High tempo music prolongs high intensity exercise

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Music has been shown to reduce rating of perceived exertion, increase exercise enjoyment and enhance exercise performance, mainly in low-moderate intensity exercises. However, the effects of music are less conclusive with high-intensity activities. The purpose of this study was to compare the effects of high tempo music (130 bpm) to a no-music condition during repeated high intensity cycling bouts (80% of peak power output (PPO)) on the following measures: time to task failure (TTF), rating of perceived exertion (RPE), heart rate (HR), breathing frequency, ventilatory kinetics and blood lactate (BL). Under the music condition, participants exercised 10.7% longer ($p = 0.035$; Effect size (ES)= 0.28) (increase of one minute) and had higher HR (4%; $p= 0.043$; ES= 0.25), breathing frequency (11.6%; $p= 0.0006$; ES= 0.57), and RER (7% at TTF; $p= 0.021$; ES=1 .1) during exercise. Trivial differences were observed between conditions in RPE and other ventilatory kinetics during exercise. Interestingly, HR recovery was 13.0% faster following the music condition ($p< 0.05$). These results strengthen the notion that music can alter the association between central motor drive, central cardiovascular command and perceived exertion, and contribute to prolonged exercise duration at higher intensities along with a quicken HR recovery.

HIGH TEMPO MUSIC PROLONGS HIGH INTENSITY EXERCISE

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Running Title: Effect of Music on Exercise

Funding: There was no direct funding received for this research.

Conflict of Interest: There were no conflicts of interests with any of the authors.

ABSTRACT

Music has been shown to reduce rating of perceived exertion, increase exercise enjoyment and enhance exercise performance, mainly in low-moderate intensity exercises. However, the effects of music are less conclusive with high-intensity activities. The purpose of this study was to compare the effects of high tempo music (130 bpm) to a no-music condition during repeated high intensity cycling bouts (80% of peak power output (PPO)) on the following measures: time to task failure (TTF), rating of perceived exertion (RPE), heart rate (HR), breathing frequency, ventilatory kinetics and blood lactate (BL). Under the music condition, participants exercised

10.7% longer (p = 0.035; Effect size (ES)= 0.28) (increase of one minute) and had higher HR (4%; p= 0.043; ES= 0.25), breathing frequency (11.6%; p= 0.0006; ES= 0.57), and RER (7% at TTF; p= 0.021; ES=1 .1) during exercise. Trivial differences were observed between conditions in RPE and other ventilatory kinetics during exercise. Interestingly, HR recovery was 13.0% faster following the music condition (p< 0.05). These results strengthen the notion that music can alter the association between central motor drive, central cardiovascular command and perceived exertion, and contribute to prolonged exercise durations at higher intensities along with a quicken HR recovery.

Key Words: aerobic exercise, cycling, heart rate, lactate

INTRODUCTION

Music has long been thought to affect the senses (Szmedra and Bacharach 1998) and can act as an external distracting stimulus during exercise and thus enhance exercise enjoyment and performance (Karageorghis and Priest 2012A/B). Music is able to promote ergogenic and psychological benefits during exercise due to three proposed explanations (Karageorghis and Priest 2012A/B). First, music may allow individuals to separate thoughts from feelings. This divergence can change one's perception of unpleasant feelings, narrowing the performer's attention and reducing the sensations of fatigue during exercise (Atkinson et al. 2004; Edworthy and Haring 2006; Yamashita et al. 2006; Murrock and Higgins 2009). Second, the divergent stimulus (i.e. music) will somehow alter psychomotor arousal (movement or muscular activity associated with mental processes) and therefore can act as either a stimulant or a sedative prior to and during physical activity (Szmedra and Bahanach 1998; Yamamoto et al. 2003; Schucker et al. 2009). The third explanation postulates that during continual submaximal activity, an individual is predisposed to respond to rhythmical elements (music being one of many rhythmical patterns); the result being synchronization between the tempo and the performer's movement making physical activity or exercise a more harmonious or less stressful experience (Rendi et al. 2008; Waterhouse et al. 2009).

