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Research Article

Effect of Music and Lemon Aroma on Anaerobic Power and Balance of Athletes After Exhausting Activity

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Abstract

Background: The aim of this study was to investigate the effect of lemon aroma (LA) and music on anaerobic power and balance in athletes following sporting activity. Recognizing the potential influence of sensory stimuli on performance, we sought to contribute valuable insights into optimizing recovery strategies for athletes.
Objectives: The primary objective was to assess the effects of LA and music on anaerobic power and balance, employing a comprehensive set of physical fitness factors.
Methods: Twelve male amateur athletes were randomly included in our study. These individuals were given LA, music, and with no supplementation (control) for 72 hours, followed by a standardized recovery phase using a Monarch ergometer, and lactic acid levels were measured after the intervention to assess the physiological effect. Balance analysis covering both static and dynamic conditions was performed using a specialized balance machine. Isometric dynamometer measurements and detailed assessments of Sargent's jumping performance were performed to analyze physical fitness factors.
Results: Significant differences were observed in balance parameters, with both static balance (SB) and dynamic balance (DB) registering higher values in the control time ($P = 0.006$; $P < 0.001$, respectively). Lemon aroma exposure resulted in the highest values for peak power (PP) and relative PP (RPP) ($P < 0.001$; $P < 0.001$, respectively). Conversely, in the control time exhibited the lowest values for relative anaerobic power (RAP) and vertical jump (VJ).
Conclusions: The findings suggest a positive influence of stimulating aroma (lemon) and music elements on sportive performance. Lemon aroma was associated with enhanced anaerobic power, while the control group exhibited superior balance outcomes. These results underscore the potential benefits of incorporating sensory interventions into athletes' recovery protocols for optimized performance.

Keywords: Static Balance, Dynamic Balance, Anaaerbic Performance, Lemon Flavor, Music

1. Background

The impact of neurological stimuli on athletic performance assumes a pivotal position in the execution of perceptual-motor skills, particularly within the realm of targeted athletic pursuits (1). Furthermore, there is a conjecture that neurological stimuli can yield favorable repercussions on psychological dimensions, encompassing mental acuity, stress modulation, and regulation of emotional states. Moreover, neurological stimuli harbor a noteworthy potential for enhancing sports performance, underscoring the imperative of incorporating these techniques into athletes' training regimens (2). Some studies have reported that music and certain aromas trigger neurological stimuli, resulting in significant changes in athletic performance (3, 4).

Music can cause a range of effects, including physiological effects as well as some physiological effects such as reduced blood pressure, heart rate and respiratory rate (5-7). In sport and exercise contexts, it has been reported in the literature that music provides ergogenic effects such as increased work output, psychological effects such as improved emotional responses, psychophysical effects such as reduced perceived exertion, and psychophysiological effects such as improved oxygen consumption (8, 9). It has been shown that synchronised music can reduce the energy cost of exercise by increasing neuromuscular metabolic efficiency during exercise, as cited by Terry et al. from Zatorre et al. (10, 11). In studies examining the effect of music on performance parameters, it has been concluded that the rhythm of music is also an important factor (12, 13). On the other hand, despite the recent expansion of the literature in the post-activity field, the role of music in recovery after physical activity has not yet been fully explored (14, 15).

The effects of aromas on individuals can be evaluated in two main categories: Physiological effects and psychological effects. Physiological effects act directly on the physical organism, whereas psychological effects act through the sense of smell or the olfactory system and consequently can cause a physiological effect (16). As quoted by Hongratanaworakit from Tesserand, the physiological effects of aromas are divided into two basic categories: those that act through stimulation of the nervous system and those that act directly on an organ or tissue through the effector-receptor mechanism (16, 17). Essential oils, widely employed in sports performance as constituents of aromatherapy, pertain to three botanical families. Within the Lamiaceae family, fragrances such as "*Lavendula angustifolia* mill (lavender)" and "*Rosmarinus officinalis* (rosemary)" play a role in facilitating athletes' recuperation post-training, mitigating stress hormone levels, and alleviating muscle spasms. The Rutaceae family, encompassing "*Citrus limon* (lemon)" and "*C. sinensis* (sweet orange)" contributes to the enhancement of repetitive high-intensity exercise performance. Within the Poaceae family, "*Cymbopogon citratus* (lemongrass)" augments athletic prowess, pulmonary functionality, cognitive acuity, and induces alterations in mood (18). Based on this information, it has been observed that the number of studies examining the effect of aromatherapy on performance parameters after a strenuous activity is limited.

