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Section II - Exercise Physiology & Sports Medicine

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The Effects of Preferred Music and Its Timing on Performance, Pacing, and Psychophysiological Responses During the 6-min Test

by
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The aim of this study was to investigate the effects of listening to preferred music during a warm up or exercise, on performance during a 6-min all-out exercise test (6-MT) in young adult males. Twenty-five healthy males volunteered to participate in this study. Following a within subject design, participants performed three test conditions (MDT: music during the test; MDW: music during the warm-up; WM: without music) in random order. Outcomes included mean running speed over the 6-min test (MRS6), total distance covered (TDC), heart rate responses (HR_{peak}, HR_{mean}), blood lactate (3-min after the test), and the rating of perceived exertion (RPE); additionally, feeling scale scores were recorded. Listening to preferred music during running resulted in significant TDC (Δ↑10%, p=0.006, ES=0.80) and MRS6 (Δ↑14%, p=0.012, ES=1.02) improvement during the 6-MT, improvement was also noted for the warm-up with music condition (TDC:Δ↑8%, p=0.028, ES=0.63; MRS6:Δ↑8%, p=0.032, ES=0.61). A similar reverse "J-shaped" pacing profile was detected during the three conditions. Blood lactate was lower in the MDT condition by 8% (p=0.01, ES=1.10), but not the MDW condition, compared to MW. In addition, no statistically significant differences were found between the test sessions for the HR, RPE, and feeling scale scores. In conclusion, listening to music during exercise testing would be more beneficial for optimal TDC and MRS6 performances compared to MDW and WM.

Key words: *rating of perceived exertion, work-rate distribution, blood lactate, aerobic exercise.*

Introduction

It is well-documented that listening to music has positive ergogenic effects, particularly during aerobic events (Barwood et al., 2009; Edworthy and Waring, 2006; Maddigan et al., 2019; Jebabli et al., 2020). Moreover, it is well known that listening to music can improve physical, physiological, and psychological

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benefits during exercise (Edworthy and Waring, 2006; Jebabli et al., 2020; Karageorghis et al., 2013; Maddigan et al., 2019; Shaulov and Lufi, 2009). According to Maddigan et al. 2019; Remiszewska et al., 2020), listening to music induced increases in physical performance, breathing frequency, respiratory exchange ratio, a decrease in the rating of perceived exertion (RPE), as well as faster heart rate (HR) recovery compared to a control condition (no music). These results support the notion that music can modify the interplay between central motor drive, central cardiovascular command, and perceived exertion. Attention has been paid to several music features such as a tempo (Birnbaum et al., 2009; Dalton et al., 2007), type (Cole and Maeda, 2015), synchronicity with the activity (Terry et al., 2012), and the type and intensity of exercise (Dyck et al., 2016). For instance, Birnbaum et al. (2009) reported that listening to music with a fast tempo enhanced aerobic performance with improvement in cardiovascular and respiratory responses compared to a slow tempo condition in healthy college-aged students. Concerning the music type, Cole and Maeda (2015) found that listening to preferred vs. non-preferred music had a greater positive effect on the 12-min Cooper test performance in young healthy females. Considering synchronized music, it has been reported that music provides ergogenic benefits during exercise, especially when movements are performed synchronously with music (Terry et al., 2012). The choice of the type and intensity of exercise is another factor which may influence physical performance. In fact, Dyck et al. (2016) suggested that the ergogenic effect of music declined with increasing intensity levels. Also, Elliott et al. (2005) reported that music could have a positive effect, especially during low-to-moderate intensity exercise (i.e., below the anaerobic threshold). Another important feature refers to the time of music application (i.e., either during exercise or a warm-up). Previous studies have investigated the effect of music on performance during submaximal (Maddigan et al., 2019; Thakare et al., 2017) and maximal (Copeland and Franks, 1991; Szabo et al., 1999) exercises. On the other hand, other studies have attempted to evaluate the effects of music during a warm-up (Eliakim et al., 2007; Yamamoto et al., 2003). According to Bigliassi et al. (2012), listening to music in different moments of the exercise session (during a warm-up, during exercise) did not affect physical condition, the heart rate, RPE and mood state during a 5-km cycling time-trial. However, there is a need for more studies comparing the effects of different times for music application in other activities such as running.

