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Article

Research on the effect of music promoting sports performance under biosensor monitoring

Yueling Lang[1], Weize Ma[2], Xiaohui Ma[3,*]

[1] School of Music and Dance, Weifang College, Weifang 261000, China
[2] Shandong Art Institute, Modern Music Institute, Jinan 250014, China
[3] Library, Weifang College, Weifang 261000, China
*** Corresponding author:** Xiaohui Ma, JIAOXIANGHUIYING@163.com

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Abstract: Music has long been considered an approach for improving physical performance and motivation in sports. This study looks into the impact of music on athletes' performance in sports, employing biosensor monitoring to detect physiological and psychological changes. A total of 100 athletes were randomly assigned to two groups: Group A (n = 50) exercised with music, while Group B (n = 50) exercised without music. Participants participated in identical physical activities, such as endurance runs and strength exercises. Biosensors measured heart rate variability (HRV), oxygen saturation, muscle activity, and galvanic skin response (GSR). Participants also self-reported their motivation levels and perceived effort. The two groups' performance measures were compared statistically using the independent t-test. Furthermore, within-group variations in recovery durations before and after exercise were assessed using paired t-tests. The association between motivation levels and performance results was evaluated using Pearson's correlation. The impact of music on a number of physiological indicators was evaluated using multivariate analysis of variance (MANOVA). The findings showed that music (Group A) improved sports performance significantly by increasing endurance, lowering perceived exertion, and encouraging faster recovery. Biosensor data showed that the music condition resulted in higher HRV and less muscular tiredness, indicating enhanced physiological efficiency. Participants reported increased motivation and enjoyment when exercising to music. The findings suggest that incorporating personalized music playlists into training programs can improve athletic outcomes.

Keywords: music; sports; biosensor; physiological and psychological changes; perceived exertion and motivation levels; statistical analysis

1. Introduction

People in the general public, as well as athletes, should engage in resistance training. Weight training is a common method used by people to enhance their performance. Performance can be enhanced by exerting maximum effort in the weight room [1]. It has contributed to the widespread usage of ergogenic supplements in resistance training and fitness regimens. By blocking signs of exhaustion like steroids, coffee, and visuals, many ergogenic products can improve body functions. Music's ergogenic benefits during warm-up, activity, and cool-down were the focus of several inquiries [2]. Listening to music is thought to improve workout performance. There are people who have decided to employ music to improve physiological function. Athletes could boost their effort, reach their peak effort, and improve their mood by listening to music while performing resistance exercises [3].

An excellent kind of distraction that makes the motions of the exercises more difficult. Sport and exercise could benefit from music's capacity to attract attention, improve mood, evoke feelings, alter or regulate mood, arouse memories, boost output, lower inhibitions, and promote rhythmic motion [4]. Enhanced mood, elevated performance metrics, arousal, and a decreased rating of perceived exertion appear to be the most common advantages of integrating music with resistance training. It leads to a greater capacity to lift weights during resistance training, which in turn improves physiological and performance gains [5].

It was frequently acknowledged that music is a potent instrument that influences human performance, including athletic ability, in addition to the artistic and cultural spheres. Music has become an increasingly important component of training regimens and competition preparation for both coaches and players [6]. Music is a useful tool for improving sports performance because of its exceptional capacity to affect both psychological and physiological processes. Athletes can benefit from increased motivation, attention, and endurance by carefully choosing music that complements the activity's rhythm and intensity [7]. By addressing the mental and physical components essential to athletic success, music can improve an athlete's overall performance both during training and in competition scenarios.

Music's physiological impacts on athletic performance are especially significant. Its ability to coordinate movement is one of its main advantages; it enhances coordination and efficiency in repeated or rhythm-based activities like cycling, swimming, and running [8]. Musical data could be used by the athletes to maintain a constant pace and even go beyond one's perceived capabilities as the participants trained and competed with music tempo as energetic. In the same manner, it also helps athletes manage pain or even fatigue by averting the feeling of effort [9]. Possibly during endurance-committing activities, music can be effective because it raises energy levels, regulates the breathing cycle, and has the potential to modify heart rates. The right music increases motivation while reducing the level of perceived effort by maintaining temporal synchronization and concentration. Together, it might enhance global performance when doing exercises, making the exercise routines feel more comfortable and less tiring [10].

Music is a strong motivator on a psychological level. It can increase confidence, improve mood, and lessen tension or anxiety, all of which are critical in high-stakes sporting events. To psychologically get ready for a major event, athletes frequently create custom playlists that feature songs with inspirational lyrics or emotional resonance [11]. Athletes can experience mental stamina and a sense of power as a result, which enables them to get into a "flow state" in which they are totally focused on their performance. Music is an adaptable tool that offers advantages beyond the physical side of sports, allowing athletes to perform at their best throughout training and competition due to its combination of psychological boost and physiological harmony [12].

This study uses biosensor monitoring to examine at physiological and psychological changes to determine how music affects athletes' performance.

Key contribution

- 100 athletes participated in the study, split into two groups, enabling a thorough examination of how music affects motivation and performance.
- Real-time physiological data was obtained through the use of innovative biosensor technology, which improved the validity of the data on the influence of music on athletic performance.
- The findings showed that listening to music while working out had significantly superior results, such as more endurance, less perceived effort, and quicker recovery periods.
- It found a favorable relationship between music and motivation, indicating that adding music to training could enhance athletes' overall workout experiences.