The available evidence on this topic is congruent and demonstrates that music can and does have a consistent and measurable effect on attention, the ability to trigger a range of emotions, affect mood, increase work output, and encourage rhythmic movement (Atkinson et al. 2004; Karageorghis 2008; Scherer 2004; Terry and Karageorghis 2011; Yamashita et al. 2006). The 'psychophysical' effects primarily examine the perception of effort (Pandolf 1978), which in almost all cases involves the Borg's Ratings of Perceived Exertion scale (RPE).

The effect of music on exercise in the low-to-moderate range of exercise intensities is a common trend in the literature (Karageorghis and Priest 2012). Since very high exercise intensities are affected to a high degree by muscle metabolite-induced failures (peripheral fatigue), there is a lesser influence of the central nervous system (central fatigue) compared to lower exercise intensities (Rejeski 1985; Tenenbaum 2004). However, it has been shown that peripheral fatigue alone is not able to explain the fatigue induced with higher intensity exercise (Noakes and Gibson 2004, Halperin et al. 2014). The few studies that have examined the effect of music on higher intensity exercise bouts show methodological weaknesses and a misuse of music terminology resulting in some incongruent results (Bharani, Sahu and Matthew 2004; Crust and Clough 2006; Nakamura et al. 2010; Schie, Stewart, Becker and Rogers 2008). In contrast, some recent studies using 'supramaximal' exercise, such as a Wingate test, have shown significant improvements in peak power output and decreases in fatigue index with the use of music (Brohmer and Becker 2006; Haluk, Turchian, and Adnan 2009). This seems to contradict the previous conclusions drawn by researchers that the 'distraction effect' of music is attenuated at higher exercise intensities (>70% maximal oxygen uptake – $\dot{V}O_{2max}$) due to the internal feedback dominating the capacity of the respective afferent nervous system (Karageorghis, Terry, Lane, Bishop and Priest 2011). More importantly, it highlights some significant gaps in the literature with regards to the so-called intensity limitations of music's benefits and the actual mechanisms that result in music's ergogenic effects on exercise performance. Further research is still necessary in order to draw decisive conclusions.

Therefore, the primary goal of this study was to examine if listening to high tempo music (130 bpm) while performing high intensity cycling bouts would improve a participant's time to task failure (TTF) and have a positive effect on the commonly seen physiological signs of fatigue.

METHODS

Subjects

Sixteen healthy and recreationally active individuals (Eight males: age 24.5 ± 3.4 yrs., mass 75.2 ± 7.4 kg, height 178.3 ± 6.2 cm, $\dot{V}O_{2max}$ 4.1 ± 0.4 L•min^{-1} and eight females: age 23.1 ± 3.0 yrs., mass 65.7 ± 4.7 kg, height 163.9 ± 5.3 cm, VO_{2max} 3.4 ± 0.3 L•min^{-1}) volunteered from the university community to participate in a counterbalanced randomized cross-over design study consisting of a preliminary testing session and two experimental sessions separated by a minimum of two days. All the participants filled out a Physical Activity Readiness Questionnaire from the Canadian Society for Exercise Physiology to determine physical activity level and to screen for a history of cardiovascular, pulmonary, metabolic and orthopedic conditions. The participants read and signed a consent form prior to the study. Subjects were blind to the hypotheses of the study. The Memorial University of Newfoundland Human Investigations Committee approved the study [IRB approval number: 11.26].

Experimental Design

Preliminary testing session

Upon the completion of questionnaire filling and anthropometric measurements, participants performed a ramp protocol starting at 50 watts at a self-selected cadence (> 60 revolutions per minute – RPM) with increment of 1 watt every 3 second to determine $\dot{V}O_{2max}$ and peak power output (PPO). The test was terminated when the participants reached one of the following criteria: 1) volitional exhaustion, 2) RPE value ≥ 19, or 3) RPM ≤ 60.

