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Listening to Fast-Tempo Music Delays the Onset of Neuromuscular Fatigue

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Abstract

Centala, J, Pogorel, C, Pummill, SW, and Malek, MH. Listening to fast-tempo music delays the onset of neuromuscular fatigue. *J Strength Cond Res* 34(3): 617–622, 2020—Studies determining the effect of music on physical performance have primarily focused on outcomes such as running time to exhaustion, blood lactate, or maximal oxygen uptake. The electromyographic fatigue threshold (EMG_{FT}) is determined through a single incremental test and operationally defined as the highest exercise intensity that can be sustained indefinitely without an increase in EMG activity of the working muscle. To date, no studies have examined the role of fast-tempo music on EMG_{FT}. The purpose of this investigation, therefore, was to determine whether fast-tempo music attenuates neuromuscular fatigue as measured by the EMG_{FT}. We hypothesized that listening to fast-tempo music during exercise would increase the estimated EMG_{FT} compared with the control condition. Secondarily, we hypothesized that maximal power output would also increase as a result of listening to fast-tempo music during the exercise workbout. Ten healthy college-aged men (mean ± *SEM*: age, 25.3 ± 0.8 years [range from 22 to 31 years]; body mass, 78.3 ± 1.8 kg; height: 1.77 ± 0.02 m) visited the laboratory on 2 occasions separated by 7 days. The EMG_{FT} was determined from an incremental single-leg knee-extensor ergometer for each visit. In a randomized order, subjects either listened to music or no music for the 2 visits. All music was presented as instrumentals and randomized with a tempo ranging between 137 and 160 $b \cdot min^{-1}$. The results indicated that listening to fast-tempo music during exercise increased maximal power output (No Music: 48 ± 4; Music: 54 ± 3 W; $p = 0.02$) and EMG_{FT} (No Music: 27 ± 3; Music: 34 ± 4 W; $p = 0.008$). There were, however, no significant mean differences between the 2 conditions (no music vs. music) for absolute and relative end-exercise heart rate as well as end-exercise rating of perceived exertion for the exercised leg. These findings suggest that listening to fast-tempo music increased overall exercise tolerance as well as the neuromuscular fatigue threshold. The results are applicable to both sport and rehabilitative settings.

Key Words: sport, physical performance, rehabilitative, quadriceps

Introduction

Music may be used to increase motivation during an exercise activity or as a distraction from perceiving fatigue (18–20). In both sport and rehabilitative settings, listening to music may have potential utility to enhance performance (18–20). Studies determining the effect of music on physical activity have primarily focused on outcomes such as running time-to-exhaustion, blood lactate, or maximal oxygen uptake (9,33). In addition, studies suggest that slow-tempo music (≤80 $b \cdot min^{-1}$) does not influence physical performance and is comparable with the control condition (no music) (9,19,20). Thus, there is growing evidence that fast-tempo music may elicit a response that enhances physical performance (19,20,34). The potential physiological mechanism(s) underlying the effect of music on performance may reside in altering perceptions of fatigue as well as changes in brain activity (18–20,32). It has been suggested that emotional responses to the music such as eliciting a unique memory may also contribute to the observed increase in performance (19,20). What remains unknown is the influence of fast-tempo music on neuromuscular fatigue.

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Surface electromyography (EMG) is a noninvasive method of examining muscle function under various exercise modalities (2). The EMG amplitude is influenced by the number of activated motor units and their firing rates (2). The EMG amplitude was reported by Travis et al. (37) to be a stable and reliable measure for continuous muscle action. The electromyographic fatigue threshold (EMG_{FT}) is the highest exercise intensity that an individual can maintain for an extended period without an increase in the EMG amplitude (6,12). It has been shown that the EMG_{FT} is a highly reliable measure (24). In a validation study, Briscoe et al. (6) reported that subjects cycling at an exercise intensity corresponding to 130% of their EMG_{FT} exhibited a significant increase in the EMG amplitude vs. time relationship and were able to maintain the exercise workbout for ~12 minutes. For exercise intensities below the EMG_{FT}, however, the EMG amplitude vs. time relationship was unchanged (6). Studies indicate that the EMG_{FT} is influenced by different modalities such as low-dose caffeine consumption (29), cognitive fatigue (10), pre-exhaustive exercise (14), and repeated exercise workbouts separated by 1 hour (5). The EMG_{FT} may provide a unique measure to determine the influence of fast-tempo music on neuromuscular fatigue.