The remaining part of the study is divided into many sections to ensure that the findings are presented in an understandable and comprehensive way. Section 2 provides pertinent research by reviewing earlier studies and foundational research that contextualizes the current investigation. Section 3 examines several techniques and describes the study tactics and procedures employed. The outcomes and implications that follow, including the experimental findings, are examined in Section 4. There is a discussion in Section 5. Effectively wrapping up the research, Section 6 summarizes the main conclusions, clarifies their relevance, and suggests possible areas for further study.

2. Related work

German college students' exercise performance and enjoyment were examined in relation to several musical genres [13]. According to the basic methodology, people enjoyed classical music the most, pop music next, and rock music last. Rock music could have a detrimental effect on motivation and mood, while classical music had a beneficial effect. According to the investigation, choosing music for a workout could enhance enjoyment.

The effect of music and destination knowledge on basketball players' achievements on the repeated countermovement jump (CMJ) test was examined in research [14]. Different knowledge conditions were tested on twenty-four players' knowledge of the variety of jumps, knowledge of the time of the activity, and unknown/no knowledge. According to the findings, preferred music considerably reduced perceived effort (RPE), increased jump height, and was coupled with shortened contact and flight times when compared to no music. Basketball players' workout reactions could be influenced by music and destination awareness.

A physiological condition known as "exercise fatigue" occurs when the body's capacity to function or exercise effectively declines [15]. The potential of music therapy, a relatively young field that combines psychology, music, and therapy, to assist in the recovery from aerobic exercise weariness has drawn interest. With the objective of developing scientific sports music recommendations and offering a theoretical foundation for additional research, it investigated the effectiveness of passive and music electrotherapy.

The effect of preferred versus non-preferred warm-up music on female athletes' anaerobic sprint performance was investigated [16]. The participants underwent two visits with varying warm-up circumstances, during which time they were assessed for power, perceived exertion, overall work, and willingness to exercise. According to the findings, listening to one's favorite warm-up music increased motivation to work out and had an ergogenic effect during repeated sprints. Collegiate athletes could profit from warm-up music before high-intensity repetitive activity to maximize their training and performance.

The effect of both liked and disliked warm-up music listening settings on exercise performance was investigated in research [17]. After undergoing three distinct warm-up experiences with no music, recommended music, and non-preferred music, twelve physically active individuals finished exercise trials. While non-preferred music failed to provide any ergogenic benefits, the results indicated that preferred music enhanced exercise performance when compared to no music. It emphasized how crucial it was to take musical tastes into account while getting ready for physical activity.

Through an emphasis on the effects of daily sports nutrition supplies, research [18] explored how music affects athletes' physical fitness. Twelve athletes were split into two groups: Group A, who jogged while listening to music, and Group B, who did not. The findings demonstrated that athletes' physical fitness was considerably enhanced and restored by music, with the impact becoming more noticeable ten minutes after the activity concluded. It implied that music could assist athletes in improving both their performance and general well-being.

Highlighted films and music could boost motivation and self-efficacy, according to research [19] on American football players. It was shown that verbal priming approaches combined with audiovisual stimuli effectively increased intrinsic motivation while lowering enthusiasm. According to the investigation, before a sporting event, practitioners could fantasize about using subliminal verbal primes, encouraging music and movies.

The impact of warm-up music level and choice on taekwondo contestants' physical performance, subjective fatigue, and enjoyment was examined in research [20]. Twenty athletes participated in the research under five different conditions: No music, 80 dB loud music, 60 dB soft music, 80 dB soft music, and 80 dB loud music. Preferred music was found to improve agility test timings, increase total kicks, and decrease perceived levels. According to the results, training and performance in taekwondo could be improved by listening to one's favorite music.

The impact of a music-listening strategy on stress in athletes with and without concussions was investigated in research [21]. The findings indicated that there was no discernible variation in the stress recovery processes for self-reported metrics. Skin conductance data, however, indicated that concussed athletes recovered more quickly and significantly after listening to music. According to the results, music could serve as a useful tool for concussed sportsmen to control their stress and avoid building excessively.

The performance and physical reactions of male athletes during progressive exercise were evaluated in relation to different musical intensities [22]. The findings demonstrated that, in comparison to listening to no music, slow music did not substantially reduce blood pressure, maximum utilization of oxygen, maximum heart rate, or time to fatigue. While slow music produced a calming effect and lowered heart rate, progressive music boosted motivation and delayed the time to tiredness. It implied that listening to relaxing music while engaging in endurance activity could lower blood pressure with hypertension.

Examining the impact of music on resistance training efficacy was the purpose of the investigation [23]. Twelve male college students were chosen, and while doing a bench press exercise test, they were exposed to either their favorite or least favorite music. According to the results, listening to one's favorite music improved the number of bench press repetitions overall as well as the mean velocity, peak velocity, peak power, and relative mean power within the first 3 repetitions. Listening to their favorite music could help athletes become more motivated and perform better.

The effects of playing their favorite music during the warm-up or test on the performance of adult males on repeated sprint sets (RSS) were examined [24]. Nineteen healthy men completed two sets of five-by-twenty-meter repeated sprints in three different settings with their favorite music playing throughout the test, during the warm-up, or without any music. The total sum sequence, rapid time index, and tiredness index significantly decreased in the listening to favored music condition as compared to the no music condition.

