Running Head: MUSIC DURING SPRINT INTERVAL EXERCISE

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Let's Go: Psychological, Psychophysical, and Physiological Effects of Music During Sprint Interval Exercise

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Abstract

Background: While sprint interval training (SIT) is time-efficient and can elicit meaningful health benefits among adults who are insufficiently active, one major drawback is that people can find it to be unpleasant. Consequently, researchers have begun to investigate the use of music to enhance people's pleasure during SIT. Presently, little is known about the application of music to SIT protocols designed for insufficiently active individuals. **Purpose:** To investigate the psychological (affective valence, arousal, enjoyment), psychophysical (perceived exertion), and physiological (heart rate [HR], power output) effects of researcher-selected motivational music during a low-volume SIT protocol performed by insufficiently active adults. **Methods:** Using a randomized, fully-counterbalanced design, 24 insufficiently active adults (12 women, 12 men; 24 ± 5 years) inexperienced with SIT completed three SIT trials (3 × 20-s "all-out" sprints with 2-min recovery periods) under different conditions: motivational music, podcast control, no-audio control. **Results:** Post-exercise enjoyment was greater in the music condition (M = 89.58 ± 17.33) compared to podcast (M = 83.92 ± 19.49; $p = .04$, $\eta_p^2 = 0.18$) and no-audio (M = 85.28 ± 17.92; $p = .04$, $\eta_p^2 = 0.17$) controls. Over the course of the SIT trial, HR responses were elevated in the music condition in comparison to the podcast ($p = .02$, $\eta_p^2 = 0.23$) and no-audio ($p = .03$, $\eta_p^2 = 0.21$) controls, and peak power output was higher in the music condition when compared to the podcast ($p = .02$, $\eta_p^2 = 0.23$) and no-audio ($p = .01$, $\eta_p^2 = 0.25$) controls. Affective responses over the course of the SIT trial were more positive in the music condition when compared to the no-audio control ($p = .03$, $\eta_p^2 = 0.18$), and tended to be more positive in the music condition when compared to the podcast control ($p = .11$, $\eta_p^2 = 0.11$). Moreover, a rebound toward more positive affect was observed post-exercise in all conditions. **Conclusions:** The application of music during SIT has the potential to enhance feelings of pleasure, improve enjoyment, and elevate performance of SIT for adults who are insufficiently active, which may ultimately lead to better adherence to this type of exercise.

Keywords: interval exercise, motivational music, exercise enjoyment, affective valence, exercise performance, exercise behavior

Over the last decade, behavioral science researchers have become increasingly interested in determining how exercise might be structured to render it more pleasant and thus increase the likelihood that individuals will adhere to it. Popular exercise protocols have been getting ever shorter and more intense in order to adapt to the demands of busy lifestyles of people in the developed world (Thompson, 2017). One form of short-duration exercise is *interval exercise*, which involves multiple brief, high-intensity efforts, separated by periods of rest or recovery (Gibala, Gillen, & Percival, 2014). Research shows that several weeks of interval exercise training can engender meaningful physical health benefits that are similar to those of traditional long-duration aerobic exercise. Importantly, such benefits hold across healthy, at-risk, and diseased populations (Batacan, Duncan, Dalbo, Tucker, & Fenning, 2017; Gibala et al., 2014; Weston, Wisløff, & Coombes, 2014). Despite convincing evidence of the numerous physical benefits elicited by interval exercise, one major drawback is that people can find it unpleasant (e.g., Stork, Banfield, Gibala, & Martin Ginis, 2017). Moreover, evidence is emerging to suggest that individuals who are insufficiently active may experience affective responses to interval exercise that are more negative than those experienced by active individuals (Frazão et al., 2016). The unpleasant nature of interval exercise might well discourage continued participation.