To date, no studies have examined the role of fast-tempo music on EMG_{FT}. The purpose of this investigation, therefore, was to determine whether fast-tempo music attenuates neuromuscular fatigue as measured by EMG_{FT}. We hypothesized that listening to fast-tempo music during exercise would increase the estimated EMG_{FT} compared with the control condition. Secondarily, we hypothesized that maximal power output would also increase as a result of listening to fast-tempo music during the exercise workbout.

Methods

Experimental Approach to the Problem

Each subject visited the laboratory on 2 separate occasions during a 7-day period. For 1 of the 2 visits, subjects listened to fast-tempo music ranging from 137 to 160 $b·min^{-1}$ during the exercise test, whereas for the other visit no music was played during the exercise test. Both testing sessions (i.e., music and no music) were randomized for each subject, and each subject had EMG electrodes placed on their rectus femoris muscle to measure the EMG activity during the exercise test.

Subjects

Ten healthy college-aged men (mean ± *SEM*: age, 25.3 ± 0.8 years [range from 22 to 31 years]; body mass, 78.3 ± 1.8 kg; height: 1.77 ± 0.02 m) were recruited for this study. The subjects were asked to refrain from exercise 24 hours before each of the testing sessions. Although there were no dietary restrictions, each subject was asked to refrain from caffeine consumption 24 hours before each testing session (8,10,13,26,27). Furthermore, the 2 testing sessions, for each subject, were separated by 7 days and performed at relatively the same time (±1 hour). Moreover, each subject wore a Polar Heart Watch system (Polar Electro Inc., Lake Success, NY) to monitor heart rate during the 2 exercise sessions. All procedures were approved by the Wayne State University Institutional Review Board for Human Subjects (IRB010918M1E), and each subject signed an informed consent before testing.

Procedures

Mood Questionnaire. Each subject completed the Brunel Mood Scale (BRUMS) before and immediately after each exercise session. The BRUMS is a 24-item questionnaire used to assess moods of tension, depression, anger, vigor, fatigue, and confusion on 5-point Likert scale; 0 = not at all to 4 = extremely (10,35,36).

Motivation Questionnaire. To determine the subject's intrinsic motivation, at each exercise session, we used the questionnaire developed and validated by Matthews et al. (28) and used in our previous study (10). This inventory consists of 7 items, which determines the subject's level of motivation and interest. All questions are based on a 5-point Likert scale (0 = not at all to 4 = extremely).

Incremental Single-Leg Knee Extensor. The single-leg knee-extensor ergometry has been used previously in our laboratory (8,10,13,26,27) and exclusively focuses the exercise demand on the quadriceps femoris muscles (31). Briefly, each subject was semirecumbent in an adjustable chair with a special ankle boot placed on the nondominant leg and connected by a bar to the ergometer. The dominant leg (based on kicking preference) was on a platform attached to the knee-extensor device (8,10,13,26,27). Contractions of the quadriceps muscles caused the lower part of the leg to extend through an angle of ~90 to ~10°. Therefore, the lower leg traveled with an arc-shaped trajectory of approximately 80° in an alternating manner. The momentum of the ergometer returned the relaxed leg passively to the start position, and, as a result, the quadriceps muscle was functionally isolated (10,13,26,27,31). After a period of stabilization at rest, subjects began kicking at 4 W for 2 minutes. The power output was then increased by 4 W every minute throughout the test until subjects reached volitional fatigue. The cadence during the exercise workbout was maintained at 70 revolutions per minute (10,13,26,27). Termination of the exercise test was determined if the subject met the following criteria: (a) rating of perceived exertion of 8 or higher (scale 0–10) and (b) inability to maintain the targeted kicking cadence (10,13,26,27).

