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LISTENING TO MUSIC DURING INDOOR CYCLING ELICITS HIGHER INTERNAL LOADS DURING PROLONGED ENDURANCE EXERCISE

TRABALHO DE CONCLUSÃO DE CURSO: FISIOTERAPIA

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LISTENING TO MUSIC DURING INDOOR CYCLING ELICITS HIGHER INTERNAL LOADS DURING PROLONGED ENDURANCE EXERCISE

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Abstract

Background: Dissociation by music may impact the rate of perceived effort (RPE), an indicator of internal loads during exercise. However, it is not clear how music affects the RPE, neuromuscular, and cognitive responses to exercise. **Aim:** To determine whether listening to preferred music during indoor endurance exercise influences RPE, neuromuscular, and cognitive responses in healthy individuals. **Methods:** Thirteen healthy adults performed sessions of prolonged indoor cycling at moderate intensity while listening or not to preferred music. Reaction time, selective attention, and memory were evaluated before, during, and after the exercise sessions. RPE, heart rate, muscle activation, pedaling torque, and cadence were recorded during the exercises. **Results:** RPE (P = 0.004, *d* = 0.40), heart rate (P = 0.048, *d* = 0.53) and cadence (P = 0,043; *d* = 0.51) were higher in the music session compared to no music. Selective attention (P = 0.233), simple reaction time (P = 0.360), working and short-term memory (P > 0.05), as well as torque (P = 0.262) and muscle activation (RMS and MDF, P > 0.05) did not differ between music and no music sessions. **Interpretation:** Indoor cycling while listening to preferred music elicited higher internal loads, which we consider result from higher cardiovascular demand. However, the effects of music on neuromuscular and cognitive responses were not evident. We conclude that music can be helpful to improve demand during indoor exercise.

Keywords: cycling; rate of perceived exertion; fatigue; music; biomechanics.

Introduction

Regular physical exercise improves physical [1] and cognitive capacities [2]. These effects are dependent on the control of effort intensity [3] and adherence [4]. While exercise intensity can be controlled, adherence relies much more on motivation and pleasure to exercise. A low adherence may result from external factors like exercise type, load, duration and frequency, and internal factors like individual motivation, effort perception, and pleasure [5]. Motivation to exercise indoor has gained an important role for health as during the COVID-19 pandemic exercises at home became a safe alternative to remain physically active.

The modification of attentional focus by music [6] can be a source of distraction positively affecting the internal sensations related to fatigue and rate of perceived exertion (RPE) [7], perception of pain and discomfort [8], and tolerance during exercise [9]. Young adults run longer distances at a higher intensity when listening to music[9]. Such improvement in endurance capacity can also benefit exercise therapies for patients with cognitive impairments and neurodegenerative conditions [10].

Listening to the preferred music style during high-intensity exercise can improve motivation and reduce the RPE [11]. Such effects may result from the modulation of emotional states by shifting the internal focus from somatic to external stimuli [12]. It could alter the association between neural drive, cardiovascular commands, and RPE, resulting in longer exercise duration at higher intensities along with a quick heart rate recovery [13]. Altogether it seems that music influences internal load during exercise, and therefore changes in RPE would be accompanied by changes in neuromuscular recruitment and cognitive responses during endurance exercise [11–13]. Here we determine whether listening to preferred music during indoor endurance exercise influences variables related to the individual RPE, neuromuscular activation, and cognitive responses in healthy individuals. We hypothesized that dissociation would occur when the participants listen to their preferred music, reducing RPE, which could prolong the exercise duration. If a longer exercise duration is achieved, some effect of music on fatigue markers could be expected.

Methods

Participants and experimental design

We advertise the project on the university campus and invited physically active young adults to participate. They should have age between 18 and 40 years old, be free of physical and cognitive impairments that could negatively impact exercise performance, and not sustain any chronic disease, including auditory impairments. Thirteen participants (6 women and 7 men) completed all the experiments. All participants signed a consent term. The local ethics committee approved the research protocol (IRB #85233618.6.0000.5323). Exclusion criteria involved not being able to sustain at least 30 minutes of exercise or report discomfort during the exercise sessions (for example, dizziness, nausea, or acute pain). Participants that failed to attend one of the exercise sessions had data excluded from the analysis (14 participants were unable to complete all the experiments in the proposed timetable, and the pandemic and university lockdown made it impossible to test additional participants in 2020).