In light of the health benefits of interval exercise and the potential for such exercise to be perceived as aversive, researchers have begun to investigate various strategies related to enhancing people’s psychological responses to interval exercise (affect, enjoyment, attitudes, self-efficacy; e.g., Brown, Teseo, & Bray, 2016; Jones, Tiller, & Karageorghis, 2017; Stork, Kwan, Gibala, & Martin Ginis, 2015; Stork & Martin Ginis, 2017). In particular, listening to music during exercise is a simple strategy that has been shown to improve affect and enjoyment, regulate arousal, and enhance exercise performance (e.g., Bigliassi, Karageorghis, Hoy, &

Layne, 2018; Jones et al., 2017; Karageorghis & Priest, 2012a, 2012b; Stork et al., 2015; Yamamoto et al., 2003). Drawing from a model pertaining to the application of music in exercise and sport (Karageorghis, 2016) as well as empirical evidence (e.g., Hutchinson & Karageorghis, 2013), it is possible that music-related interventions can be used to create more positive exercise experiences when people engage in interval exercise. This approach may improve the likelihood of future interval exercise participation (see Stork & Martin Ginis, 2017). However, there is limited research investigating the effects of music during high-intensity interval exercise (e.g., Jones et al., 2017; Stork et al., 2015; Stork & Martin Ginis, 2017).

Stork et al. (2015) investigated the effects of self-selected music on the performance and enjoyment of a particularly intense form of interval exercise, referred to as sprint interval training (SIT). The protocol consisted of four repetitions of the 30 s “all-out” Wingate Anaerobic Test (WAnT) (Bar-Or, 1987) on a cycle ergometer, separated by a 4-min rest period. Results showed that peak and mean power output during the WAnT bouts were significantly higher over the course of the SIT protocol, and that post-SIT enjoyment was significantly greater in the music condition compared to a no-music control. Despite the supramaximal nature of the exercise, music had a positive influence on affective responses during SIT, whereby affect was consistently more positive in the music condition (although this influence did not elicit a statistically significant finding). It is important to note that this study implemented a particularly intense SIT protocol among individuals who are *active*. Little is known about the effects of music during SIT protocols that are designed for individuals who are *insufficiently active*.

In recent years, exercise physiologists have adopted SIT protocols that may be more appropriate for people who are less active (see e.g., Vollaard & Metcalfe, 2017). One such protocol consists of 3 × 20-s “all-out” WAnT sprints, separated by a 2-min recovery period and lasts for a total of 10 min (including warm-up and cool-down; Gillen et al., 2016, 2014). Notably, this SIT protocol has been shown to elicit significant physiological benefits among previously inactive individuals following several weeks of exercise (Gillen et al., 2016, 2014). Given that this low-volume SIT protocol requires little total work time (60 s), is of short duration (10 min), and can elicit meaningful health benefits, it may be more appealing than traditional SIT protocols that require longer work periods and a greater exercise duration (see Stork, Gibala, & Martin Ginis, 2018; Vollaard & Metcalfe, 2017). Further, it is logical to surmise that if music can be used to improve people's experiences during traditional SIT (Stork et al., 2015), it should also have positive effects on the experience of a lower-volume SIT protocol.

The aforementioned study (Stork et al., 2015) provided initial evidence of the psychological and physiological effects of music use during a SIT protocol; however, this study employed *self-selected* music. Personalized music playlists were created for each participant based on selections they suggested would be appropriate for exercise. Consequently, a limitation of the study was that there was large variability in the characteristics of the music used (e.g., genre, tempo, epoch) and some participants may have selected music with inappropriate psycho-acoustic properties for the high-intensity nature of the exercise. For example, while there is evidence that it is ideal to match high-intensity exercise with fast-tempo music (135–140 bpm; Karageorghis, 2016; Karageorghis et al., 2011), some participants in the Stork et al. (2015) study selected tracks with slower tempi (e.g., 95–100 bpm). Additionally, the motivational ratings of the tracks were not consistently high across all participants. This is an important consideration given that the positive influence of asynchronous music during high-intensity exercise is believed to be associated with the motivational qualities of the music (Hutchinson & Karageorghis, 2013; Karageorghis, 2016). In order to have a more rigorous test of the effects of music and to maximize the efficacy of a music-related intervention, it is critical for music characteristics to be controlled and to ensure that the music is motivational in nature (cf. Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006).

It is also important to control for the effects of auditory distraction per se (Bigliassi, Karageorghis, Wright, Orgs, & Nowicky, 2017; Chanda & Levitin, 2010). It has been suggested that during high-intensity exercise, the psychological effects of music are driven by the motivational qualities of the music as opposed to the dissociative effects of music (Atkinson, Wilson, & Eubank, 2004; Hutchinson & Karageorghis, 2013). If this explanation is sound (i.e., that music functions to *motivate* rather than *dissociate* during SIT), then SIT performed in the presence of music should elicit greater psychological and physiological benefits than when SIT is performed in the presence of a non-musical auditory distraction. To test this possibility, the present study incorporated a non-music audio control (i.e., a podcast) condition in addition to a no-audio control (i.e., silent) condition.