During aerobic events, athletes generally regulate their energy during competition in order to optimize performance (Abbiss and Laursen, 2008; Joseph et al., 2008; St Clair Gibson et al., 2005). This distribution, called pacing strategy, refers to the variation of velocity by regulating the rate of energy expenditure, it also aims to prevent homeostatic disturbances during exercise or competition (Tucker and Noakes, 2009). Athletes choose naturally a fast beginning with high velocity, greater than the mean velocity for the race, with a gradual decrease during 80-90% of the entire distance followed by an increase in the pace during the last 10-20% of the race (end-spurt) (Atkinson et al., 2004; Joseph et al., 2008; St Clair Gibson et al., 2005). However, it is not known whether fast-start pacing strategies are the best choice for optimal performance. A theoretical framework offered by Noakes (2011) indicates that pacing strategy depends on specific factors such as knowledge of the endpoint (Hamilton and Behm, 2017), the performance level, the presence of competitors (Tomazini et al., 2015), and also music (Atkinson et al., 2004; Elliott et al., 2005; Lima-Silva et al., 2012). Regarding music, it has been reported that music conditions can affect performance and pacing (Atkinson et al., 2004; Elliott et al., 2005; Lima-Silva et al., 2012). Indeed, previous studies have found that music helps participants improve performance, suggesting that it may be a consequence of a change in intentional focus (Baden et al., 2004; Lima-Silva et al., 2012). It has been reported that athletes follow two different intentional pathways during exercise: association, where they focus on body signals, and disassociation, where attention is directed to external cues such as music. That is to say that music may be able to distract the intentional focus from body signals in order to reduce the RPE and improve physical performance. In contrast, Jebabli et al. (2020) showed that listening to the preferred music during exercise improved the total distance covered with an increase in running speed throughout the 6min test without a reduction in the RPE or change of the pacing strategy profile among male sport-science students with no professional experience in middle distance running. On the basis of existing studies, it is still difficult to achieve a definitive conclusion as to whether music features and pacing profiles can simultaneously influence physical performance. Few studies have introduced whether listening to music during a warm-up or exercise can improve performance from the regulation of pacing strategy executed under real competition conditions such as against a time-trial with medium duration. To date, it is unresolved whether the moment of application impacts performance and physiological outcomes.

Consequently, the main aim of the current study was to examine the effects of listening to preferred music delivered at different time points of the session compared with not listening to music on a 6-min "all out" running test performance in adult male young men.

Based on previous findings suggesting that preferred music improves physical performance during aerobic exercise (Jebabli et al., 2020; Lima-Silva et al., 2012), we hypothesized that listening to preferred music during a warm-up or exercise could improve physical performance compared with no music condition. This improvement could increase running speed of exercise without changing the pacing profile.

Methods

Participants

Twenty-five male sport-science students aged 21.0±1.1 years (body mass:71.3±7.1kg; body height:1.80±0.2m; BMI:22.0±1.7kg/m^2) volunteered to take part in this study. The sample size of our study was calculated (G*Power 3.1 software, Germany) with assumed α=0.05, and an effect size=0.55. The results revealed that 22 participants would be needed to reach 80% of statistical power. Therefore, we recruited few additional participants (n=25) to take potential drop-outs into consideration.

These participants were selected because they were active in athletics (6h·wk^{-1}) and with previous competitive experience in middle distance running (3±1 years). There were no participants who reported neuromuscular disorders or specific musculoskeletal injuries of ankles, knees or hips according to medical examinations. Participants performed all the tests at the same time of day, under three experimental conditions in counterbalanced order separated by at least 72 hours. Participants were asked to follow a balanced diet (10 kcal/kg, 55% of which came from carbohydrates, 33% from lipids and 12% from proteins, as determined by an experienced nutritionist). Written informed consent was obtained from all participants after verbal and written explanations of the experimental design and potential risks of the study. The present study was conducted according to the latest version of the Declaration of Helsinki, and the protocol was fully approved by the Ethics Committee of the High Institute of Sports and Physical Education of University of La Manouba (Tunisia) before the commencement of the tests.

Procedures

Familiarisation testing and the Vameval test

The week before the main experiment, all test procedures, instruments, and equipment were explained and practiced. After anthropometric measures, participants performed the Vameval test, on two different days, to assess maximal aerobic speed (MAS) and to estimate maximum oxygen uptake (VO_{2max}).