Participation in the study consisted of 3 visits to the laboratory, always at the same time of the day. On the first visit, participants completed a cycle ergometer test to determine the individual maximal power output, answered a general questionnaire regarding their daily habits, personal information, preference, and tolerance of exercise intensity questionnaire, PRETIE-Q[14], and completed a familiarization session for assessment of the simple reaction time and selective attention in a Stroop task. On this day, the participants were also questioned about their preferred music gender and some of the songs most listened to during daily life. The humor status was assessed before each of the exercise sessions using the Brunel Mood Scale, BRUMS[15,16].

On the second and third visits, participants performed submaximal cycling trials on the same cycle ergometer at the workload of 50% of their maximal power output. The two submaximal sessions were performed until voluntary exhaustion or a time limit of 60 min. For one of these submaximal sessions, the participant was exposed to the music of the preferred genre. Before each submaximal session, humor, exercise tolerance, exercise preference were assessed. During the submaximal sessions, we continuously monitored the rate of perceived effort (RPE), heart rate, neuromuscular activation, pedaling torque, and pedaling cadence. At specific time points during the exercise, participants were evaluated for short-term (15' and 45' of exercise) and working memory (0' and 30' of exercise). Reaction time and selective attention were evaluated before and after each of the submaximal sessions. A period of at least 72 h was considered between the visits. Data were compared between the submaximal sessions with or without music. The study design is illustrated in figure 1.

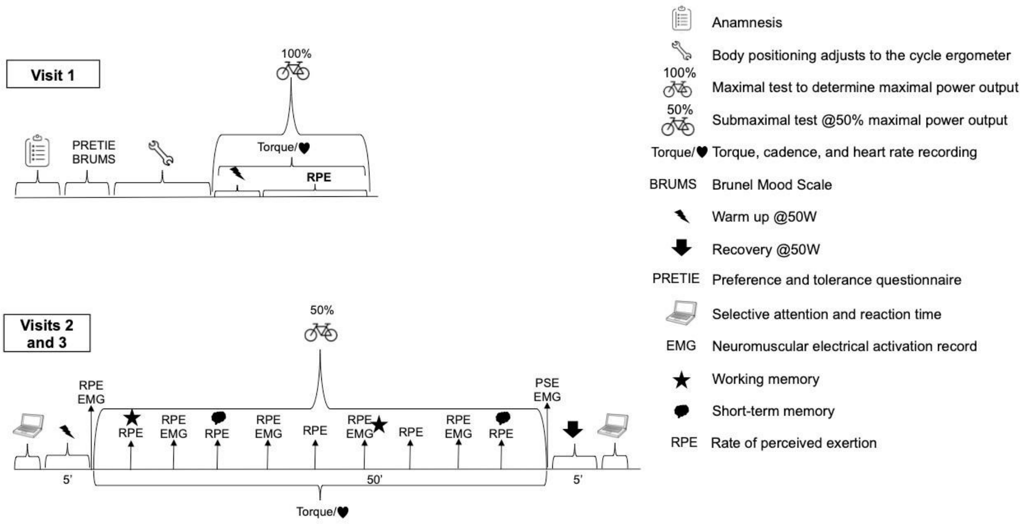

Figure 1. Experimental design.

Exercise sessions

Exercise sessions were performed on a high-performance cycle ergometer (Excalibur Sport, Lode, The Netherlands) with dimensions adjusted to the participant anthropometrics characteristics. [17] Maximal power output was determined during an incremental maximal exercise starting with a 5-min warm-up at 50 W followed by progressive increments of 25 W every minute until the participant was no longer able to maintain the pedaling cadence higher than 70 rpm. The maximal power output was determined as the last workload stage fully completed. RPE was monitored using the 6 to 20 points Borg scale to ensure that exercise was performed to the maximal. Verbal encouragement was used throughout the entire test. Heart rate was continuously recorded using a chest heart rate monitor (F50, Polar Electro Oy., Finland) integrated into the cycle ergometer. On the second and third visits, the submaximal exercises were performed on the same cycle ergometer that controlled the exercise load to elicit a resistance load corresponding to 50% of the individual maximal power output. The submaximal sessions were performed until exhaustion or a time limit of 60 min.