Purpose and Hypotheses

The purpose of this study was to compare the psychological (i.e., affective valence, arousal, enjoyment), psychophysical (i.e., perceived exertion), and physiological (i.e., heart rate, power output) responses to a low-volume SIT protocol when insufficiently active adults completed SIT under three conditions: researcher-selected motivational music, podcast control, and no-audio control. Based on previous studies of the effects of music during traditional SIT (Stork et al., 2015) and a single WAnT performance (Hutchinson et al., 2011), we hypothesized that the application of motivational music during low-volume SIT would lead to more positive affect (H_1), greater post-exercise enjoyment (H_2), and higher peak and mean power output (H_3) when compared to an audio podcast and no-audio control conditions. Further, we hypothesized that ratings of perceived exertion would not differ across the three conditions (H_4) (Stork et al., 2015).

Methodology

Study Design

A repeated-measures, crossover design was employed wherein each participant completed three exercise trials: motivational music, podcast (control), and no-audio (control). The order of conditions was randomized, counterbalanced (using a 3 × 6 Williams Square design; Williams, 1946), and stratified by gender in blocks of six. Each participant made five visits to a laboratory over the course of 2–3 weeks.

Participants

Based on previous studies that found effect sizes (Cohen's *d*s) of 0.36 and 1.57 for differences in enjoyment and affect (respectively) between interval exercise completed under music and no-music control conditions (Jones et al., 2017; Stork et al., 2015), we powered for an effect of 0.96, which was the mean of these effect sizes. Using a repeated-measures (RM) analysis of variance (ANOVA) statistical test in G*Power 3 (Faul, Erdfelder, Buchner, & Lang, 2009), a sample size of 18 was estimated to have 80% power ($\alpha = 0.05$) to detect an effect of $d = 0.96$ (Cohen, 1992). In order to estimate conservatively and achieve perfect stratification by gender, a sample of 24 participants was sought. Twenty-four insufficiently active women ($n = 12$) and men ($n = 12$) inexperienced with SIT completed the study. Participants were excluded from the study if they had previously participated in similar SIT protocols or had any contraindications to exercise based on the Physical Activity Readiness Questionnaire (PAR-Q). They were considered "insufficiently active" based on similar criteria used in a previous interval exercise study (Frazão et al., 2016) and as assessed by the International Physical Activity

Questionnaire – Short Form (IPAQ-SF; *Mdn* = 260.00 MET-min/week, *M* = 312.50 MET-min/week of moderate and vigorous activity). The University of British Columbia Clinical Research Ethics Board and the Brunel University London Research Ethics Committee approved the study protocol and participants were recruited by means of poster advertisements on campus. All participants provided written informed consent and received a £50 honorarium upon completion of the study.

Psychological Measures

Affective valence. Hardy and Rejeski's (1989) Feeling Scale (FS) was used to measure affective valence before, during, and following the exercise trials. The FS is an 11-point bipolar, single-item scale anchored by "very bad" (-5) and "very good" (+5) along a displeasure–pleasure continuum. The FS has been established as a reliable and valid measure of exercise-related affective states (Hardy & Rejeski, 1989).

Affective arousal. Svebak and Murgatroyd's (1985) Felt Arousal Scale (FAS) was used to measure perceived activation before, during, and following the exercise trials. The FAS is a 6-point, single-item scale anchored by "low arousal" (1) and "high arousal" (6). It has been suggested that the concurrent use of FS and FAS strengthens the discriminant validity of these two measures (Ekkekakis, 2003).

Exercise enjoyment. Enjoyment of each exercise trial was measured immediately post-exercise using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991). The PACES was modified slightly to render each item in the simple past tense (see Stork et al., 2018, 2015). This scale has 11 negatively worded and 7 positively worded items that participants rated on a 7-point bipolar scale (from 1 to 7), indicating how they felt about the exercise they completed. For example, the item that was anchored by "I enjoyed it" (1) and "I hated it" (7) is considered to be a negatively worded item. The internal consistency was acceptable at each administration (Cronbach's αs ≥ .95).