The effects of listening to one's favorite music following a stressful incident on amateur players' anxiety, and heart rate were examined in research [25]. Responses from the twenty healthy golfers who took part were assessed both before and after the intervention. In terms of swinging, carry distance, ball speed, launch angle, and putting performance, the results revealed no discernible differences. According to the findings, golf performance and anxiety were not instantly impacted by listening to one's favorite music after a stressful event.

To investigated how mature adults' performance on a routine sprinting set (RSS) or another test changed as they listened to their favourite music. The test results indicated an improvement in both test skills and achievement indicators during the prior test condition, given the fact that there had been no discernible effect overall.

To understand the mechanics behind the utilization of music to motivate persistent exercise, suggested by author [26] a theoretical framework termed music as an adaptive inducer to exercise (MASPA). The model follows to fill the ignorance concerning music-based interventions and enhanced comprehension of its best application as a sensory, ergogenic, and emotional stimulant for physical activity (PA) improvement.

To examined [27] how mental strain affects musicians' performances in live concert environments. Both kinds of anxiety proved to be indicators of declining performance. Performance quality was improved by public self-consciousness and diminished by personal self-consciousness. The results implied that self-awareness adaptation has a protective impact.

3. Methodology

100 athletes participated in the study and were split into two groups at random: Group A (n = 50) worked out while listening to music, while Group B (n = 50) worked out without any music. While biosensors recorded EMG, oxygen saturation,

HRV, and GSR, both groups engaged in physical activities. The participants self-reported their perceived effort and motivation levels. Independent *t*-test for group comparisons, paired *t*-test for recovery evaluations, MANOVA to evaluate the impact of music on several dependent variables, and Pearson's correlation for motivation performance connections were among the statistical analyses used.

3.1. Data collection

A total of 100 athletes-One half of them composed Group A and the other half formed Group B-took part in a fitness program. While training, 50 of the athletes in Group A used music, while Group B exercised without music. The sample consisted 53 males and 47 females aged between 18 and 30 years and required to have at least a year of training experience within a specific sport. The results of the survey will be generated from the subjects who have undergone at least 3 training sessions per week for a more reliable research conclusion. This criteria for selection ensured that equal numbers-50-formed Group A and 50-formed Group B. Thus, the effects of music on performance could best be accounted and the demographic information of the data is found in **Table 1**.

Table 1. Demographic data.

Demographic Variable	**Group A (with Music)**	**Group B (without Music)**	**Total**
Total Participants	50	50	100
Gender			
Male	27	26	53
Female	23	24	47
Age			
18–22	21	19	40
23–26	18	20	38
27–30	11	11	22
Sports Experience			
1–3 years	15	16	31
4–6 years	23	22	45
7 + years	12	12	24
Primary Sport			
Endurance (Running, Cycling, etc.)	28	26	54
Strength-based (Weightlifting, etc.)	14	16	30
Mixed (Team Sports)	8	8	16

3.2. Research instrument

A self-reported scale called the Rating of Perceived Exertion (RPE) scale is used to measure how hard people believe they are working during physical activity based on feelings like dehydration and breathlessness. Participants identify their effort levels in a standardized way, usually on a scale of 0 to 10 or 6 to 20. The perceived effort of athletes throughout both with music and without music exercise sessions will be measured in this study using the RPE scale. The study intends to demonstrate how music affects athletes' workout experiences and effort levels by comparing RPE scores under various conditions. This could emphasize music's function as a motivational tool that can change perceptions of intensity and increase enjoyment during physical activity.

3.3. Biosensor measurements

3.3.1. HRV

HRV refers to the variation in the intervals between subsequent beats that result from the autonomic nervous system's regulation of the heart. It is represented by the standard deviation of the intervals or another statistic; this is often studied by electrocardiograms (ECGs). Elevated levels of HRV reflect increased cardiovascular system pliability and more extensive cardio-protective potential, a relationship that implies better physiological condition and rehabilitation. Due to the fact that it suggests a good autonomic nerve balance that can respond to physical stimuli, high HRV reflects improved performance in sports situations. Due to the existing relationship between HRV and various stressors, including physical or mental exhaustion, or overtraining, the measurements of this parameter can be beneficial for monitoring athletes' rehabilitation and overall health.

3.3.2. Oxygen saturation

The proportion of oxygen-saturated hemoglobin in the blood is indicated by oxygen saturation (SpO_2), a vital physiological parameter. It is determined using a non-invasive tool known as a pulse oximeter, which measures how well oxygen is transported from the lungs to the body's tissues. The useful range for normal oxygen saturation is 95% to 100%; values below this range could indicate circulatory or respiratory problems. Monitoring oxygen saturation during exercise can provide information about an athlete's cardiovascular endurance and efficiency as it evaluates how well the body uses oxygen while exercising. Low oxygen saturation levels during exercise can indicate that muscles are not receiving enough oxygen, which could affect recovery and performance.

3.3.3. EMG

Electromyography (EMG) is a method for assessing muscle activity, which is based on the electrical activity of skeletal muscles during contraction. As for the EMG, the electrical impulses generated by muscle fibers when it is stimulated are attained with electrodes placed on the skin over these muscular regions or by using electrodes with a needle inserted into the muscular tissue. This data allows them to evaluate muscle performance, fatigue status, and coordination during movement tasks because of the information it provides regarding muscle activation magnitude, phasing, and temporal characteristics. EMG measures help to the extent that they enable the identification of how music effects muscular activation during exercise, within the context of the research that suggests athletes exercising with music perform better and are less tired than those exercising without music.