Experimental sessions

Participants completed three exercise sessions (6-MT) individually and in random order: (1) listening to the preferred music during the 6-min all-out exercise test (6-MT) (MDT), (2) listening to the preferred music during the warm-up (MDW), and (3) without music (WM). Before the tests started, participants performed a standard 10-min warm-up, including 4-min of light jogging, lateral displacement, dynamic stretching and jumping. For each condition, participants had to run for 6-min as fast as possible to cover the greatest possible distance. Figure 1 represents the experimental protocol. Participants were asked to select their preferred music with which they felt more inclined to the 6-MT. Using the "Edjing Mix" application (version 6.45.00, Android, France), we observed that the mean rhythm for the preferred song chosen by participants was characterized by a fast rhythm (130±10 beats·min^{-1}). All preferred tracks were played only 6-min, using the same mp3 player (Beats Power beats Wireless, Beats Electronics Ttc, US), always keeping the same volume (moderate music, 70dB) for all participants. During experimental sessions, all procedures were separated by at least 48-h.

Vameval Test

The Vameval test was performed on a 400-m outdoor running track. Twenty cones were placed on the track every 20-m as a mark. The test was started at a running speed of 8.5km·h^{-1} and speed was increased by 0.5km·h^{-1} every minute until exhaustion (Cazorla and Léger, 1993). Participants adjusted their running speed to the audio beep at 20-m intervals. The test ended when the participant could no longer maintain the required running speed dictated by the audio beep, for 2 consecutive occasions. MAS corresponded to the last completed stage and was used for further analysis. Pilot data from 25 participants collected on two different days were used to determine the reproducibility of the test (ICC 0.951; 95%CI: 0.948-0.964).

6-min all-out exercise test

The 6-min all-out exercise test (6-MT) was conducted on a 400m outdoor track (Bolonchuk, 1975). After a 10-min warm up which included running, walking and stretching exercises, participants were required to maintain the fastest possible running speed throughout the entire test. As a reference, marks were placed at 20m intervals along the 400m athletics track to measure the distance covered and calculate running speed each 30s. The 6-MT performance variables were mean running speed over the 6-min (MRS6), and total distance covered (TDC).

No verbal encouragement was provided during tests. Also, participants were not informed of the time-elapsed or time-remaining to avoid external influence on pacing. Both the peak heart rate (HR_{peak}) and mean heart rate (HR_{mean}) values were evaluated during the tests using a heart rate monitor (Polar team 2, Polar Electro Oy, Finland). Immediately after the test, the rating of perceived exertion (RPE) scale (6-20 Borg-scale; Borg, 1982) was used to measure the overall physical perceptions of exertion. Also, the feeling scale (FS) was used to measure the affective dimension (pleasure and displeasure), ranging from -5 (Very bad) to +5 (Very good) (Hardy and Rejeski, 1989). The instructions were as follows: "try to inform us, by a number, on your inner feeling without concerning yourself with feelings of physical stress, effort, and fatigue". The RPE scale was presented first, immediately followed by the FS. Three minutes after the test, blood lactate concentrations were measured using a portable Lactate Monitor (lactate pro2, Akray, Japan).

Statistical analyses

Data were expressed as means and standard deviations (SD). Normality of data was assessed and confirmed using the Kolmogorov-Smirnov test. The reliability of the Vameval test and 6-MT was assessed by the intra-class correlation coefficient (ICC).

A one-way analysis of variance (ANOVA) was performed for total distance covered, MRS6, HR_{peak}, HR_{mean}, lactate, RPE, and FS to compare differences between the three conditions.

Two-way analysis of variance (ANOVA) (3 conditions: MDT, MDW, WM) x 12 (times: every 30-s over the 6 min run) was computed for 30 s running speed interval comparisons. When significant differences were observed, Bonferroni post hoc tests were used. Effect sizes were classified according to Hopkins et al. (2009) as trivial ≤0.2, small >0.2–0.6, moderate >0.6–1.2, large >1.2–2.0, and very large >2.0 magnitudes. The level of significance was set at $p \leq 0.05$. All analyses were carried out using SPSS 16 for Windows (SPSS, version 17 for Windows. Inc., Chicago, IL, USA).