Experimental sessions.

Participants sat on a stationary bike with feet secured while wearing an oro-nasal facemask to record cardiorespiratory parameters for the duration of the experiment. Every minute during the 4-min of the high intensity cycling bout, participants were asked to rate their perceived exertion (RPE) on the Borg scale, (6 – 20). After each 4-min high intensity cycling bout, HR and BL were recorded. HR was continuously recorded throughout the session using a Polar® HR monitor. Upon exercise termination, four of the five pre-test measurements (minus blood pressure) were repeated (See description below). Participants were then asked to remain in position and relax for 5-min to ensure proper recording of HR and BL recovery (Lambert, 2012). Prior to being released from the experiment an adequate recovery period (resting heart rate ≤ 100 bpm) was given to all participants.

Instrumentation

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Cardiorespiratory Measurements. Oxygen uptake ($\dot{V}O_2$), carbon dioxide output ($\dot{V}CO_2$), breathing frequency and tidal volume were continuously collected with an automated breath-by-breath system (Metamax, Sensor Medics® version Vmax ST 1.0) using a nafion filter tube and a turbine flow meter (opto-electric). Respiratory exchange ratio (RER) and minute ventilation ($\dot{V}E$) were calculated as the quotient of $\dot{V}CO_2$ on $\dot{V}O_2$ and as the product of breathing frequency by tidal volume, respectively. HR values were transmitted with a Polar HR monitor (PolarElectro, Kempele, Finland). Prior to testing, gas analyzers and volume were calibrated with medically certified calibration gases (16.0%O_2 and 3.98% CO_2) and with a three-liter calibration syringe. In addition, a propane gas calibration was performed to assess the sensitivity of the oxygen and carbon dioxide analysers.

Lactate Measurements. All lactate measurements were taken using the Lactate Pro (LP, Arkray KDK, Japan) hand-held portable analyzer. A blood sample of ≥ 5 µL was taken from the participant's fingertip using a spring loaded lancet and then blood lactate values were recorded. The company supplied a check strip to confirm that the analyzer operated correctly, and a calibration strip that provided a non-quantitative indication of analyzer accuracy, which was used at the beginning of each testing session to ensure validity of the measures.

Cycle Ergometer. All exercise protocols were performed on the Velotron Dynafit Pro cycle ergometer (RacerMate, Inc., Seattle, WA). Factory calibration of the cycle ergometer was performed using Velotron CS software (RacerMate, Inc.) and the Accuwatt rundown verification procedure. Individual positional adjustments (saddle and handlebar height) were made before the first exercise test and were replicated for all subsequent exercise tests. Visual feedback of pedalling rate (RPM) was available to the participants during each exercise session.

Music. All participants listened to the exact same playlist of popular music which was set to a 130 bpm tempo; meaning each song was not originally 130 bpm but was altered to keep a consistent tempo throughout the playlist. Music was played through an Ipod® nano using 'earbud' type head phones and volume was held constant for each participant at 50% of the maximum volume approximately 65 decibels, based on manufacturer specifications of maximum volume being 130 decibels.

Exercise Bouts. Participants were given an explanation of the 6-20 point Borg RPE scale and told that if at any time they wished to stop exercising they could do so. After participants were fitted with an armband that held an Ipod© nano and ear bud type headphones (headphones and armband were worn regardless of condition), the facemask and mesh headpiece were secured next and hooked up to the indirect calorimetric system. Each participant then had a 5-min warm up period where they were instructed to keep a cadence of 60-70 rpm for the duration of the exercise protocol, a parameter displayed on a large computer screen. In both music and no music conditions, the experimental sessions started at 40% of PPO (active recovery), followed by a 4-min high intensity cycling bout at 80% of PPO. The participants were asked to report the RPE score every minute of the 4-min cycling bout. In addition, at the end of the 4-min high intensity cycling bout BL was assessed. Participants repeated the cycle [4-min work load and 2-min active recovery] until reaching one of the following criteria: 1) volitional exhaustion, 2) RPE value $\geq$ 19, or 3) RPM $\leq$ 60. At that point of exhaustion, time elapsed from the start of the cycling bouts and final RPE values were recorded. A final BL sample was also taken. Afterwards, they removed the Ipod© and quickly and carefully moved back to the bench to perform subsequent MVC's.