Psychophysical Measures

Perceived exertion. Borg's CR-10 (1998) rating of perceived exertion (RPE) scale was used to assess perceived physical exertion during exercise and is a valid and reliable measure (Borg, 1998).

Physiological Measures

Heart rate. Participants' heart rate (HR) was recorded continuously, second-by-second, throughout baseline fitness testing and each of the exercise trials by use of a HR monitor (Polar H7).

Power output. Peak and mean power output during cycling (in watts [W]) was measured using Velotron Wingate software (version 1.0.2; RacerMate).

Post-Experimental Measures

A questionnaire was administered to assess the degree to which participants liked, and were motivated by, the auditory stimulus during each condition.

Liking. A single-item rated on a 10-point scale ranging from "I did not like it at all" (0) to "I liked it very much" (10), adapted from Karageorghis and Jones (2014), was used to measure the degree to which participants liked the auditory stimulus (or no audio) during each condition. For example, the liking item question for the music condition was, "Please rate how much you *liked* the music while it was played during that exercise session."

Motivation. A single-item rated on a 10-point scale ranging from "It did not motivate me at all" (0) to "It motivated me very much" (10) was used to measure how much the auditory stimulus (or no audio) motivated participants during each condition. For example, the motivation item question for the music condition was, “Please rate how much the music *motivated* you while it was played during that exercise session.”

Protocol

Familiarization 1 (visit 1). Following confirmation of eligibility, participants provided their written informed consent. Eligible participants then performed a submaximal Åstrand–Rhyming predictive maximal oxygen consumption ($\dot{V}O_2$max) test (Åstrand & Rhyming, 1954) on an electronically-braked cycle ergometer (Velotron, RacerMate, Seattle, WA, USA). Thereafter, they completed a 2 min warm-up on the cycle ergometer followed by a single 20 s WAnT maximal sprint effort. Participants were then given a 30-s and 20-s warning before the start of their “all-out” sprint and were instructed to start increasing their pedal rate. Participants were given a verbal 10-s countdown until their “all-out” sprint began. During the 10 s leading up to the sprint, the ergometer resistance was dropped to 0 W and thus no resistance was applied. As soon at the countdown finished, participants were verbally prompted to begin the “all-out” sprint. Specifically, they were asked to pedal as hard and as fast as they could against a set resistance of 5% of their body mass (Gillen et al., 2016, 2014) for the entire 20-s “all-out” sprint. During the sprint, the experimenter provided the same verbal script to each participant which consisted of non-motivational prompts of time remaining. This protocol was followed for each “all-out” sprint performed in all subsequent exercise trials. Participants were asked to report RPE, FS, and FAS at the very end of the sprint and were subsequently administered the PACES. The cycle ergometer was positioned in such a way that participants directly faced a wall on which the three measurement scales were posted. The scales were color-coded to clearly differentiate between each and minimize common-method variance (see Stork et al., 2017, 2018).

Familiarization 2 (visit 2). Participants were asked to complete a SIT trial consisting of 3 × 20-s “all-out” sprints, separated by 2 min of low-intensity cycling at 50 W (Gillen et al., 2016, 2014). The exercise trial lasted a total of 10 min, with the inclusion of a 2-min warm-up and 3-min cool-down at 50 W. During the rest periods, participants were asked to pedal very lightly at 50 W, without physically exerting themselves any more than a 1 (“very weak”) on the RPE scale. Participants were asked to remain seated on the bike at all times, including sprint bouts and rest periods. Following suit with visit 1, the “all-out” sprints were performed on the cycle ergometer with an applied resistance of 5% of body mass (Gillen et al., 2016, 2014). Participants were prompted to report RPE, FS, and FAS (in this order) before, during (at end of/immediately following sprints 1, 2, and 3, and during the last ~35 s of recovery periods) and immediately following the final sprint, during the cool-down, and at the end of the cool-down. They were prompted to report RPE, FS, and FAS with ~35 s left in the recovery periods (as opposed to the last 15 s of the recovery periods) in order to allow sufficient time for the verbal instructions leading into the 20-s all-out sprints. This ensured that participants were performing the sprints at the desired “all out” intensity.