Results

TDC and MRS6 performances measured during the 6-MT are displayed in Table 1. A significant increase in TDC and MRS6 values was found between MDT (TDC:Δ↑10%; p=0.006; ES=0.80; MRS6:Δ↑14%; 112% MAS; p=0.012; ES=1.02) and MDW (TDC:Δ↑8%; p=0.028; ES=0.63; MRS6:Δ↑8%; 107%MAS; p=0.032; ES=0.61) conditions compared to WM, during the 6-AOET. No significant difference was observed between MDT and MDW conditions during the 6-MT.

Figure 2 presents the effects of listening to preferred music at different moments on mean speed at each 30-s interval during the 6-MT. No significant condition×time interactions were observed (p=0.431; ES=0.02). However, our results showed a significant main effect of condition (p=0.021; ES=0.10) and a significant mean effect of time (p<0.001; ES=0.78) between the three conditions. A significant increase in speed

($p<0.05$) was found in both MDT and MDW compared to the WM condition. However, no significant ($p>0.05$) change in speed was observed between MDT and MDW.

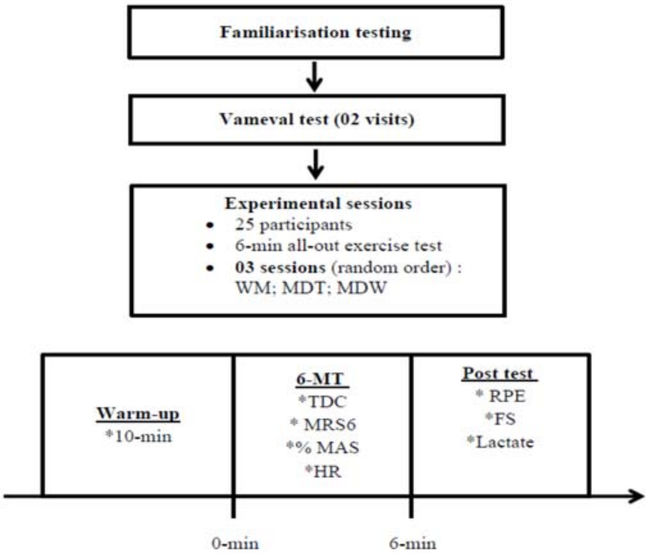

Figure 1

The experimental protocol.
6-MT: 6-min all-out exercise test; WM: without music; MDT: music during the test; MDW: music during the warm-up; MRS6: mean running speed over the 6-MT; % MAS: mean data of maximal aerobic speed; TDC: total distance covered; HR: heart rate; RPE: rating of perceived exertion, FS: feeling scale.

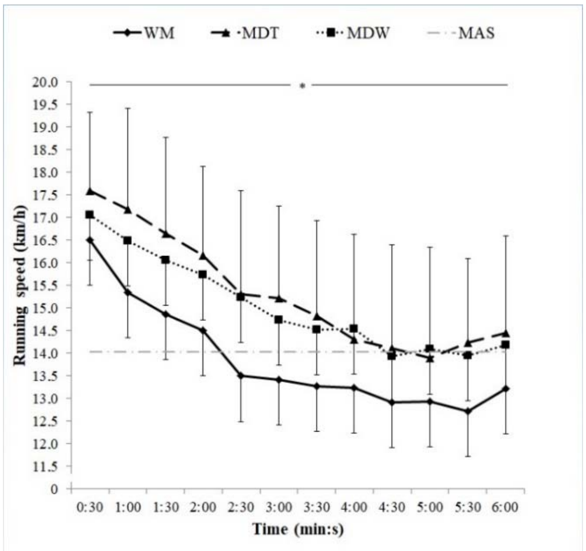

Figure 2
The effect of the moment of listening to music on speed at each 30-s interval during a 6-min running exercise.
*WM: without music; MDW: music during a warm-up; MDT: music during the test; MAS: mean data of maximal aerobic speed; * significant main effect of condition ($p<0.05$).*

Table 1

*The effect of the timing of listening to music on physical performance, heart rate, and RPE, during and after 6-min running exercise. Data were expressed as means ± standard deviations; WM: without music; MDW: music during the warm-up; MDT: music during the test; ES: effect size; %MAS: the percentage of mean running speed in variation with mean data of maximal aerobic speed of the Vameval test; HR: heart rate; FS: feeling state; Lac: blood lactate; AU: arbitrary units. ¥ significantly different between the three conditions; * significantly different between MDT vs. WM at p<0.05; Ŧ significantly different between MDW vs. WM (p<0.05); no significant difference between MDT and MDW (p>0.05).*