When the previous studies on the subject are examined, the effects of music and aroma therapy applications on athletic performance level while the participants were at rest were analyzed. However, it has been determined that the studies examining the effect of the applications on anaerobic performance and balance performance after strenuous exercise are insufficient.

2. Objectives

The aim of this study is to analyze the effects of music and lemon aroma (LA) application on anaerobic and balance performance after strenuous exercise. In this context, the hypothesis of our study was determined as "after strenuous exercise; LA has a more positive effect on anaerobic and balance performance than music and no intervention."

3. Methods

3.1. Participants

The participants of the study were selected from a pool of athletes and 12 male amateur athletes aged between 19 - 22 years were included in our study. Demographic information of the participants is given in Table 1.

Table 1. Characteristics of Participants (N = 12)

Variables	Mean ± SD
Age (y)	20.12 ± 2.14
Height (cm)	1730.50 ± 4.40
Weight (kg)	70.50 ± 7.47
BMI (kg/m^2)	23.39 ± 1.98

Abbreviation: BMI, body mass index.

Table 1 presents the descriptive statistics for test variables (balance and anaerobic power).

The minimum sample size was realized with G-Power (3.1.9.7) software (Düsseldorf, Germany) (19). F tests for this: multivariate analysis of variance (MANOVA): Repeated measures, within factor analysis with the number of groups 1 and the number of measurements 3; α err prob = 0.05; minimum effect size = 0.65; and power (1-β err prob) = 0.80, it was determined that at least 11 participants should be included in the study with 80.7% actual power. Participants who actively practiced sports were included in this study. This study excluded athletes with chronic diseases, cardiovascular disease, current infection, allergy to LA, and athletes who have been out of sports due to injury in the last 1 year.

Before this study, the participants were informed about the purpose and method of the study. Voluntary consent forms were signed by all participants. The necessary permissions were obtained from the non-interventional ethics committee for this study with decision number 2023/5204. This study was conducted in accordance with the principles set out in the Declaration of Helsinki.

3.2. Interventions

To establish a baseline for each participant, a standardized recovery stage was implemented using the Monarch ergometer. Participants were closely monitored until they had fully recovered and returned to their initial physiological state.

Following the recovery phase, the athletes underwent specific interventions 72 hours apart as follows: LA phase, exposed to lemon scent by inhaling two to three drops of lemon scent through a handkerchief impregnated with lemon scent; Musiz phase, listened to music at a moderate speed (130 bpm) through headphones; Control phase, no intervention.

3.3. Measurements

3.3.1. Wingate Anaerobic Power Test

A Monark 834' bicycle ergometer connected to a modified computer and running with compatible software was used for the Wingate Anaerobic Power Test (WAnT). Participants were given a warm-up protocol for 4 - 5 minutes after the training phase, which included 2 or 3 sprints of 4 - 8 s duration at 60 - 70 workload at 4 - 8 s duration. After the warm-up, a passive rest of 5 minutes was performed. After adjusting the saddle and handlebars for each subject, a resistance equal to 7.5% of each participant's body weight was placed on the bicycle pan. At the end of the test, peak power (PP), relative PP (RPP), and relative anaerobic power (RAP) values were recorded (20).

3.3.2. Vertical Jump Test

The participants' vertical jump (VJ) performance was assessed using the Sargent test methodology (21). The participant so positioned both feet against a smooth wall while they waited. At the highest point it reaches, a mark is made. After that, the individual was instructed to jump as high as he could, and the distance he covered was measured again using chalk. The two drawings' separation was measured in centimeters. After two trials, the participant's best result was noted (22).

3.3.3. Static and Dynamic Balance Performance

For measuring static and dynamic balance (DB), the Good balance instrument (Metitur, Jyvaskyla, Finland) was employed. The subjects were given input from the visual stimuli to maintain balance in both static and dynamic settings. Previous research have validated this tool's validity and reliability (23). The area covered by the participants' feet was tested for static balance (SB). The DB performance was determined by the person's swings to the right and left (Speedtrav).

3.4. Procedure

The experimental procedure included the following steps: participants were subjected to 3 different testing protocols. Control variables such as weight, age, height, and body mass index (BMI) were meticulously recorded. Participants completed a standardized recovery phase to ensure that their baseline condition was consistent. Prescribed interventions were administered to each group as outlined previously. Following the interventions, balance was assessed and physical fitness factors were evaluated. Throughout the experiment, participants wore headphones during all phases, except for the control phase when no music was played. Adequate hydration was ensured by water availability and environmental conditions, including ambient temperature, were closely controlled for consistency throughout the testing period.