Data Reduction

All data sets were analysed using Sigmaplot (version 10.0; Systat Software Inc). First, cardiorespiratory parameters of the incremental test and of the high intensity cycling bouts were smoothed using second-order polynomial function to determine $\dot{V}O_2$, and its corresponding values of $\dot{V}CO_2$, breathing frequency, and tidal volume. Second, HR was time-aligned with the cardiorespiratory parameters and smoothed using the same data reduction technique. Third, RPE scores were interpolated to produce a continuous linear even data point distribution using a two-dimensional interpolation function and were then time-aligned as above-mentioned. Fourth, the high intensity cycling bout epochs were summed to represent time-to-fatigue. Finally, all above time-aligned parameters were expressed in a relative form to correspond to 25, 50, 75 and 100% of TTF.

Statistical Analysis

All statistical analyses were conducted using Jamovi (version 0.8). Differences between music and no-music conditions in time to task failure (measured in seconds and excluding recovery period) were examined using paired t-test. Cardio-respiratory parameters (Bf, V_T, $\dot{V}_E$, $\dot{V}O_2$, $\dot{V}CO_2$) and rating of perceived exertion were analyzed with a 2-way analysis of variance [ANOVA] (2 conditions x 4 time [25%, 50%, 75% and 100% of time of failure]). Differences between conditions in blood lactate were measured with 2-way ANOVA (2 conditions x 3 time [pre-test, immediate post-test, 5-min post-test]). HR was analyzed in two ways. First, with a 2-way ANOVA (2 conditions x 4 time [25%, 50%, 75% and 100% of time of failure]). Second, the effect of music upon recovery at the same absolute time period for all subjects (pre-test and 5 min post-test) was analyzed with paired t-tests. Gender was treated as a between-subjects variable in all tests. Differences were considered significant at $p<0.05$. If significant main effects or interactions were present, a Bonferroni (Dunn) procedure was conducted. Cohen *d* effect sizes were also calculated using the following equation ($d = \frac{\text{Mean differences}}{\text{SD average}}$) in which SD average is $\frac{\sqrt{\text{SD condition 1} + \text{SD condition 2}}}{2}$ to provide qualitative descriptors of standardized effects using these criteria: trivial < 0.2, small 0.2-0.5, moderate 0.5-0.8, and large> 0.8 (Cohen 1988). Note that since each participant exercised to volitional fatigue, each testing session was a different length of time; therefore, some variables were collapsed over time or reported as a percentage of TTF.

RESULTS

Time to Task Failure (TTF)

The average TTF in the music condition (10:30 ± 3:38 mins:secs) was 10.7 % longer than the average TTF in the no-music condition (9:33 ± 3:42 mins:secs) ($p = 0.035$; ES = 0.28). These averages reported times did not include the time spent in active recovery period (Figure 1A). Therefore on average participants in the music condition completed approximately 2.6 intervals and exercised for one minute longer while participants in the no-music condition only completed approximately 2.3 intervals.

Rate of Perceived Exertion (RPE)

Small magnitude and non-statistically significant ($p \geq 0.26$, ES = ~0.15) differences were observed between conditions in absolute RPE across the four time points (Figure 1B). A main effect for time was identified in which RPE increased over the course of the exercise across both conditions ($p < 0.001$).

Blood Lactate (BL)

While no statistical differences were observed between conditions at any time point (p = 0.250), the average BL levels post-exercise in the music condition at TTF exhibited a moderate magnitude 12.5% higher blood concentration than those at post-exercise in the no-music condition (13.5 ± 2.7 mmol•L^{-1} vs. 12.0 ± 3.0 mmol•L^{-1}; ES = 0.51) (Figure 1C).