3.3.4. GSR

The term GSR describes a change in the skin's electrical conductance brought by modifications to sweat gland activity, which is impacted by physiological stress or emotional excitation. The sympathetic nervous system becomes active when a person feels intense emotions like excitement or worry, which causes them to sweat more and alters the conductivity of their skin. GSR provides information about an individual's emotional state through a variety of activities, including exercise, and is frequently used as a physiological measure when trying to evaluate emotional and physiological reactions. GSR can assist academics in comprehending how music affects athletes' stress levels, arousal, and general emotional involvement during exercise in the context of sports performance.

3.4. Statistical analysis

The impact of musical on athletic performance was evaluated in this study using biosensor monitoring, and the collected data were examined using SPSS version 29.0. Groups exercising with and without music were compared on performance metrics using independent *t*-tests, and groups' recovery times were assessed using paired *t*-tests. The association between motivation and performance was also investigated using Pearson's correlation coefficients, and the impact of music on a number of variables was examined using MANOVA. These statistical techniques revealed how music improves athletic performance and rehabilitation.

4. Result

The study used independent *t*-tests to evaluate performance differences between athletes who exercised with music and those who did not and paired *t*-tests to compare recovery times before and after exercise within each group. Performance results and motivation levels were compared using Pearson's correlation coefficients. An in-depth understanding of music's impact on athletic performance and recovery was provided using MANOVA, which examined its impacts on several factors immediately.

4.1. Paired *t*-test

Measurements of several physiological indicators, both pre and post-exercise showed notable improvements in Group A are demonstrated in **Table 2** and **Figure 1**. With a t-statistic of 6.78 (df = 49, $p < 0.001$), the mean HRV improved from 45.6 (SD = 5.2) pre-exercise to 53.2 (SD = 4.5) post-exercise, suggesting improved autonomic control for post-exercise. Additionally, pre and post-exercise for oxygen saturation increased significantly from 95.3 (SD = 1.2) to 98.1 (SD = 0.8), as indicated by a t-statistic of 7.12 (df = 49, $p < 0.001$), indicating better oxygen delivery. A decrease in muscular tiredness was shown by the measurement of muscle activity, which dropped from 120.5 (SD = 10.2) to 110.2 (SD = 8.5) with a t-statistic of 4.29 (df = 49, $p < 0.001$). Finally, changes in physiological arousal were reflected in the GSR, which decreased slightly from 50 (SD = 10) to 48 (SD = 7), as indicated by a t-statistic of 5.92 (df = 49, $p < 0.001$). All of these findings demonstrate the benefits of music-assisted exercise on athletes' physiological performance and rehabilitation.

Table 2. Paired *t*-test values for Group A.

Variables	Mean Pre-Exercise (SD)	Mean Post-Exercise (SD)	*t*-Statistic	df	*p*-value
HRV	45.6 (5.2)	53.2 (4.5)	6.78	49	< 0.001
Oxygen Saturation	95.3 (1.2)	98.1 (0.8)	7.12	49	< 0.001
Muscle Activity	120.5 (10.2)	110.2 (8.5)	4.29	49	< 0.001
GSR	50 (10)	48 (7)	5.92	49	< 0.001

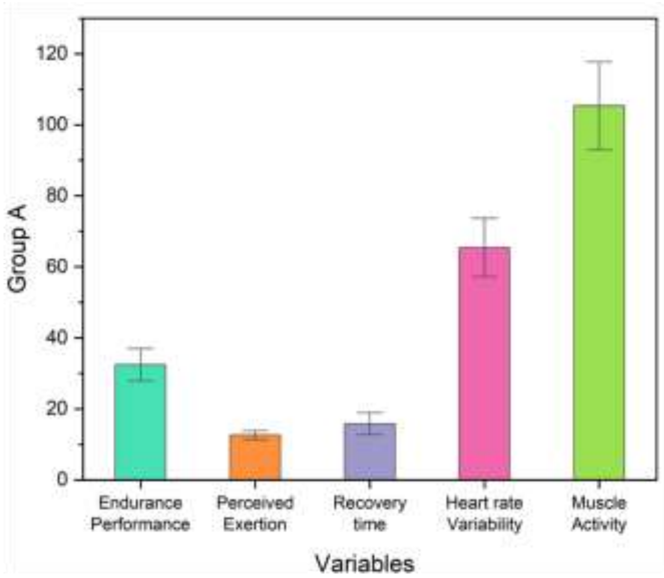

Figure 1. Group A performance for paired *t*-test.

The examination of physiological variables in Group B, both pre and post-exercise revealed no discernible changes in any of the metrics that were examined in **Table 3** and **Figure 2**. No statistically significant difference was found, as the mean HRV increased marginally from 44.8 (SD = 5.1) to 45.1 (SD = 5.0), with a t-statistic of 0.32 (df =49, p = 0.75). Similarly, there was no significant change in oxygen saturation, which dropped slightly from 95.0 (SD = 1.1) to 94.8 (SD = 1.0) with a t-statistic of 1.01 (df = 49, p = 0.32). A drop in muscle activity from 112.0 (SD = 9.0) to 108.5 (SD = 0.0) was confirmed by a t-statistic of 1.25 (df = 49, p = 0.22). The GSR also showed stability, declining from 52 (SD = 11) to 51 (SD = 9), with a *t*-statistic of 0.47 (df =49, p = 0.64). Overall, these results indicate the potential advantages of music as a motivating and performance-boosting assistance in sports situations, indicating that working out without music had no discernible effect on the physiological reactions of athletes in Group B.