	WM	MDW	MDT	*p*	ES
Total distance covered (m)	1396.68±175.38	1510±183.97 Ŧ	1539±177.43*	0.015¥	0.89
Mean running speed (km/h)	13.87±1.85	15.04±1.96 Ŧ	15.75±1.82*	0.020 ¥	0.10
	99% MAS	107% MAS	112% MAS		
HRpeak (beat/min)	192.30±8.07	192.30±8.09	191.40±8.40	0.885	0.41
HRmean (beat/min)	177.69±9.41	179.21±7.47	178.12±7.02	0.490	0.23
RPE (AU)	17.40±1.24	16.90±1.00	17.30±1.41	0.475	0.19
La (mmol/L)	17.30±1.38	15.96±1.48	15.84±1.25*	0.048¥	0.56
FS (AU)	2.05±0.94	2.20±1.00	1.45±1.50	0.113	0.30

Pacing strategies were not modified during MDT, MDW or WM since participants adopted the same reversed "J-shaped" profile.

Regarding metabolic responses, a significantly lower blood lactate concentration was recorded during MDT when compared to WM condition (Δ↓8%, *p*=0.01, ES=1.10). However, no significant difference was observed between MDT and MDW conditions during the 6-MT. Also, no significant changes were recorded in the HR_{peak}, HR_{mean}, RPE, and feeling scale scores between particular conditions.

Discussion

The main purpose of this study was to analyze the effect of listening to preferred music and its timing during a 6-min all-out exercise test on performance and pacing, blood lactate, heart rate, RPE and feeling scale scores. In agreement with our research hypothesis, the main results of this study were that both MDT and MDW improved TDC with an increase in mean running speed throughout the 6-MT compared to WM condition. Additionally, a significant decrease in blood lactate at 3-min after the end of the test was also observed in MDT only. In agreement with our research hypothesis, participants adopted the same reversed "J-shaped" profile for all conditions. In contrast to previous research which used ergometers under laboratory conditions, the current study used an outdoor self-paced running exercise to better reflect the real-world training conditions, thus making the present findings useful for further applications in the field (i.e., more representative of a "real world" exercise situation).

The current results are in line with a number of laboratory studies which have previously shown the beneficial effects of music on continuous aerobic performance (>3-min) by enhancing submaximal exercise performance duration (Maddigan et al., 2019; Thakare et al., 2017), maximal exercise (Copeland and Franks, 1991; Szabo et al., 1999) or total distance covered (Barwood et al., 2009; Edworthy and Waring, 2006).

In our study, TDC values improved during MDT and MDW compared to WM condition. In addition, a significant main effect of condition (*p*=0.021; ES=0.102) was observed. It has been shown that the use of music during a warm-up (Macone et al., 2006) and during exercise (Barwood et al., 2009; Edworthy and Waring, 2006), results in improved aerobic performance. However, other studies showed that music neither during a warm-up or during exercise could improve performance (Bigliassi et al., 2012; Elikim et al., 2007). Therefore, it is necessary to carefully study the interaction of different aspects of music such as the rhythm, the type, the volume and the harmony of the music. As part of our study, these factors were controlled in order to have a major effect on physical performance.

During the 6-MT, participants adopted the same reversed "J-shaped" profile speed with no significant end spurt during the 6-MT under the three conditions. During the J-shaped profile, the participant ran faster at the start, then the speed reduced progressively with a small increase (non-significant) during the end spurt. In accordance with the present study, Jebabli et al. (2020) reported that listening to preferred music during 6 min self-paced maximal exercise improved performance without changing the pacing strategy profile. In addition, Tucker et al. (2004) reported that acceleration at the last minute of exercise during the music condition could be an indication of the maintenance of a reserve capacity, thus allowing the speed to increase secondary to an increase in the central neural drive to exercising muscles. They also observed no significant difference between music and control conditions. Similarly, Bigliassi et al. (2012) reported that listening to music in different moments (during a warm-up and exercise) did not affect performance and psychophysiological variables during a 5-km cycling time-trial.