Listening to Music During Exercise. For the visit in which the subject listened to music, a selection of songs ranging from 137 to 160 $b·min^{-1}$ was selected by the investigators. The compilation of instrumental music (~30 minutes, double the anticipated exercise testing time) did not focus on any one genre (Table 1). The order of music presented was randomized, using the shuffle feature on the computer audio program, for each subject. Subjects wore over-the-ear headphones to listen to the music. The volume of the music was set at the same level for all subjects. For the control visit, subjects also wore the headphones, but no music was played. In addition, communication between the researchers and the subject were conducted through signs for both visits that replaced the strong verbal encouragement provided to subjects throughout the exercise workbout (10,13,26,27).

Electromyography Electrode Placement. Separate bipolar (20-mm center-to-center) surface electrode (EL500-6; BIOPAC Systems, Inc., Santa Barbara, CA) arrangements were positioned over the longitudinal axes of the rectus femoris muscle. This site was traced with a permanent marker for the subsequent visit to maintain the consistency of the electrode placement (10,13,26,27). The electrodes for the rectus femoris muscle were placed at 50% the distance between the anterior superior iliac spine and the superior border of the patella (15). The reference electrode was placed over the iliac crest. The shaved skin at each electrode site was carefully abraded and cleaned with alcohol, and interelectrode impedance was kept below 2,000 ohms consistent with our previous work (10,13,26,27). The EMG signal from each electrode placement site was amplified (gain: ×1,000) using differential amplifiers (EMG 100B; BIOPAC Systems, Inc.).

Determination of EMG_{FT} and Signal Processing. The EMG_{FT} was determined for each subject at each visit. Briefly, the absolute EMG amplitude (microvolts root mean square, μVrms) was calculated from 6 data points for each 1-minute stage and then plotted vs. time (Figure 1) (5,10,14,22). Specifically, each data

Table 1

List of instrumental music used in this study.*

Song title	Artist	$b·min^{-1}$
(I Can't Get No) Satisfaction	The Rolling Stones	137
Beat It	Michael Jackson	139
Danger Zone	Kenny Loggins	158
Fever	Peggy Lee	137
Heatseeker	AC/DC	160
Maniac	Michael Sembello	159
Old Yellow Bricks	Arctic Monkeys	136
Pump It Up	Elvis Costello and The Attractions	139

*The order of music presented was randomized, using the shuffle feature on the computer audio program, for each subject.

point represents a 10-second epoch in which all completed bursts within that window were selected for signal processing. The raw EMG signals were digitized at 1,000 Hz and stored in a personal computer (Dell Inspiron E1705; Dell Inc., Round Rock, TX) for subsequent analysis (10,13,26,27). All signal processing was performed using custom programs written with LabVIEW programming software (version 2014; National Instruments, Austin, TX). The EMG signals were bandpass-filtered (fourth-order Butterworth) at 10–500 Hz. Thus, for each power output, the EMG amplitude vs. time relationship was analyzed using linear regression (Figure 1). The EMG$_{FT}$ is a derived value from the average of the highest power output with a nonsignificant slope coefficient and the lowest power output with a significant positive slope coefficient (5,6,10,12–14,22).

Statistical Analyses

All data presented in the current study are mean ± *SEM*. For the responses to the BRUMS questionnaire two-way repeated-measures analysis of variance (ANOVAs) were used (25). The EMG$_{FT}$ for each subject and each condition was calculated as described above. Therefore, the comparison of the EMG$_{FT}$ between the 2 conditions as well as other exercise outcomes was analyzed using a paired-sample *t*-test (25). In addition, to determine the potential influence of order effect, we compared the EMG$_{FT}$ from the 2 visits independent of the experimental conditions (i.e., no music vs. music) using a paired-sample *t*-test. Statistical significance was set at $p \leq 0.05$, and data were analyzed using the Statistical Package for Social Sciences Software (SPSS, v. 25; IBM, Armonk, NY).