Table 3. Values for Group B.

Variable	Mean Pre-Exercise (SD)	Mean Post-Exercise (SD)	*t*-Statistic	df	*p*-value
HRV	44.8 (5.1)	45.1 (5.0)	0.32	49	0.75
Oxygen Saturation	95.0 (1.1)	94.8 (1.0)	1.01	49	0.32
Muscle Activity	112.0 (9.0)	108.5 (0.0)	1.25	49	0.22
GSR	52 (11)	51 (9)	0.47	49	0.64

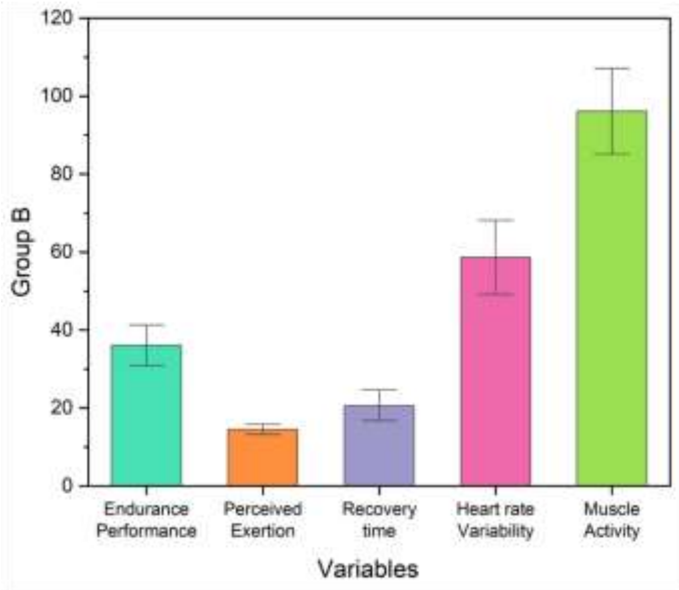

Figure 2. Group B performance for paired *t*-test.

4.2. Independent *t*-test

Significant disparities in a number of performance parameters between the two athlete groups are shown in **Table 4** and **Figure 3**. With a *t*-value of 4.32 and a *p*-value of 0.000, Group A, who exercised while listening to music, had better endurance performance (32.4 ± 4.5) than Group B (36.1 ± 5.2), suggesting a high effect size (Cohen's *d* = 1.00). A *t*-value of 5.10 and *p*-value of 0.000 indicate an even greater effect size (Cohen's *d* = 1.15), with participants in Group A reporting lower perceived effort (12.6 ± 1.2) compared to those in Group B (14.5 ± 1.3). Furthermore, Group A recovered faster (15.8 ± 3.1 min) than Group B (20.4 ± 3.7 min), with a moderate effect size (Cohen's *d* = 0.90) indicated by a *t*-value of 3.87 and a *p*-value of 0.000. *T*-value of 3.56 and *p*-value of 0.001 (Cohen's *d* = 0.85) were obtained by comparing the HRV values of Group A (65.4 ± 8.2) and Group B (58.6 ± 9.5). Group A had higher muscular activity as determined by muscle activity (105.3 ± 12.4) than Group B (96.1 ± 11.0). *T*-value of 2.45 and *p*-value of 0.017 suggest an average to moderate effect size (Cohen's *d* = 0.65). According to the results, working out while listening to music improves athletic performance, lowers perceived effort, and speeds up recovery.

Table 4. Independent *t*-test values for Group A and B.

Variable	Group A (Music)	Group B (No Music)	*t*-value	*p*-value	Effect Size (Cohen's d)
Endurance Performance	(32.4 ± 4.5)	(36.1 ± 5.2)	4.32	0.000	1.00
Perceived Exertion	(12.6 ± 1.2)	(14.5 ± 1.3)	5.10	0.000	1.15
Recovery Time	(15.8 ± 3.1)	(20.4 ± 3.7)	3.87	0.000	0.90
HRV	(65.4 ± 8.2)	(58.6 ± 9.5)	3.56	0.001	0.85
Muscle activity	(105.3 ± 12.4)	(96.1 ± 11.0)	2.45	0.017	0.65