3.5. Monark Recovery Phase

Participants pedaled at low resistance and low speed. This was continued until the heart rate and respiratory frequency returned to normal. Then, 5 minutes of active rest was performed. After the ergometer, the participants performed stretching exercises and then the test protocols were applied.

3.6. Statistical Analysis

In this study, statistical analyses were performed with SPSS (version 26, IBM, Chicago, USA). Normality analysis was performed with Shapiro Wilk test. Levene's test was applied for homogeneity of variances. It was determined that the data were normally distributed. Therefore, all results were given as mean and SD. Repeated measures ANOVA (Group*Factor) test was applied to determine the differences between the 3 groups in SB, DB and anaerobic power. The significance level was set as 0.05.

4. Results

Table 2 shows the mean and SD values of SB, DB and Anaerobic Power values of the participants before and after the test in control, lemon and music phase.

Table 3 shows the results of analysis covariance in each sub-scale. Covariance adjusted the effect of the confounding variables in the pre-test by statistical methods. Figure 1 shows the post hoc test for comparison of the means after intervention.

Table 2. Descriptive Statistics for Anaerobic Power, Static and Dynamic Balance [a]

Sub-scales	Control		Music		Lemon	
	Pre	Post	Pre	Post	Pre	Post
SB						
Covered Area (mm)	9.33 ± 3.45	9.50 ± 2.97	8.92 ± 3.26	5.75 ± 2.73	10.25 ± 3.05	8.17 ± 3.27
DB						
Speedtrav (mm/s)	206.92 ± 21.75	202.83 ± 29.28	203.50 ± 21.39	166.92 ± 20.39	202.83 ± 18.97	173.58 ± 18.99
Anaerobic Power						
PP (W)	707.97 ± 197.36	588.06 ± 208.22	761.91 ± 204.54	720.67 ± 219.54	787.03 ± 230.39	792.19 ± 212.36
RPP (W/kg)	10.15 ± 1.64	7.70 ± 1.99	10.84 ± 1.75	10.60 ± 1.77	10.63 ± 1.24	10.77 ± 1.69
RAP (W/kg)	7.89 ± 1.60	6.16 ± 1.50	8.07 ± 1.47	7.97 ± 1.41	8.07 ± 1.43	7.13 ± 1.67
VJ (cm)	44.29 ± 2.12	45.21 ± 1.21	45.21 ± 1.39	46.83 ± 1.50	45.50 ± 1.33	47.13 ± 1.54

Abbreviations: SB, static balance; DB, dynamic balance; PP, peak power; RPP, relative peak power; RAP, relative anaerobic power; VJ, vertical jump.
[a] Values are expressed as mean ± SD.

Table 3. Analysis of Variance Test Results for Group Comparison

Sub-scales	SS		df		MS		F		Sig		Effect Size	
	Pretest	Intergroup	Pretest	Intergroup	Pretest	Intergroup	Pretest	Intergroup	Pretest	Intergroup	Pretest	Intergroup
Static												
Covered Area (mm)	93.28	75.33	1	2	93.28	37.67	13.88	5.60	0.001	0.008	0.303	0.259
Dynamic												
Speedtrav (mm/s)	14814.20	6993.63	1	2	14814.20	22.71	96.20	22.71	0.000	0.000	0.750	0.587
Anaerobic power												
PP (W)	1493019.8	99260.67	1	2	1493019.8	49630.38	283.83	9.44	0.000	0.001	0.899	0.371
RPP (W/kg)	73.57	49.94	1	2	73.57	24.97	40.64	13.79	0.000	0.000	0.559	0.463
RAP (W/kg)	52.33	16.48	1	2	52.33	8.24	58.98	9.29	0.000	0.001	0.648	0.367
VJ (cm)	44.45	9.99	1	2	44.45	1.19	37.31	4.20	0.000	0.024	0.538	0.208

Abbreviations: PP, peak power; RPP, relative peak power; RAP, relative anaerobic power; VJ, vertical jump.