Results

Mood and Motivation Questionnaire

For the BRUMS questionnaire, we examined fatigue and vigor that are the 2 categories most relevant to the present investigation. For fatigue, the 2 [exercise condition: no music or music] × 2 [time: before and immediately after exercise] repeated-measures ANOVA indicated no significant interaction [F(1,18) = 1.26; p = 0.276] or main effect for exercise condition [F(1,18) = 0.037; p = 0.850]. There was, however, a significant main effect for time [F(1,18) = 8.08; p = 0.011], which revealed a significant mean difference (pre: 1.7 ± 0.3 vs. post: 3.9 ± 0.7; p = 0.011).

For vigor, the 2 [exercise condition: no music or music] × 2 [time: before and immediately after exercise] repeated-measures ANOVA indicated no significant interaction [F(1,18) = 1.73; p = 0.205] or main effect for exercise condition [F(1,18) = 0.334; p = 0.570]. There was, however, a significant main effect for time [F(1,18) = 12.03; p = 0.003], which revealed a significant mean difference (pre: 3.8 ± 0.6 vs. post: 5.3 ± 0.8; p = 0.03).

For the motivation questionnaire, we performed a paired-sample *t*-test since subjects completed the questionnaire once for

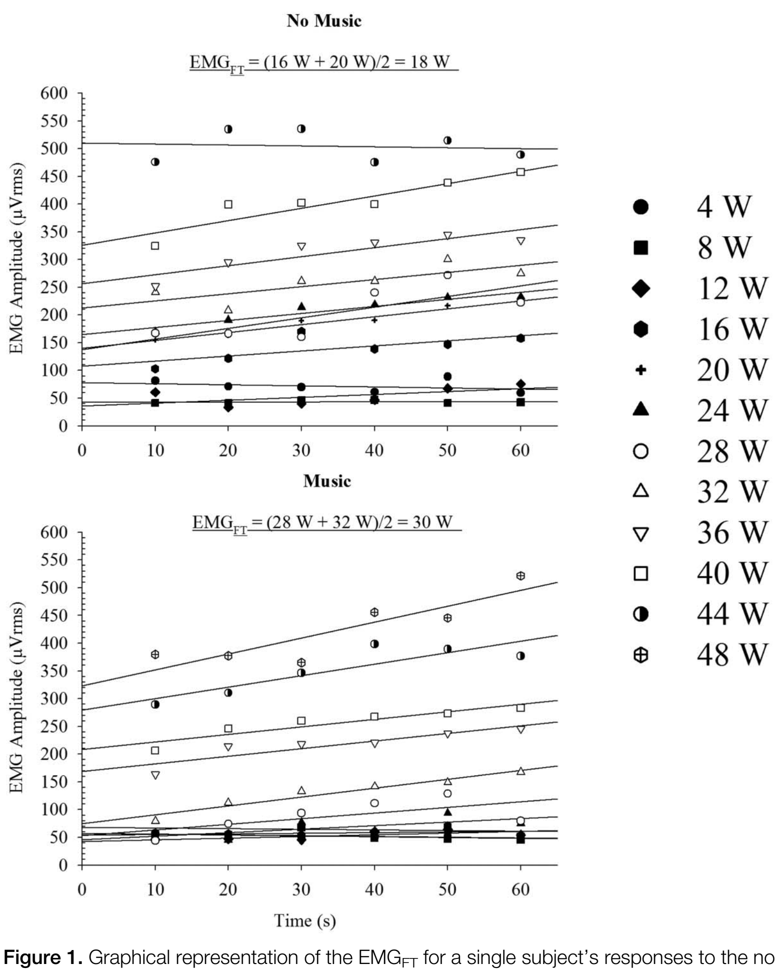

Figure 1. Graphical representation of the EMG$_{FT}$ for a single subject's responses to the no music and music conditions.

each exercise condition. Therefore, we found that intrinsic motivation (no music: 22.0 ± 1.0 vs. music: 22.2 ± 0.9; $p = 0.805$) and success motivation (no music: 17.4 ± 1.5 vs. music: 18.4 ± 1.5; $p = 0.177$) were not statistically different between the 2 exercise conditions. Moreover, we found no significant mean differences between the 2 conditions when subjects were asked to score the following question "*I am motivated to do this task*" (no music: 3.3 ± 0.2 vs. music: 3.0 ± 0.1; $p = 0.08$).