In the present study, post-exercise blood lactate concentrations were significantly lower during exercise with MDT. This result is in accordance with Jebabli et al. (2020) who showed that blood lactate was significantly lower (9%) when compared to the control condition after the 6-min run test with preferred music. Those researchers suggested that the decrease in blood lactate under the music condition could be due to the relaxing effect of music, which led to a decrease in muscle tension, thereby increasing the blood flow and lactate clearance. It may be hypothesized that synchronization of movement with musical rhythm occurs, which enables participants to perform more efficiently, thus resulting in increased work output. In fact, Fritz et al. (2013) suggested that listening to music during biceps exercise could have improved blood flow to the working muscle and helped in lactate clearance and decreasing the production of plasma lactate. However, the current data were not in agreement with previous studies which have shown that maximal blood lactate concentrations were not significantly different between music and no music conditions (Dyer and Mckune, 2013; Hagen et al., 2013; Lee and Kimmerly, 2016). These differences could be due to the choice of music, the population studied, and the exercise protocols (Bigliassi et al., 2013). Therefore, further research on the effects of music during exercise on metabolic cost, neuromuscular and metabolic efficiency, and stress hormones is warranted. In contrast to blood lactate, there were no differences in HR_{mean} and HR_{peak}, between the three exercise conditions. Logically, if athletes work hard, their heart rate should increase. Conversely, Birnbaum et al. (2009) reported that the heart rate between music and no music groups remained relatively unchanged. However, Lee and Kimmerly (2016) reported that listening to fast music resulted in a faster self-selected running speed and a higher exercise HR during a 20-min self-paced maximal treadmill exercise. Likewise, Atkinson et al. (2004) reported that the improvement in 10-km cycling time was accompanied by a significant increase in the HR_{mean}. However, Dyer and McKune (2013) indicated that listening to music did not affect performance and HR during 20-km cycling in well-trained cyclists. Similarly, Yamashita et al. (2006) observed that the effect of music was not significant when exerting at intensities of 40% and 60% of maximal aerobic power and concluded that differences in autonomic nervous system activity were affected more by the exercise intensity than music. Results of that study (Yamashita et al., 2006) showed that participants increased their running speed without increasing their chronotropic responses, which may indicate that the cardiovascular system works more efficiently with music. Although the HR is considered the most practical variable for exercise monitoring, other indicators of the cardiovascular system could be adopted like stroke volume and cardiac output. Further research is needed to better clarify the effects of music on cardiac function and elucidate the contradictory findings.

Our results showed no significant difference in the RPE and FS between conditions despite the significant increase in running speed and TDC during experimental conditions. In other words, participants were able to run with higher intensity during the MDT condition, but were in a similar mood, perceived similar effort, strain, discomfort and fatigue at the end of test, as those experienced during MDW and WM conditions. This is in accordance with several studies which have shown no change in the RPE and FS when testing the effect of fast tempo music (> 140 beat/min) on aerobic performance (Brownley et al., 1995; Dyer and McKune, 2013; Lee and Kimmerly, 2016; Lima-Silva, 2012).

The current data are at odds with Potteiger et al. (2000) who observed that the RPE was significantly reduced after a 20 min run test under fast music compared to no-music condition. In addition, Terry et al. (2012) demonstrated that listening to motivational music was associated with more positive mood responses and FS compared to neutral music and no-music. Therefore, the specific characteristics of the music used in the current study (preferred music, moderate music volume and fast tempo) may explain differences with previous studies. A limitation of the current study is that we recorded the RPE and FS only at the end of the all-out test, which makes it difficult to compare our findings with those of other studies which recorded the RPE throughout the application of exercise protocols. The results of the current study showed that the RPE, HR and FS did not change significantly despite a significant improvement in TDC, MSR6 and a significant decrease in blood lactate concentrations. Borg et al. (1985) observed that the best prediction of the RPE requires a dual evaluation of the HR and lactate. Despite the fact that stroke volume is linked to changes in cardiac output (HR×stroke volume), lactate, respiratory quotient, VO_{2max}, and aerobic VO_{2max} capacity, Foster et al. (2007) indicated that the RPE was more influenced by the afferent feedback of the cardiovascular system (e.g., HR) rather than by metabolic activity (e.g., concentration of blood lactate). Therefore, future studies should expand on the relationship between the RPE and cardiovascular responses in the context of understanding the different responses with or without music interventions.

Conclusions

In conclusion, our results showed that listening to preferred music before or during exercise improved aerobic performance and decreased blood lactate without any change in other psychophysiological responses. Regardless of the time of application, music can improve running performance. Practitioners may consider using this strategy before and during exercise to enhance endurance running performance.

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