Music condition

The submaximal sessions were randomized with and without music. The playlist was individualized and created using commercial music streaming applications after the first visit to the laboratory when the participants were interviewed about the preferred music genre and songs. The playlist included songs with 120-150 bpm, similar to the cadence considered in a previous study with similar scope [18]. The music was listened to by using an earphone (reference model Samsung S5360) connected to a mobile music application controlled by the researcher. We did not control the sound volume to make the participant feel as comfortable as possible with the music, but the participant should be able to hear orientations from the researcher during the exercise. For the other exercise session, no music was presented to the participant.

Measurements

After the BRUMS assessment, participants were seated on the cycle ergometer for assessment of simple reaction time and selective attention. The tests considered congruent and incongruent stimulus for selective attention, before and within 2 minutes after the end of each of the exercise sessions. A 14” flat LED screen was placed 1 m ahead at eye level where information was presented to the participant. Simple reaction time was defined by the time interval between the presentation of a visual stimulus (aleatory symbol) and the participant response by pressing any button of the mouse. Selective attention was assessed by the time response to the correct answers in the Stroop task. The visual stimuli considered the presentation of geometrical forms that could appear and disappear in the screen at random times for the time reaction test and the presentation of color names written in different colors for the selective attention test. Simple reaction time and selective attention tests were configured using PsychoPy [23], and the experimental approach is similar to the one used in a recent investigation with trained cyclists [19].

After the cognitive assessment, the participants were prepared for the measurements during exercise. The neuromuscular electrical activation signals from surface electromyography (EMG) were recorded bilaterally from the vastus lateralis and the biceps femoris. Data were sampled at 3 kHz using an EMG acquisition system (miniDTS and MyoMuscle, Noraxon, USA) following the SENIAM recommendations [20]. EMG signals were recorded for one minute every 10 minutes in the exercise sessions. The further analysis considered the first, the middle, and the last EMG recording during exercise. The EMG signals were zero mean-centered and filtered by a zero-lag 4th order finite impulse response Butterworth filter with a band-pass of 20 to 450 Hz. The Teager-Kaiser energy operator threshold-based method was used to detect onsets and offsets of individual EMG bursts [21]. From each contraction burst, the root mean square (RMS) value was determined and values were averaged to be considered as an indicator of the magnitude of activation [22], and the fast Fourier transform was computed to determine the median frequency, which was used as an indicator of fatigue [23]. EMG signals were normalized considering the average of three maximal isometric voluntary contractions performed against manual resistance for knee extension and flexion before exercise [24]. All EMG signals were processed using custom codes written in Matlab (version 2016, The MathWorks, Inc., Natick, USA).

During the exercise sessions, the rate of perceived effort was assessed every 5 minutes using a 6-20 points Borg scale [25]. The scale was presented to the participants on a 14” flat LED screen placed 1 m ahead at eye level, and the answer was recorded by a researcher. The heart rate was continuously monitored by a heart rate monitor (A300, Polar Electro Oy., Finland).

The bilateral peak crank torque and pedaling cadence were continuously recorded during exercise. The LODE Excalibur instrumented crank arms recorded torque at every 2º of the crank cycle (LODE Excalibur Sport, Groningen, The Netherlands). Participants were instructed to remain seated on the saddle with their hands on the handlebars. They were allowed to drink water ad libitum, and the room temperature was controlled by air-conditioned to remain between 21ºC and 23ºC.

When the participants started each of the submaximal exercise sessions, the working memory was assessed by presenting a sequence of 7 aleatory numbers for 10 seconds at the 14” flat LED screen placed 1 m ahead at eye level. They were requested to verbally recall the sequence 10 seconds later. The short-term memory was assessed 15 min later when participants were requested to verbally recall the numeric sequence again. After the first 15 min of exercise, another assessment of work memory was conducted, by presenting a new sequence of numbers that should be recorded 10 seconds later, and for short-term memory again 15 min later. For each recall condition, the number of hits was recorded and the percentage of correct recalls was determined [19]. During testing, only the participant and one researcher were in the room.