Heart Rate (HR)

First, a small magnitude and statistically insignificant (p = 0.223; ES= 0.27) difference was identified between conditions at resting baseline. Second, a main effect for condition was observed in which HR was 4% higher in the music condition across the four time points (p = 0.043; ES = 0.25) (Figure 1D). HR increased in both conditions over time (p < 0.001; ES = 1.84). At post 5-minutes HR was 13% lower in the music condition (99.6 ± 7.6 bpm) than in the no-music condition (112.6 ± 10.6 bpm) (p < 0.001; ES = 1.40) (Figure 1D).

$\dot{V}O_2$ and $\dot{V}CO_2$

Small magnitude and statistically insignificant differences were identified in both $\dot{V}O_2$ and $\dot{V}CO_2$ between conditions and across time ($p \geq 0.192$; ES≤ 0.31) (Figure 2A and B).

Ventilation and Tidal Volume

Small magnitude and statistically insignificant differences were identified in ventilation and tidal volume between conditions ($p \geq 0.012$; ES≤ 0.27) (Figure 2C and E). A main effect for time was observed in which ventilation increased from beginning to the end of the cycling bout (p< 0.001; ES = 0.91).

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Breathing Frequency (Bf)

A medium magnitude, statistically significant (ES = 0.57; p = 0.006) main effect for condition was observed in which average Bf was 11.6% higher in the music condition (43.2 ± 8.7 breath•min^{-1}) compared to the no-music condition (38.7 ± 8.2 breath.min^{-1}) (Figure 2F). A large magnitude and statistically significant main effect (p < 0.001; ES = 1.17) for time was identified in which Bf increased by 23% over time in both conditions from 34.7 ± 6.2 breath•min^{-1} to 45.5 ± 11.5 breath•min^{-1}.

Respiratory Exchange Ratio (RER)

A significant interaction was observed between conditions and time (p = 0.040). While post-hoc testing only revealed statistical differences favoring the music condition at TTF (7%; p = 0.021; ES = 1.1) (Figure 2D). RER was also 5% greater (non-significant with a large effect size magnitude) at 75% of TTF (p= 0.12; ES= 0.85). RER increased over time across both conditions by 5% (p = 0.006; ES = 0.78).

DISCUSSION

The primary purpose of this study was to determine the effects of listening to high tempo music (130 bpm) on physical performance and acute physiological responses during high intensity interval bouts of cycling. Listening to music led to a small increased TTF, accompanied by an increase in BF, HR, as well as a steeper heart rate recovery post-exercise in the high tempo music condition. Yet, RPE scores were similar between conditions although participants exercised longer and recovered faster in high tempo music condition.

A possible explanation for the participant's increased TTF while experiencing a build-up of peripheral metabolites (increased BL), albeit still reporting comparable RPE scores, can be attributed to the CNS regulation and its impacts on exercise performance. Models that emphasise the role of the brain in exercise regulation have pointed to the lack of clear peripherally based fatigue reasons to explain why participants reach the point of exercise failure (i.e., inability to continue exercising) since not all muscle fibers are recruited at the point of exhaustion (Kayser 2003; Noakes 2000). As such, even during high intensity exercise efforts, the brain has a role in regulating effort despite the accumulating metabolites in the muscles. Henceforth, the CNS must have some control over exercise performance (Kayser 2003; Noakes 2000). The increased breathing frequency response of our participants implies that central command cardiovascular drive regulates through medullar integration the dual-talk between the sympathetic and parasympathetic nervous systems even with high intensity exercise. Breathing frequency is controlled via the autonomic nervous system, by the respiratory centers located in the medulla oblongata in the lower brainstem, functioning largely below the level of consciousness (Bechbache and Duffin 1977; Williamson 2010). Hence, at some point during the cycling intervals, performed with high tempo music, the central neural command seemed to modulate the cardiovascular centres. As a result, the participants breathing frequency was higher during high intensity cycling bouts, which could be an indication of the involvement of the cerebral cortex in cardiovascular control mechanisms (Williamson, 2010). Although the exact mechanism for this physiological response is unclear, these findings do support the idea that further research into the underlying cortical modulation mechanisms involved with the beneficial effects of music on exercise duration are warranted.