Reports of RPE, FS, and FAS were prompted *immediately following* the sprint bouts for the SIT protocol as it was not feasible to interrupt participants *during* the supramaximal, “all-out” cycling efforts in order to ask them a question. At these time points, participants were carefully instructed to report how they “felt *during* the final few seconds of the exercise.” At all other time-points (including rest periods), participants were instructed to indicate how they “feel *right now*.” Participants were reminded of these explicit instructions prior to each exercise trial. Participants were also prompted to report FS and FAS and filled out the PACES immediately following each exercise trial (following cool-down).

Experimental trials (visits 3–5). Each exercise trial was scheduled approximately 48–72 hr apart and most trials were completed approximately 3 days apart (*M* = 2.65 days, *SD* = 0.76). Participants were instructed to maintain consistent dietary and sleep habits, and to avoid any other physical activity for the entire day of their visits to the laboratory. They were scheduled at approximately the same time of day for visits 3–5 in order to reduce diurnal variation in SIT performance. Before completing the exercise trials, participants had the exercise procedures explained to them and an opportunity to ask questions. All three exercise trials completed at laboratory visits 3–5 were performed according to the same SIT and measurement protocols used for visit 2. The only difference was that participants were asked to remain in the laboratory for 10 min following the experimental trials and prompted to report FS and FAS at 5 and 10 min post-exercise.

For the music and podcast conditions, audio was played from a portable stereo (JVC RV-NB20B) at a volume of 72 dBA for the duration of the warm-up, sprints, and recovery periods. No audio was played during the 3-min cool-down as investigation of the effects of recuperative, post-exercise music did not pertain to this study’s research question. The audio was not played via headphones in order to enable verbal interaction between the participant and experimenter. In order to conceal the true purpose of the study, we did not specify that either music or audio would be played during any of the laboratory visits when the research team sent out recruitment materials or corresponded with participants. However, participants were aware that the study aimed to examine people’s psychological responses to SIT exercise.

Motivational music. Motivational music has been described as upbeat and stimulating music that “tends to have a fast tempo (> 120 bpm) and a strong rhythm, and is proposed to enhance energy and induce bodily action” (Karageorghis, Terry, & Lane, 1999, p. 714).

Participants were given the option to choose between three music genres that corresponded to three edited tracks (see *Audio Selection and Editing* below). As soon as participants were set up on the bike, the experimenter said, “Oh, by the way, I’ve got my iPod with me today, so I will put on some music. What type of music do you prefer – pop, rock, or hip-hop?” If participants did not indicate a preference, pop music was selected. Eight participants indicated no genre preference, 8 selected pop, 6 selected rock, and 2 selected hip-hop.

Podcast control. As soon as participants were positioned on the bike, the experimenter said, “Oh, by the way, I’m going to be playing a podcast over the speakers today.” If participants happened to query why the podcast was being played, the experimenter explained that he just wanted to have something playing in the background.

No-audio (silent) control. No music or audio of any type was played during SIT.

Two experimenters were always present during the exercise trials and they only interacted with participants to provide instructions, take measures, and ensure their safety during the experimental protocols. They did not provide any additional verbal encouragement. The same scripted set of instructions were provided throughout each exercise trial by the same male experimenter (MJS). Following their final exercise trial, participants completed the post-experiment questionnaire.

Audio Selection and Editing

Music selection. Music was selected by the experimenters based on the criteria outlined by Karageorghis, Priest, Terry, Chatzisarantis, and Lane (2006) and with reference to Karageorghis’ (Karageorghis, 2016) model pertaining to music selection in the domain of exercise and sport. Sixteen asynchronous motivational tracks that fit the epoch (within the last 10 years), genre (pop, rock, hip-hop), and tempo (fast: 132–142 bpm) criteria were chosen by the researchers and their motivational ratings were assessed using a music rating panel. The panel was comprised of eight British nationals who were not involved in the experimental phase of the study, but were representative of the population sampled for the study. As outlined in a paper by Karageorghis et al. (2006), panel members listened to 90 s of excerpts of the 16 tracks and were asked to assess the extent to which each piece of music would motivate them during a 3 × 20-s "all-out" SIT protocol by responding to each item of the Brunel Music Rating Inventory-3 (BMRI-3; Karageorghis, 2008). The BMRI-3 is a tool designed to assess the motivational qualities of musical pieces, with total possible scores ranging from 6 to 42 (Karageorghis, 2008). The three tracks with the highest average motivational ratings, according to each of the three genres, were as follows: *Let's Go* by Calvin Harris ft. Ne-Yo, 2012 (pop; $M = 32.63$, $SD = 3.66$), *Bleed It Out* by Linkin Park, 2007 (rock; $M = 32.38$, $SD = 4.60$), and *Can't Hold Us* by Macklemore & Ryan Lewis ft. Ray Dalton, 2011 (hip-hop; $M = 32.13$, $SD = 4.61$).