Statistical analysis

Data distribution was checked using the Shapiro-Wilk test. Mean, standard deviation, and coefficients of variation (standard deviation to mean ratio) were computed. Main effects and interactions considering the music condition (music vs no music) and the exercise time (start, middle, end) were verified using an ANOVA in a general linear model for repeated measures before, during, and/or after the exercise. Paired comparisons were performed by a dependent t-test or Wilcoxon test for variables averaged for each exercise session. For paired comparisons with statistical different identified, Cohen's *d* effect size was calculated to quantify the differences between conditions [26]. An alpha of 5% was considered for all statistical comparisons.

Results

The characteristics of the participants and the main outcomes from the experimental sessions are presented in Table 1. The humor status assessed by the BRUMS scale before each exercise session did not differ for music and no music sessions (Table 2). The absolute ($P = 0.005$, $d = 0.47$) and relative to maximal heart rate were higher in the music session compared to the no music ($P = 0.048$, $d = 0.53$). The music session also resulted in higher RPE than no music condition ($P = 0.004$, $d = 0.40$).

Table 1. Participants characteristics and outcomes of measurements performed during the exercise. Data are mean and standard deviation (SD).

Variables	Mean	SD
Age (years old)	24	4
Body mass (kg)	68.30	8.5
Height (m)	1.70	0.1
Body mass index (kg/m^2)	24.50	1.6
Physical activity habits (min/day)	65.3	22.9
Preferred music cadence (bpm)	129.39	12.19
PRETIE-Q high tolerance	12.70	3.50
PRETIE-Q low tolerance	11.80	2.80
PRETIE-Q high preference	14.90	3.00
PRETIE-Q low preference	8.20	2.50
Maximal power output (W)	219.70	69.3
Maximal power to mass ratio (W/kg)	3.20	0.9
Submaximal power (W)	98.90	34.9
Submaximal power to mass ratio (W/kg)	1.60	0.5
Maximal hear rate (HRmax, bpm)	179	30
Average heart rate no music session (bpm)	163*	15
Average heart rate music session (bpm)	170	17
Average heart rate no music session (% HRmax)	88	7
Average heart rate music session (% HRmax)	92*	8
Exercise duration no music session (min:seg)	44:60	8:30
Exercise duration music session (min:seg)	44:20	9:10
Rate of perceived exertion no music session (Borg scale)	13	3
Rate of perceived exertion music session (Borg scale)	14*	3

* higher than no music session ($p < 0.01$, paired t-test).

Table 2. Average points in the BRUMS scale measured before each exercise session.

BRUMS	no music	music	p-value*
Tension	1.92	2.00	0.85
Anger	1.23	1.62	0.42
Depression	3.15	2.92	0.59
Fatigue	3.38	3.38	0.57
Vigor	7.77	7.92	0.84
Confusion	0.54	0.54	0.99

* paired t-test

Simple reaction time did not differ between the pre- and post-exercise sessions (no music P = 0.059, music P = 0.526) and between music versus no music sessions (pre-exercise music *versus* no music P = 0.520, post exercise music versus no music P = 0.360). Selective attention also did not differ between pre- and post-exercise sessions (no music P = 0.151, music P = 0.380) and between music versus no music condition (pre-exercise music versus no music P = 0.266, post exercise music versus no music P = 0.233) (Table 3). Working memory (0’ P = 0.197 and 30’ P = 1.000) and short-term memory (15’ P = 0.247 and 45’ P = 0.071) (Figure 2) did not differ between the music and no music exercise sessions.