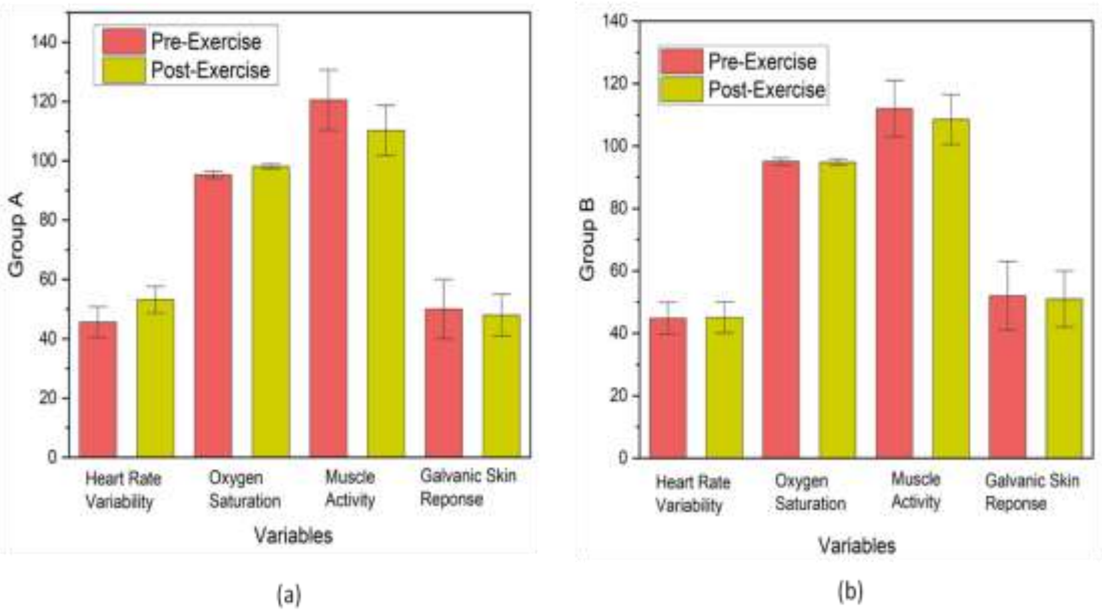

Figure 3. Independent *t*-test; **(a)** Group A **(b)** Group B.

4.3. Pearson's Correlation Coefficients

The correlation matrix in Group A shows a number of physiological indicators and motivation levels to be significantly correlated in **Table 5**. Higher motivation is related to improved autonomic control, as demonstrated by the substantial positive association between motivation levels and HRVat 0.60. Additionally, there is a favorable relationship between motivation andmuscle activity (0.40) and oxygen saturation (0.50), indicating that motivated athletes could utilize oxygen more effectively and activate their muscles more effectively during exercise. The weaker and non-statistically significant connection with GSR (0.10) suggests that motivation and this physiological measure have a small impact. HRV also demonstrates a weak correlation with muscle activity (25), GSR (15), and oxygen saturation (0.30), indicating that although HRV is related to overall physiological function, its relationship with skin response and muscle activity remains less.

Table 5. Group A values for correlation.

Variable	Motivation Level	HRV	Oxygen Saturation	EMG	GSR
Motivation Level	1.00	0.60	0.50	0.40	0.10
HRV	0.60	1.00	0.30	0.25	0.15
Oxygen Saturation	0.50	0.30	1.00	0.20	0.25
Muscle activity	0.40	0.25	0.20	1.00	0.15
GSR	0.10	0.15	0.25	0.15	1.00

The correlation matrix in Group B shows the connections between the several variables that were assessed in **Table 6** during the workouts. With a value of 0.25, the strongest link was discovered between HRV and motivation level. This suggests a modest positive association, indicating that improved HRV could be marginally correlated with higher motivation. While muscle activity demonstrated no relationship with other variables, maximum at 0.10 with motivation and HRV, oxygen saturation showed a similar modest link with both motivation (0.15) and HRV (0.15). With all correlations below 0.10, GSR showed the poorest associations. Overall, Group B's correlations indicate a limited dependency between muscular activity, motivation, and physiological indicators, highlighting the fact that these variables did not significantly affect one another during the music-free exercise.

Table 6. Group B values for correlation.

Variable	Motivation Level	HRV	Oxygen Saturation	EMG	GSR
Motivation Level	1.00	0.25	0.15	0.10	0.05
HRV	0.25	1.00	0.15	0.10	0.05
Oxygen Saturation	0.15	0.15	1.00	0.05	0.10
Muscle activity	0.10	0.10	0.05	1.00	0.05
GSR	0.05	0.05	0.10	0.05	1.00

4.4. MANOVA

Significant differences between the two groups (A: Exercising with music and B: Exercising without music) are demonstrated in **Table 7** and **Figure 4**, the MANOVA findings for physiological measurements across a number of variables. With an *F*-value of 12.34 and a *p*-value of 0.001, Group A's mean for Heart Rate Variability (HRV) was 85.4 (SD = 10.2), whereas Group B's mean was 78.1 (SD = 9.7). This provided rise to a partial eta squared of 0.24, which indicates a substantial effect size. Significant variations were observed in oxygen saturation, with Group A's mean of 97.1 (SD = 1.3) and Group B's having 95.6 (SD = 1.5). A medium effect size was indicated by a partial eta squared of 0.18, $F = 8.56$, and $p = 0.004$. Similarly, muscle activity was impacted, with Group A's mean of 56.7 (SD = 7.4) and Group B's was 62.3 (SD = 6.8). This resulted in a substantial effect size, with *F*-value of 10.67 ($p = 0.002$) and a partial eta squared of 0.22. Group A's mean GSR was 65 (SD = 9.0) whereas Group B's was 58 (SD = 7.0). This resulted in an F-value of 5.89 and a *p*-value of 0.019, with a partial eta squared of 0.12, indicating a small effect size. All of these results indicate to the beneficial effects of music on athletes' physiological reactions during their exercise.