Music editing. Each track was edited to last for a total of 7 min in order to match the duration of the warm-up, sprints, and recovery periods. The tempo of each track was edited slightly (where necessary) in order to remain within a fast tempo range (e.g., Karageorghis, 2016; Karageorghis et al., 2011) and within 7 bpm of each other. In order to create 7-min versions of the tracks, the entire track or segments of each track were looped and edited slightly. All tracks were downloaded from Apple's iTunes Store (Apple Inc., 2017) and edited using Apple's GarageBand (Apple Inc., 2017).

Podcast selection and editing. An audio podcast about the history of consumerism and that was devoid of musical qualities (https://www.youtube.com/watch?v=Y-Unq3R--M0) was shortened from its original 10-min duration, to 7 min.

The sound intensities of the audio files were standardized at 72 dBA using a decibel meter before being exported to an iPod Nano (7th Generation, Apple Inc.). This volume was selected following pilot testing in order to ensure the sound quality was sufficient, the experimenters could hear and record the scale measures accurately, and to maintain effective communication with participants during the experimental procedures.

Statistical Analyses

Following data screening and appropriate diagnostic tests (Tabachnick & Fidell, 2013), data were analyzed using multivariate analysis of variance (MANOVA) or ANOVA, with the choice of analysis dependent on the hypothesis being tested, conventional analytic approaches, timing of measurements, and which dependent variables were conceptually and statistically correlated (Field, 2013; Huberty & Morris, 1989).

Primary analyses. Separate Condition × Time RM ANOVAs were performed on RPE, HR, FS, and FAS to examine differences across the three conditions over time. Differences in RPE and HR were assessed throughout the exercise protocol (warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3). Differences in FS and FAS were assessed pre-exercise and throughout the exercise protocol (pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3). A one-way RM ANOVA was conducted to assess differences across the three conditions for PACES.

A Condition × Time RM MANOVA was computed to examine differences in power output (peak and mean power output) during the three sprint bouts (sprint 1, sprint 2, sprint 3). Any significant *F* test was followed by two Condition × Time RM ANOVAs in order to discern differences in peak and mean power output across the three conditions over time.

Secondary analyses. A one-way RM MANOVA was conducted on the two post-experimental measures of liking and motivation. Any significant *F* test was followed by two

Condition × Time RM ANOVAs in order to discern differences in liking and motivation across conditions.

Owing to the testing of directional hypotheses for FS, PACES, HR, and power output, significant main effects of condition were followed by simple contrasts, with the music condition defined as the comparator (Field, 2013). When significant main effects of time were detected, simple contrasts were used to examine differences, with the first measurement time point serving as the comparator. When the sphericity assumption was violated, a Greenhouse-Geisser correction was applied to the relevant *F* test (Field, 2013). The magnitude of the observed effects are reported as partial eta squared (η_p^2).

Based on expected gender differences in power output between women and men (e.g., Mayhew & Salm, 1990), gender was initially included as a between-subjects factor in the analyses for peak and mean power output in order to examine it as a potential moderator. No Condition × Gender, or Condition × Time × Gender interactions were found for peak or mean power output, suggesting that the effects of the three conditions did not vary by gender. Accordingly, the data were collapsed across women and men for the final power output analyses. SPSS version 21.0 was used for all analyses, and significance was set at $p < .05$. When two RM ANOVAs were conducted to discern differences following a significant RM MANOVA *F* test, a Bonferroni correction was applied to adjust the alpha level to .025 (.05/2).

Results

Participants

Participant characteristics are presented in Table 1. Due to technical difficulties, HR data were not captured in full from one male participant and, as a result, this single case was not included in the HR analyses.