Table 3. Results from the simple reaction time and selective attention in the Stroop task performed before and after the exercise sessions. Data are mean and standard deviation (SD).

		no music		music	
		pre	post	pre	post
Reaction time (ms)	Mean	281.51	284.73	310.14	317.15
	SD	60.26	46.97	51.36	78.89
Stroop task (ms)	Mean	751.29	702.15	773.16	741.81
	SD	156.85	126.69	92.56	144.09

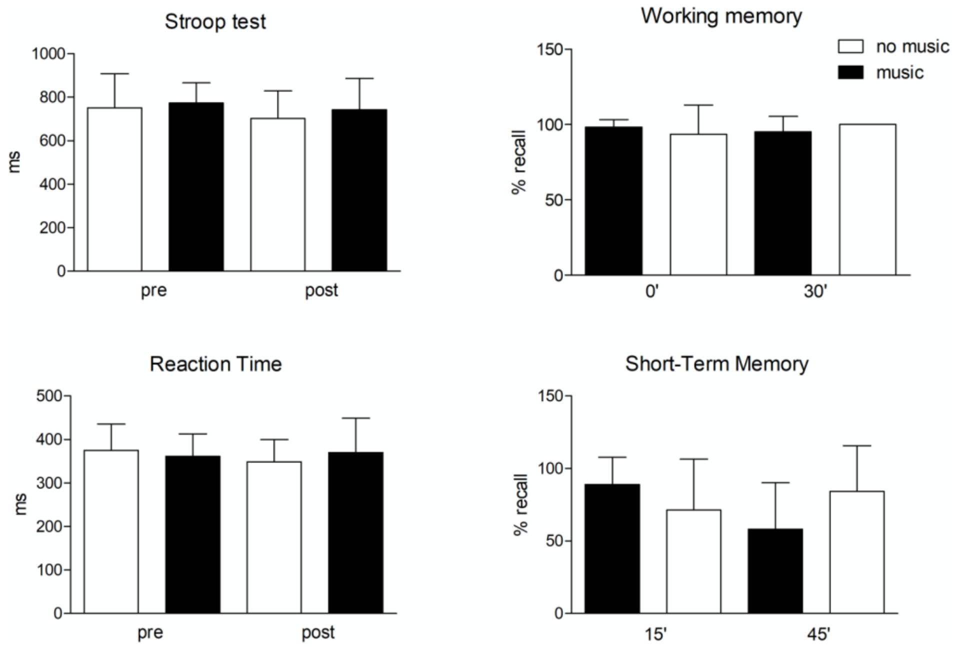

Figure. 2. Results from working and short-term memory. Data are mean and standard deviation (SD). ms: milliseconds.

Peak torque did not differ when comparing between the music (P = 0.262) and no music sessions (P = 0.469). Asymmetries were not found (Table 4). Peak torque also did not differ between the no music and music sessions for the right (P = 0.838) and left leg (P = 0.769). The pedaling cadence was higher in the music session (P = 0,043; *d* = 0.51, Table 4).

Table 4. Mean, standard deviation (SD), and coefficient of variation (CV) of peak torque e cadence during the exercise sessions. Torque values are reported to the right and left legs.

		no music		music	
		right	left	right	left
Torque (N/m)	Mean	37.73	37	37.60	36.75
	SD	5.62	5.29	5.54	5.40
	CV (%)	15.14	14.53	15.03	15.20
Cadence (rpm)	Mean	83.80		85.45 *	
	SD	2.97		3.49 *	
	CV (%)	3.54		4.08 *	

* higher than no music session ($p < 0.01$, paired t-test).

The RMS ($P > 0.05$ across the muscles) and median frequency ($P > 0.05$ across the muscles) did not differ between the music and no music sessions. An increase in neuromuscular electrical activation along the exercise was found for some of the muscle analyzed, and a drop in median frequency suggesting muscle fatigue was also observed, but these behaviors did not differ between the music and no music sessions. Results from neuromuscular activation are summarized in Figure 3.