Exercise Responses

As shown in Table 2, there were significant mean differences for maximal power output between the 2 exercise conditions. For the absolute and relative maximal heart rate values; however, there were no significant mean differences between the 2 exercise conditions. For the 2 exercise conditions, a similar pattern of responses was found for the rating of perceived exertion for the exercised leg. For the EMG_{FT} (Figure 1), we found that listening to music increased the subject's neuromuscular threshold relative to the no music condition (Table 2). In addition, the paired-sample *t*-test indicated no influence of order effect [$t(9) = 0.993$; $p = 0.35$] on the EMG_{FT} for the 2 visits independent of experimental condition (mean ± *SEM*: visit 1: 27 ± 5 W vs. visit 2: 32 ± 3 W).

Discussion

The main and unique finding of this study was that listening to fast-tempo music, during incremental single-leg knee-extensor ergometry, increased the EMG_{FT} compared with listening to no music. In addition, we found that subjects achieved a higher maximal power output when listening to music during the exercise workbout. Moreover, we found that fast-tempo music did not influence absolute or relative end-exercise heart rate. To the best of our knowledge, this is the first study to show that the EMG_{FT}, derived from incremental single-leg knee-extensor ergometry, may be influenced by fast-tempo music.

Previous studies have examined the relationship between listening to music during various modes of exercise (9,17,23). For example, Hutchinson et al. (17) examined the effects of fast-tempo music while subjects were performing the Wingate test. To this extent, the investigators found that peak power and mean power significantly increased by ~7.2 and ~6.3%, respectively, when subjects were listening to music compared with the no music condition (17). Stork et al. (33) examined the influence of self-selected music on performance and perceived enjoyment of sprint interval exercise in a group of healthy college-aged men and women. Similar to the Hutchinson et al. (17) study, the Wingate test was performed with and without subjects listening to music. It should be noted, however, that Stork et al. (33) had subjects perform the Wingate test for the 2 conditions (music or no music) on the same day separated by 4 minutes of rest. The investigators reported significant increases in peak power and mean power as well as increased perceived enjoyment for the music condition (33). Overall, the results of these studies indicate that music can enhance exercise performance; however, several factors need to be considered.

Most studies examining the effects of music on physical performance have focused on in-task applications (21). That is, subjects listen to music during the exercise workbout (21). It should be noted, however, that pretask and posttask applications of music are also studied, but to a lesser extent. Nevertheless, for in-task studies of music, there is a distinction between music that is synchronous and asynchronous to the physical activity the subject is performing (21). Exercise to synchronous music is operationally defined as when the subject's movement is in concert with the rhythm of the music, whereas exercise to asynchronous music is operationally defined as when the subject's movement is not in concert with the rhythm of the music (21). For example, Bacon et al. (1) reported that oxygen uptake measured during cycle ergometry was significantly lower for the synchronous music condition than the slow-tempo asynchronous condition. Crust (7) reported that although subjects were significantly more motivated when listening to familiar asynchronous music during treadmill exercise than listening to unfamiliar asynchronous music. Moreover, there were no significant mean differences for heart rate response between the 2 music conditions (7).