5. Discussion

This study is an original study investigating the effects of ergogenic aids such as music and lemon flavor on anaerobic power and balance parameters. In our study, it was found that PP, RPP, and VJ performances were higher in the LA phase than in the other phases. There was a significant difference in RAP value in the music phase compared to the control phase. Static balance and DB values were worse in the control phase compared to the other phases. To the best of our knowledge, this is the first study in which the effects of lemon and music on balance and anaerobic power parameters in athletes were examined. In this context, our hypothesis that ”LA application has more effect on balance and anaerobic power parameters in athletes than music and non-intervention time” was confirmed.

Music has been found to balance blood flow in regions of the brain thought to be associated with motivation, happiness, arousal and emotion, such as the ventral striatum, ventral medial, midbrain, orbitofrontal cortex and amygdala (24). Another study revealed that music regulates respiratory rhythm and blood pressure and positively affects physiologically important hormones such as testosterone, serotonin, dopamine and adrenaline (25). Hormones that have a balancing and regulating effect on human physiology positively affect the physical performance of individuals (26). When the literature is examined in the light of these data, there are many studies showing that music positively affects sportive parameters such as warm-up (27), aerobic power (28), anaerobic power (29, 30), and strength (31). Svoboda et al. reported that the fast music group exhibited higher athletic performance in a study conducted with 3 different groups of fast music, slow music and no music at a self-selected music tempo (31). In our study, it was observed that calming and low-tempo music genres that individuals did not choose positively affected athletic performance. There are also studies showing that there is no relationship between music and athletic performance. These results