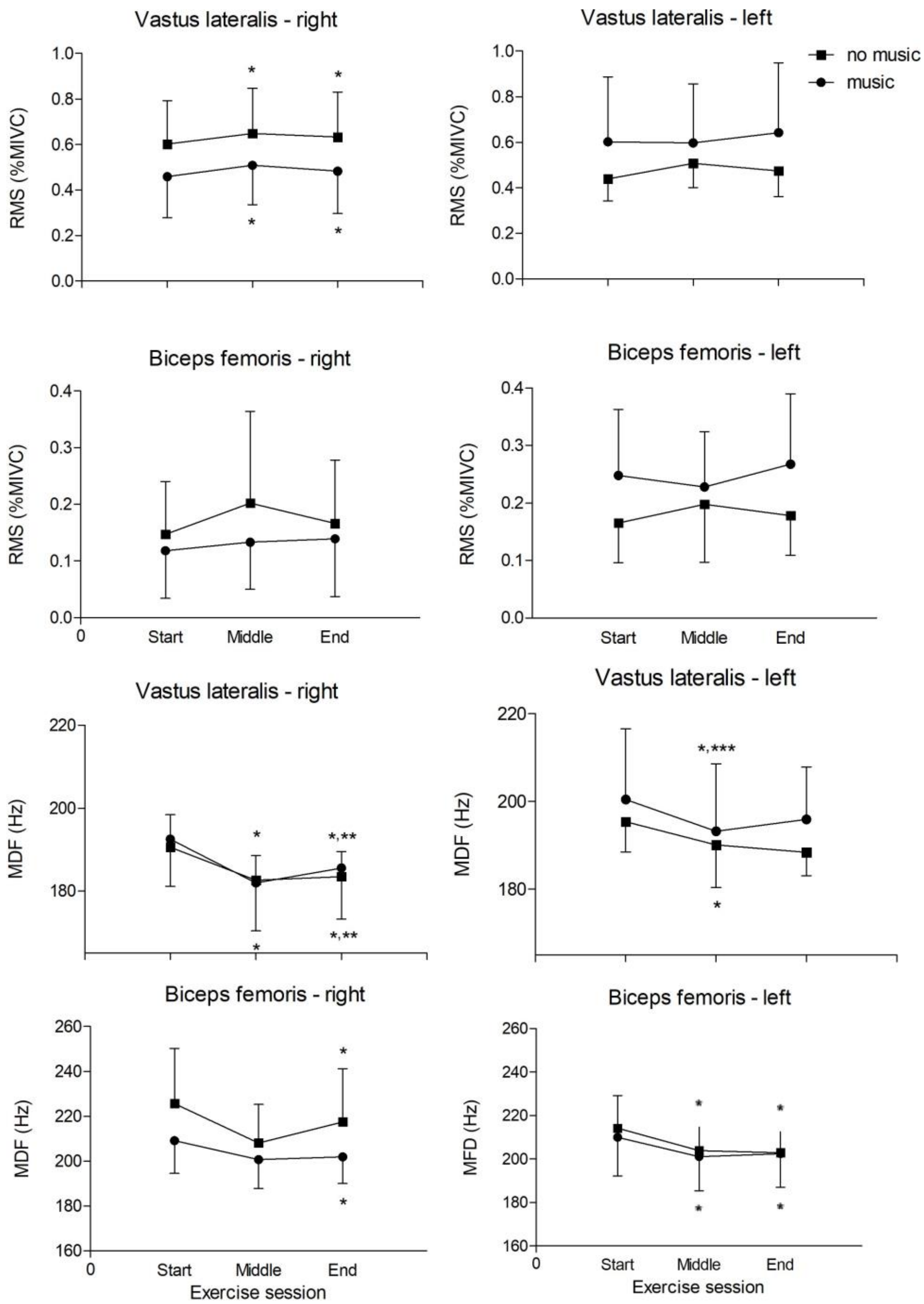

Figure 3. Neuromuscular activation outcomes from muscle activation (RMS) and median frequency (MDF), in the different conditions. * indicates a time effect during the exercise session ** indicates a time effect compared to the start of the exercise *** indicates a time effect comparedto the end of the exercise. There were no differences between no music and music sessions. Data are mean and standard deviation (SD). RMS: root mean square. MDF: median frequency. MIVC: maximal isometric voluntary contraction.