In the present investigation, we found that our in-task application of listening to fast-tempo music (Table 1) increased maximal power output and the EMG_{FT} by ~13 and ~26%, respectively, for incremental single-leg knee-extensor ergometry (Table 2). Moreover, the music tempo and movement of the single-leg knee-extensor ergometry were asynchronous. That is, subjects were asked to maintain a kicking cadence of 70 revolutions·min^{-1}, whereas the tempo of the music subjects listened to was twice the kicking cadence (mean = 146; *SEM* = 4 b·min^{-1}). In addition, there were no significant exercise condition by time interaction for the BRUMS questionnaire related to fatigue and vigor, yet there was no significant difference in the level of motivation between the 2 conditions. Other physiological outcomes such as absolute and relative end-exercise heart rates were not significantly different between the 2 conditions. This finding was consistent with those of Crust (7). One potential explanation for the lack of increase in end-exercise heart rate, in the current study, may be the exercise paradigm that was used. The single-leg knee-extensor ergometry was designed to minimize the contribution of the cardiovascular and respiratory systems to exercise since it is a single-joint exercise (5,26,31). Taken together, these results suggest that listening to fast-tempo music during incremental exercise, as described in this study, may increase exercise tolerance and influence neuromuscular fatigue.

Table 2
Comparison of exercise outcomes for the no music and music conditions.*

Exercise variables	Exercise conditions: No music	Exercise conditions: Music	Effect size (Cohen's *d*)	*p*
Maximal power output (W)	48 ± 4	54 ± 3	0.57	0.02
EMG_{FT} (W)	27 ± 3	34 ± 4	0.66	0.008
End-exercise heart rate (b·min^{-1})	130 ± 5	138 ± 6	0.50	0.21
End-exercise heart rate (% of predicted)	66.6 ± 2.7	71.0 ± 3.0	0.49	0.20
End-exercise leg RPE (scale 0–10)	9 ± 0	9 ± 0	0.08	0.80

*Mean ± *SEM*. 220-age was used to calculate predicted maximal heart rate.

The increased maximal power output and EMG$_{FT}$ observed in the current study when subjects listened to music during the exercise workbout may be, in part, due to potential changes in brain activity (18–20). Specifically, investigators have used techniques such as EEG (electroencephalography) and functional magnetic resonance imaging (*f*MRI) to identify various changing in the brain that are influenced by listening to music during exercise. For example, Bigliassi et al. (4) used a 64-channel EEG system to measure the electrical activity in the brain of subjects while performing submaximal isometric ankle-dorsiflexion task with and without listening to music. In addition, the investigators also measured EMG activity in the tibialis anterior and lateral gastrocnemius muscles (4). Bigliassi et al. (4) concluded that listening to music during the exercise task may result in switching from associative to dissociative thoughts, which increased performance. This was, in part, observed in the EEG signal that indicated a reduction in theta waves in various regions of the brain when the task was performed with music relative to the no music condition (4). To determine which regions of the brain are activated when listening to music during exercise investigators have used *f*MRI (3). Briefly, *f*MRI is a noninvasive methodology of measuring the brain's activity during various modalities (11,16). Bigliassi et al. (3) used *f*MRI to identify brain regions that are effected by listening to music during exercise. It should be noted, however, that the exercise mode used in the study was isometric grip test (3). Indeed, the investigators reported that the temporal regions and insular cortex showed increased activity when subjects listened to music during exercise than the no music condition (3). Moreover, the authors stated, "…significant activation in the LIFG [left inferior frontal gyrus] that was elicited by the interactive effects of exercise and music…" (3) (p. 136). Taken together, these results suggest that listening to music, during an exercise workbout, influences brain regions that result in attenuating internal cues related to fatigue (3).

Practical Applications

The findings of the current investigation indicate that listening to fast-tempo music increased overall exercise tolerance and the neuromuscular fatigue threshold. These results are applicable to both sport and rehabilitative settings. In either scenario, listening to fast-tempo music during the exercise workbout may, in part, distract the individual from the perception or sensation of fatigue. This, in turn, may allow the athlete (or client) to continuing performing the exercise workbout rather than stopping. One caveat that should be noted, however, is that in the current study, the exercise mode was an isolated single-joint aerobic exercise that minimizes the contribution of the cardiovascular and respiratory responses to exercise (10,14,30). Nevertheless, our findings are consistent with results from other laboratories showing the beneficial effects of listening to fast-tempo music during whole-body exercise.

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