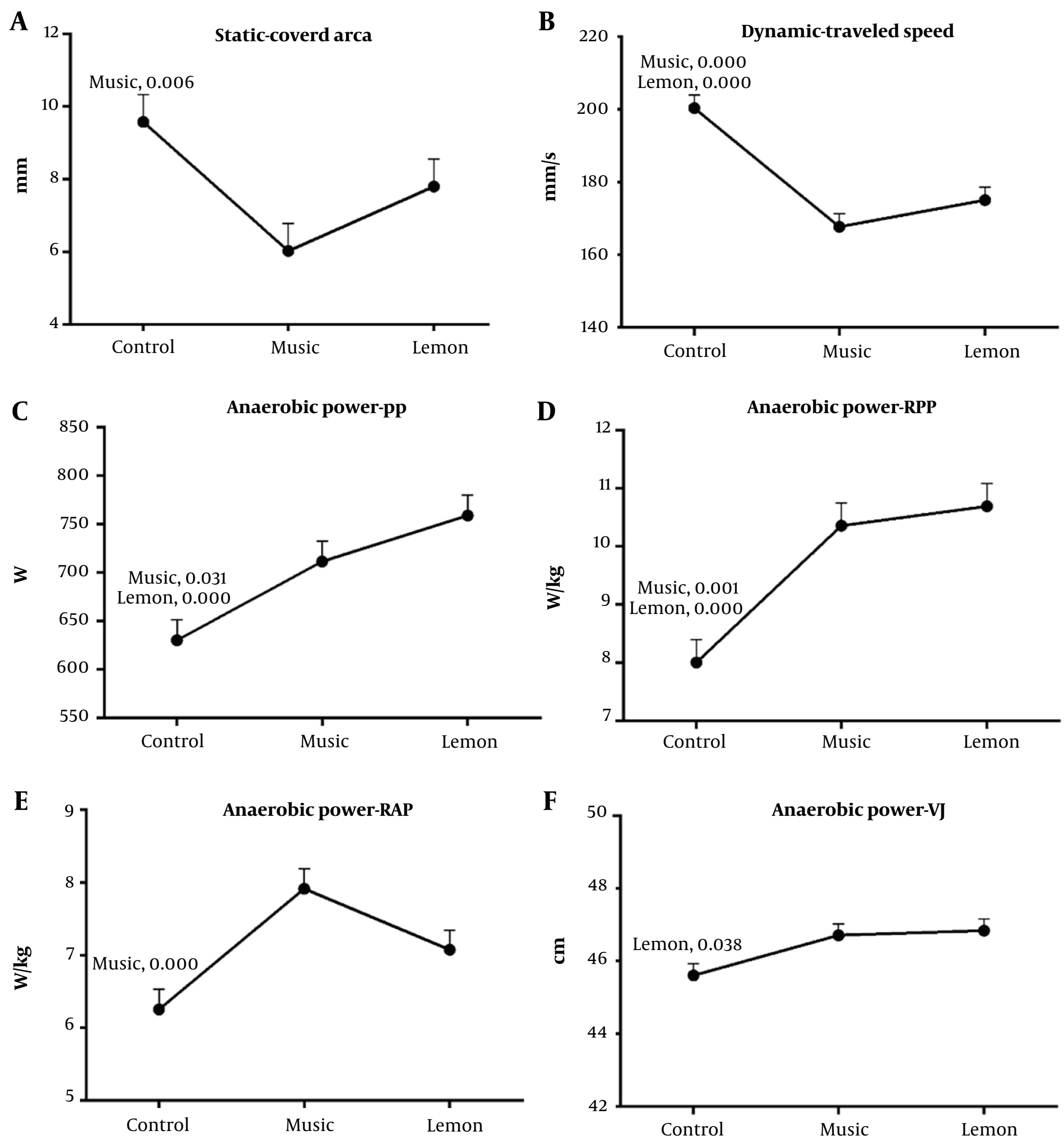

Figure 1. Results of Bonferroni post-hoc test. (A) Static balance; (B) dynamic balance; (C) peak power; (D) relative peak power; (E) relative anaerobic power; and (F) vertical jump.

vary depending on the tempo, type and rhythm of the music and whether individuals choose it or not. Jebabli et al. explained that the performance of basketball players who worked with music increased compared to those who worked without music (32). Pusey et al. reported that different music tempos increase anaerobic performance and are an important ergogenic aid for sports performance (30). Considering the relationship between music and human physiology, it has been observed that music increases anaerobic performance. These results support our research.

It has been explained that aromatherapy applications have effects that stimulate the olfactory center of the brain through the respiratory system (33) support and relax individuals physiologically (34). It has been reported that with the feeling of relaxation in the individual, the brain secretes endorphin hormone, reduces stress and positively affects the mental state (35). It has been stated that as the mental well-being level of the individual increases, physical performance increases linearly. When the literature is examined in the light of these data; Rambod et al. reported that LA therapy applied on acute myocardial patients for 3 days reduced systolic blood pressure and anxiety and positively affected the heart rate of individuals (36). In addition, a randomized trial in pregnant women found that common complaints of vomiting and nausea were reduced with lemon or ginger aromatherapy applied for 4 days (37). Kwon et al. reported that orange aromatherapy reduced fatigue during exercise and positively affected mood and recovery in university students who performed aerobic exercise at least 2 times a week (38). In addition, in a study conducted on 30 healthy university students, it was found that aromatherapy had positive effects on aerobic power in favor of the experimental group (39). Similarly, in another study, LA therapy was reported to support high-intensity exercise (18). Since LA therapy stimulates brain function (33) increases heart rate and regulates blood pressure (16). It is thought to positively affect the performance outcomes of individuals during exercise.

Twelve athletes from the athlete pool participated in the study. The range of participants can be expanded so that possible effects on different groups can be examined. Calming music and LA were used in the study. Different studies can be designed using different flavors and music at different tempos. In this study, the effect of biological rhythm was not examined. People's chronotypes may have a positive or negative effect on performance parameters. Therefore, it may be recommended to take this into consideration in future studies. In this study, participants' physiological responses to different ergogenic aids were cross-sectionally examined. Therefore, routine nutrition and hydration status were not analyzed. This is an important limitation of our study.

These results show that aromatherapy applications positively affect the physiological status of individuals. It supports our study in terms of the positive effect of aromatherapy on physiological parameters.

5.1. Conclusions

The use of music and aromatherapy applications separately or in combination positively affected anaerobic power and balance performances. These applications were found to be important ergogenic aids that increase athletic performance. Various seminars can be organized on the effects of ergogenic aids such as music and lemon flavor on performance. Such ergogenic aids are recommended to be used by coaches to enhance athletic performance. The effects of different flavors such as rose, mint, lavender, ginger and orange on physical performance can also be studied. The effects of different types of music and rhythms can be evaluated in isolated or combined studies.

Footnotes

Authors' Contribution: M. O., M. T., Ö. E., A. K., developed the original idea and the protocol, abstracted and analyzed data, wrote the manuscript, and is a guarantor. O. A., B. Y., E. S., J. M. contributed to the development of the protocol, abstracted data, and prepared the manuscript.

Conflict of Interests: The authors declare no conflict of interest.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

Ethical Approval: The study was conducted according to the Declaration of Helsinki guidelines and was approved by the Inonu University (IU) and the Human Research Ethics Committee of IU (approval number: 2023 /5204).

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Informed Consent: An informed consent form was signed by all subjects who agreed to participate in this study.

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