Similar to most of the current literature on this topic, HR during exercise was only slightly affected by the music. However, there was an anomaly in the present study, which has to do with post-exercise recuperative effects of music. Participants who completed the cycling intervals with music had a steeper HR recovery. There is very little known about the impact of music on post-exercise performance. Music seems to relieve stress and improve affective states in non-exercise settings (Särkämö et al. 2008). Note that participants in this study had the music stimulus removed immediately at the end of high intensity cycling bouts, however, five minutes post-exercise HR were significantly lower compared to no-music condition. This translates again to a possible effect of distracting stimuli on the autonomic nervous system; whereby attention to the external environment seems to reduce the awareness of physiological sensations and negative emotions, which may have triggered a quicker parasympathetic response leading to steeper post-exercise HR recovery. These results further support the theory that the CNS has the ability to control some types of exercise performance and aid in the ability to exercise longer at higher intensities; unfortunately the verification of these theories were not within the scope of this investigation.

Although the research is somewhat conflicting when it comes to measuring the extent to which music can enhance exercise performance at maximal or near-maximal levels, this study demonstrated that listening to high tempo music (via headphones) during high intensity cycling intervals can lead to greater efforts without increasing individual's perceived exertion. The ability to alter perception is consistent with a vast majority of the current research, which is focused on the psychological effects of music on exercise, mood, and emotion and affect. It is the 'psychophysical' effects or more prudently the physiological effects that have been noted in this study that should motivate future research endeavours. If music can truly distract or disguise the peripheral signs of fatigue it may increase exercise duration, and perhaps enjoyment and adherence. In view of the results presented here, the central motor drive can be uncoupled from the central cardiovascular command to evoke different circulatory responses (Williamson 2010);

indeed, the individuals worked harder while breathing at a higher frequency, and experiencing greater muscle fatigue, all whilst diminishing the feeling of discomfort. The association between central motor drive, central cardiovascular command and perceived exertion was clearly altered by distracting stimuli (high music tempo).

CONCLUSIONS

The music condition in the present study elicited an increase in TTF, breathing frequency, and HR while not influencing RPE. Additionally, a steeper heart rate recovery post-exercise compared to the control condition was observed. These results support the notion that music can modify the interplay between central motor drive, central cardiovascular command and perceived exertion. Changes in factors such as breathing frequency suggest that this modification may occur at a subconscious level. Therefore, further studies of the effect of music on exercise performance should focus on the physiological mechanisms responsible for the beneficial acute physiological responses, including potentially more complex procedures (i.e. fMRI) as opposed to the psychological mechanisms and responses**.**

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Figure captions

Figure 1. All figures include means+SD. **A:** TTF= Time to failure. **B**: RPE= Rate of perceived exertion. **C:** BL= Blood lactate. **D:** HR= Heart rate.

Figure 2. All figures include means+SD. **A:** $\dot{V}O_2$= Maximal oxygen uptake. **B:** $\dot{V}CO_2$= Carbon dioxide output. **C:** V_T= Tidal volume. **D:** RER= Respiratory exchange ratio. **E:** $\dot{V}E$= Minute ventilation. **F: Bf** = Breathing frequency.

Figure 1

Performance messures

All figures include means+SD. **A:** TTF= Time to failure. **B**: RPE= Rate of perceived exertion. **C:** BL= Blood lactate. **D:** HR= Heart rate.