Table 7. MANOVA test outcomes for Group A and B.

Variable	Group	Mean	SD	*F*-value	*p*-value	Partial Eta Squared
Heart Rate Variability	A	85.4	10.2	12.34	0.001	0.24
	B	78.1	9.7			
Oxygen Saturation	A	97.1	1.3	8.56	0.004	0.18
	B	95.6	1.5			
Muscle Activity	A	56.7	7.4	10.67	0.002	0.22
	B	62.3	6.8			
Galvanic Skin Response	A	65	9.0	5.89	0.019	0.12
	B	58	7.0			

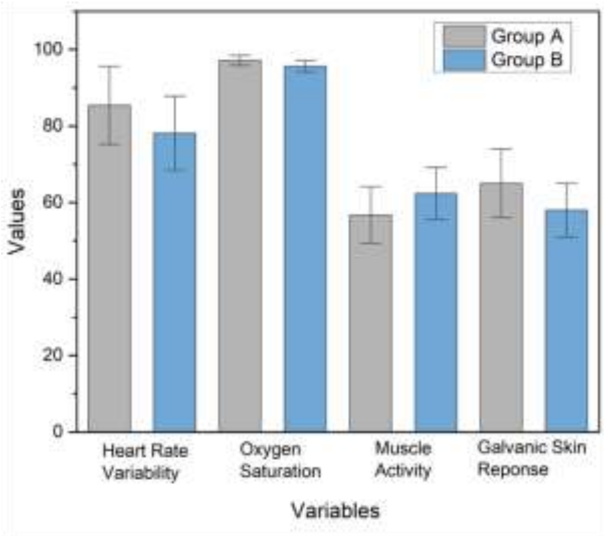

Figure 4. MANOVA performance for Group A and B.

5. Discussion

Independent *t*-tests were employed to compare the performance of those who exercised with music and those without music, paired *t*-tests were used to compare recovery times pre- and post-exercise within each group. It determined the strengths of associations between performance results and motivation levels using the Pearson's correlation coefficients. By using MANOVA if it affects multiple factors immediately it provides an in-depth understanding of music change to athletic performance and recovery. HRV and oxygen saturation both significantly improved after exercise in Group A, according to the paired *t*-tests, with *p*-values less than 0.001. Although GSR remained constant but also showed a statistically significant shift, EMG decreased after exercise, indicating a decrease in muscle activation. Group B did not show any discernible changes in muscle activity, oxygen saturation, HRV, and GSR pre and post-exercise, according to a *P*-value greater than 0.05. Exercise did not appear to have a discernible effect on these variables in this group, according to the t-statistics and mean differences. The findings of the independent *t*-test show that Group A (music) performed considerably better than Group B (no music) on a number of metrics, such as perceived effort and endurance performance, with all *p*-values being less than 0.05. Music appears to have a significant to moderate impact on performance outcomes, especially in endurance performance and perceived effort, according to the effect sizes (Cohen's d). HRV and oxygen saturation have a substantial positive link with motivation level, according to Group A's Pearson correlation values, which show coefficients of 0.60 and 0.50, respectively. Stronger correlations are found between other variables, especially between motivation level and GSR, which has a very modest correlation of 0.10. Motivation level, HRV, oxygen saturation, EMG, and GSR all have weak associations, according to Group B's Pearson correlation values, with the strongest connection between the two at 0.25. All things considered, these findings indicate few linear correlations between the variables in this cohort. Heart rate variability, oxygen saturation, muscular activity, and galvanic skin reaction are among the physiological measurements where the MANOVA findings show significant differences between Groups A and B, with *p*-values less than 0.05. Partial eta squared values, which indicate impact sizes, indicate moderate to substantial effects for the majority of measurements, especially muscular activity and HRV.

6. Conclusion

This study uses biosensor monitoring to identify physiological and psychological changes as it examines how music affects athletes' performance. Two groups of 100 athletes were randomly assigned: Group A (n = 50) exercised while listening to music, while Group B (n = 50) exercised without any music. Every participant engaged in the same physical activities, including strength training and endurance runs. EMG, oxygen saturation, HRV, and GSR were all evaluated using biosensors. Additionally, participants self-reported their actual exertion and inspiration levels. Paired *t*-test, independent *t*-test, MANOVA, and Pearson correlation coefficient are used. In the paired *t*-test there is no changes in Group B, while Group A has improved exercise in oxygen saturation and HRV ($p < 0.001$). Group A outperformed in perceived effort and endurance scores ($p < 0.05$), showing the motivational effect of music. The indices of Group A were very much linked with HRV, oxygen saturation, and motivation, while poor correlational values were obtained in Group B treatment using Pearson correlation. MANOVA confirmed significant differences between the groups in physiological parameters, especially muscle activity and HRV ($p < 0.05$).

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Ethical approval: Not applicable.

Limitations: According to the research, adding customized music playlists to training programs could improve athletes' performance. Individual differences in how they react to music and the narrow range of biosensors that were employed could limit the experiment's capacity to fully capture all physiological factors affecting athletic performance.

Future scope: Future studies could examine the long-term benefits of music on athletic training and performance enhancement, investigate a wider variety of musical genres, and integrate innovative biosensor technology for thorough physiological monitoring.

