interpretation of the potential mechanisms underlying the observed performance changes. Additionally, sprint performance was assessed using a handheld stopwatch rather than an automatic electronic timing system (e.g., touchpads or photoelectric timing), which may introduce a small degree of measurement error and reduce timing precision compared with fully automated systems. Moreover, the control condition was consistently performed first to establish a stable baseline; although this approach may introduce potential order, familiarization, or learning effects that could have influenced subsequent performance trials, the subsequent experimental conditions were randomized to minimize potential learning or fatigue influences. Moreover, the acute nature of the intervention does not allow conclusions regarding the long-term effects of repeated aromatherapy exposure in competitive swimmers. Also, complete participant blinding was not possible due to the perceptible nature of the olfactory stimuli, and participants may have been aware of odor exposure and may have partially distinguished between experimental conditions, potentially introducing expectancy-related influences on performance outcomes. Finally, detailed compositional information regarding the essential oil formulations used in the activation and relaxation conditions was not fully available from the manufacturer, limiting precise chemical characterization, standardization, and reproducibility of the olfactory stimuli. Future studies should incorporate psychophysiological markers, larger samples, and different swimming distances, as well as examine chronic exposure protocols, to better elucidate the mechanisms and applied relevance of aromatherapy as a potential adjunct strategy in competitive swimming.

Practical Applications

The present findings suggest that olfactory exposure to relaxation-oriented aromas may influence psychophysiological responses associated with sprint swimming performance. Given the absence of a statistically significant overall condition effect and the exploratory nature of the pairwise findings, practical application should be approached cautiously. Further research with larger samples and objective psychophysiological measurements is required before aromatherapy can be recommended as a performance-enhancing strategy in competitive swimming.

Conclusion

In conclusion, this study examined the acute effects of olfactory stimulation on 50-m sprint swimming performance in competitive swimmers using a partially randomized within-subject design. Although no statistically significant overall effect of condition was observed, exploratory analyses suggested lower sprint times following the relaxation essential oil condition compared with control. These findings should be interpreted cautiously and require confirmation in larger and fully randomized studies incorporating psychophysiological measurements.

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