Discussion

In this study we hypothesized that listening to preferred music during exercise could lead to dissociation, reducing RPE, which could prolong the exercise duration. If longer exercise duration is achieved, the additional effect of music on fatigue markers could help explain the results. To test this hypothesis, we submitted healthy individuals to indoor prolonged exercise while listening or not to their preferred music genre. Different from our hypothesis, exercise duration, neuromuscular, and cognitive responses remained mostly unaffected by the music, but RPE and heart rate were higher in the music session. The music may influence the capacity to filter the irrelevant information and prioritize the most relevant, impacting the individual sensations during exercise [27]. Therefore, the higher RPE and heart rate may rely on music altering the focus of attention from the exercise to the music, which is known to also affect neural dynamics during stationary cycling [28]. One possible effect of the involuntary attempt to synchronize the music and movement frequencies [29]. We consider that the lack of significant changes in muscle activation and torque production, but the higher heart rate in the music session, suggests that music increases the cardiovascular demand of the exercise, explaining the higher heart rate and RPE.

This intervention may serve as a strategy to increase exercise cardiovascular demand, which can be useful for people with lower tolerance to exercise [30]. Adding music to indoor cycling can be a strategy to increase internal load without increasing the exercise duration or increasing the external load. The music also contributes to promoting exercise adherence [31]. Previous studies also reported that music benefits performance at higher exercise intensities [32,33], and our results show that similar effects can be observed for indoor cycling at moderate intensity. We did not find an effect of music on exercise duration, which was previously reported for exercise at lower or self-selected intensities [9]. A possible explanation for this different result may be the intensity observed among the participants. As they were not trained, the exercise may have resulted in a higher intensity than initially planned.

One could argue that pedaling cadence was higher in the music session. We recommended the participants to keep pedaling cadence similar to the cadence observed in the incremental test. It means that all participants would cycle at cadences between 80 and 90 rpm. The spontaneous increase in pedaling cadence may result from an involuntarily attempt to synchronize exercise frequency with the music cadence [29]. This synchronization can improve movement efficiency and positively impact exercise performance [34], but the exercise duration did not differ between the sessions. The higher cadence would help to explain the higher heart rate, but RPE is not a critical variable in cadence selection during submaximal power output cycling [35]. When changes in the cadence were considered determinants of changes in heart rate, the magnitude of changes in cadence was larger, like from 60 to 90 rpm [36]. To consider an exact match of movement cadence and music cadence can be an interesting approach in neurological conditions [37]. In our study, a match of pedaling cadence (usually between 80 and 90 rpm for all participants) with the preferred music cadences (120-150 bpm) would result in a movement of very high frequency, and most likely unable to be sustained without proper training.

We monitored the muscle activation of the main muscles producing power during cycling [38], and found that either the changes in cadence or changes in the music condition did not elicit changes in neuromuscular demands. The higher group variability found in the activation of biceps femoris most likely results from the participants being not cyclists [39]. Considering that music session showed higher heart rate and RPE, but similar exercise duration, torque, and neuromuscular activation, music may have contributed to increasing tolerance to fatigue, which agrees with a previous report [40].

The acute effects of exercise on cognitive responses are more complex than chronic benefits. We did not observe differences in simple reaction time, selective attention, and memory between music and no music sessions. We consider that moderate intensity has played a major role in this result. As recently demonstrated, moderate to low intensity has variable effects on these cognitive parameters while higher intensities show more consistent effects on the improvement of selective attention [19]. Therefore, we consider that a future experiment should consider music intervention and performances at higher intensities.

We acknowledge that our study has limitations. We considered the preferred music gender and created playlists including the preferred participants' songs. The preferred music seems to benefit endurance performance [41]. Although our participants were physically active, they had different levels of physical conditioning. It may have influenced the determination of the maximal power output resulting in underestimated values. It may have affected the submaximal loads but did not commit our experiment as they performed paired sessions with similar outcomes being assessed. Finally, we did not control the pedaling cadence and we cannot ensure if different results would emerge if they matched music and exercise cadences [34].

Conclusion

Listening to the preferred music during indoor cycling elicits a higher internal load accompanied by higher heart rate, but did not affect the neuromuscular and cognitive responses to the exercise. The lack of effect on neuromuscular and cognitive responses may explain the similar exercise duration for music and no music sessions.

We consider that this intervention can be useful to increase internal load during exercise and can be useful for indoor exercise programs performed at home, for example.

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