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

References

1. Nixon KM, Parker MG, Elwell CC, et al. Effects of music volume preference on endurance exercise performance. Journal of Functional Morphology and Kinesiology. 2022; 7(2): 35.
2. De La Cruz N. Evaluating the Impact Music May Have on High School Student-Athletes (Doctoral dissertation, University of Arizona Global Campus). 2021.
3. Wu J, Zhang L, Yang H, et al. The effect of music tempo on fatigue perception at different exercise intensities. International Journal of Environmental Research and Public Health. 2022; 19(7): 3869.

4. Shepherd D, Pedersen M, Vashista G, et al. Investigating the ability of music to induce calm in young adults. BioRxiv; 2024. pp. 2024–02.
5. Gill A. Enhancing music performance self-efficacy through psychological skills training. Unpublished doctoral dissertation]. University of Melbourne. 2020.
6. Chen CC, Chen Y, Tang LC, Chieng WH. Effects of interactive music tempo with heart rate feedback on physio-psychological responses of basketball players. International Journal of environmental research and Public Health. 2022; 19(8): 4810.
7. Küçükkurt A. Running with music: analyzing experiences and interactions of runners with digital and tangible interfaces (Master's thesis, Middle East Technical University). 2023.
8. Yang L, Du H. The Role of Psychological Suggestion Combined With Sports in Music Teaching. Revista de Psicología del Deporte (Journal of Sport Psychology). 2023; 32(4): 437–446.
9. Van Dyck E, Buhmann J, Lorenzoni V. Instructed versus spontaneous entrainment of running cadence to music tempo. Annals of the New York Academy of Sciences. 2021; 1489(1): 91–102.
10. Zhuang N, Weng S, Bao S, et al. October. Personalized synchronous running music remix procedure for novice runners. In International Conference on Entertainment Computing. Cham: Springer International Publishing; 2022. pp. 372–385.
11. Sedikides C, Leunissen J, Wildschut T. The psychological benefits of music-evoked nostalgia. Psychology of Music. 2022; 50(6): 2044–2062.
12. Zarian E, Mohamadi Orangi B, Yaali R, et al. Effect of Aerobic Rhythmic Exercises with and without Music on Emotional Intelligence and Motor Proficiency in Preadolescent Males. International Journal of Motor Control and Learning. 2021; 3(2): 3–13.
13. Louis K. Effects of Different Types of Music on Exercise Performance and Enjoyment among College Students in Germany. International Journal of Physical Education, Recreation and Sports. 2024; 2(1): 1–12.
14. Jebabli N, Khlifi M, Ouerghi N, et al. Single and combined effects of preferred music and endpoint knowledge on jump performance in basketball players. Sports. 2023; 11(5): 105.
15. Liu C, Li Z, Du X. The effect of musical stimulation in sports on sports fatigue of college students. Journal of Internet Technology. 2021; 22(1): 187–195.
16. Meglic CE, Orman CM, Rogers RR, et al. Influence of warm-up music preference on anaerobic exercise performance in division I NCAA female athletes. Journal of Functional Morphology and Kinesiology. 2021. 6(3): 64.
17. Karow MC, Rogers RR, Pederson JA, Williams, T.D., Marshall, M.R. and Ballmann, C.G., 2020. Effects of preferred and nonpreferred warm-up music on exercise performance. Perceptual and motor skills, 127(5): 912–924.
18. Zhou N. Improvement and Recovery of Athletes' Physical Fitness by Music Regulation Combined with Sports Nutrition. Art and Performance Letters. 2021; 2(6): 52–62.
19. Pettit JA, Karageorghis CI. Effects of video, priming, and music on motivation and self-efficacy in American football players. International Journal of Sports Science & Coaching. 2020; 15(5–6): 685–695.
20. Ouergui I, Jebabli E, Delleli S, et al. Listening to preferred and loud music enhances taekwondo physical performances in adolescent athletes. Perceptual and Motor Skills. 2023; 130(4): 1644–1662.
21. Léonard C, Desaulniers-Simon JM. Tat D, et al. Effects of Music Intervention on Stress in Concussed and Non-Concussed Athletes. Brain sciences. 2021; 11(11): 1501.
22. Torkamandi P, Akbarnejad A, Gaeini AA, GharecheshmeiGhahremanloo A. The Effects of Music Intensity on Performance and Cardiovascular Responses in Athletes. Sport Sciences and Health Research. 2020. 12(1): 93–100.
23. Ballmann CG, McCullum MJ, Rogers RR, et al. Effects of preferred vs. nonpreferred music on resistance exercise performance. The Journal of Strength & Conditioning Research. 2020; 35(6): 1650–1655.
24. Jebabli N, Ben Aabderrahman A, Boullosa D, et al. Listening to music during a repeated sprint test improves performance and psychophysiological responses in healthy and physically active male adults. BMC Sports Science, Medicine and Rehabilitation. 2020; 15(1): 21.
25. Wang HT, Chen YS, Rekik G, et al. The effect of listening to preferred music after a stressful task on performance and psychophysiological responses in collegiate golfers. PeerJ. 2022; 10: e13557.
26. Park KS, Williams DM, Etnier JL. Exploring the use of music to promote physical activity: From the viewpoint of psychological hedonism. Frontiers in Psychology. 2023; 14: 1021825.

27. Hörster A, Hansen J. Self-consciousness and trait anxiety influence music performance in high-pressure situations. Musicae Scientiae. 2024; 10298649241249667.