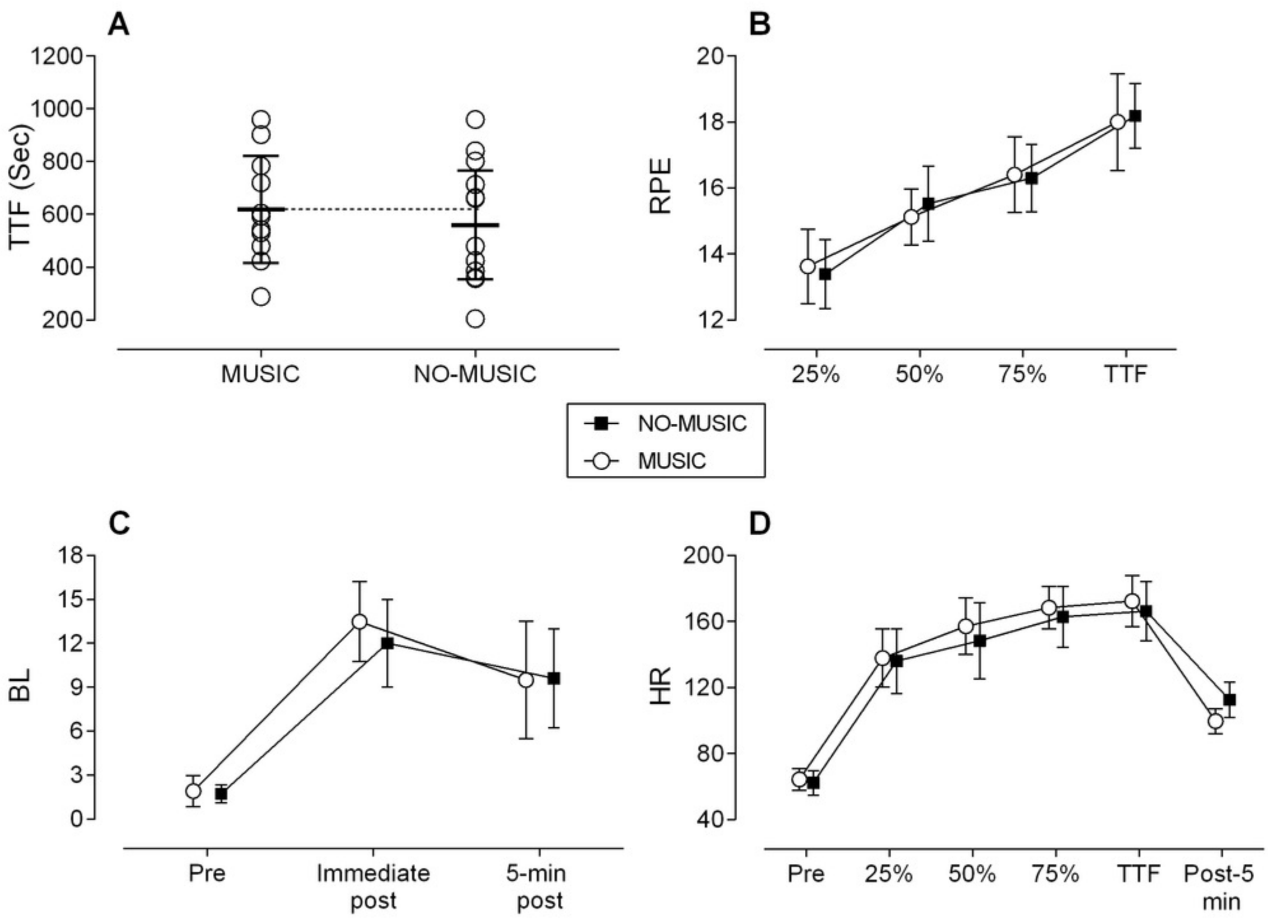

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Figure 2

Metabolic data

All figures include means+SD. **A:** $\dot{V}O_2$**=** Maximal oxygen uptake. **B:** $\dot{V}CO_2$**=** Carbon dioxide output. **C:** V_T**=** Tidal volume. **D:** RER**=** Respiratory exchange ratio. **E:** $\dot{V}E$**=** Minute ventilation. **F: Bf =** Breathing frequency.