Psychological Measures

Affective valence. A 3 (Condition) × 7 (Time Points: pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) RM ANOVA on pre- and in-task FS showed significant main effects of condition, $F(2, 46) = 3.53$, $p = .04$, $\eta_p^2 = 0.13$, and time, $F(1.79, 41.16) = 16.74$, $p < .001$, $\eta_p^2 = 0.42$ (see Figure 1). However, there was no significant condition × time interaction ($p = .68$, $\eta_p^2 = 0.03$). The contrasts for condition revealed that, over the course of the SIT trial, FS responses were more positive in the music condition when compared to the no-audio control ($p = .03$, $\eta_p^2 = 0.18$). Although FS responses tended to be more positive over the course of the SIT trial in the music condition compared to the podcast control, these differences were not statistically significant ($p = .11$, $\eta_p^2 = 0.11$). Contrasts for time indicated that FS scores significantly increased from pre-exercise to warm-up ($p = .001$, $\eta_p^2 = 0.39$) and decreased from pre-exercise to sprint 2 ($p = .01$, $\eta_p^2 = 0.25$) and sprint 3 ($p < .001$, $\eta_p^2 = 0.43$), with no differences in FS from pre-exercise to sprint 1 ($p = .94$, $\eta_p^2 = 0.00$), rest 1 ($p = .30$, $\eta_p^2 = 0.05$), and rest 2 ($p = .22$, $\eta_p^2 = 0.07$) across all conditions.

Affective arousal. A 3 (Condition) × 7 (Time Points: pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) RM ANOVA on pre- and in-task FAS showed only a significant main effect of time, $F(2.67, 61.38) = 81.00$, $p < .001$, $\eta_p^2 = 0.78$. None of the other main effects or interactions were significant (*p*s > .05). Contrasts for time indicated that FAS scores increased significantly from pre-exercise to all other time points during exercise (*p*s < .01) across all conditions.

Exercise enjoyment. Mean enjoyment scores differed across the three conditions, $F(2, 46) = 3.41$, $p = .04$, $\eta_p^2 = 0.13$. Enjoyment was greater in the music condition ($M = 89.58$, $SD =$

17.33) compared to podcast (*M* = 83.92, *SD* = 19.49; $p = .04$, $\eta_p^2 = 0.18$) and no-audio (*M* = 85.28, *SD* = 17.92; $p = .04$, $\eta_p^2 = 0.17$) controls.

Psychophysical Measures

Perceived exertion. A 3 (Condition) × 6 (Time Points: warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) RM ANOVA on RPE showed only a significant main effect of time, $F(1.61, 37.04) = 192.29$, $p < .001$, $\eta_p^2 = 0.89$. None of the other main effects or interactions reached significance ($p > .05$). Contrasts for time indicated that RPE scores significantly increased from warm-up to all other time points during exercise (*p*s < .01) across all conditions.

Physiological Measures

Heart rate. A 3 (Condition) × 6 (Time Points: warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) RM ANOVA on HR showed significant main effects of condition, $F(1.55, 34.15) = 5.35$, $p = .02$, $\eta_p^2 = 0.20$, and time, $F(2.38, 52.28) = 438.32$, $p < .001$, $\eta_p^2 = 0.95$ (see Figure 2). However, there was no significant condition × time interaction ($p = .36$, $\eta_p^2 = 0.05$). Contrasts for condition revealed that, over the course of the SIT trial, HR responses were elevated in the music condition in comparison to the podcast ($p = .02$, $\eta_p^2 = 0.23$) and no-audio ($p = .03$, $\eta_p^2 = 0.21$) controls. Contrasts for time indicated that HR responses increased significantly from warm-up to all other time points (*p*s < .001) across all conditions.

Power output. Using Pillai's trace, there was a significant omnibus effect of condition, $V = 0.24$, $F(4, 92) = 3.06$, $p = .02$, $\eta_p^2 = 0.12$, and time, $V = 0.50$, $F(4, 92) = 7.58$, $p < .001$, $\eta_p^2 = 0.25$.

Peak power. A 3 (Condition) × 3 (Time Points: sprint 1, sprint 2, sprint 3) RM ANOVA on peak power output showed significant main effects of condition, $F(2, 46) = 4.44$, $p = .02$, $\eta_p^2 = 0.16$, and time, $F(2, 46) = 4.96$, $p = .01$, $\eta_p^2 = 0.18$ (see Figure 3). However, there was no significant condition × time interaction ($p = .84$, $\eta_p^2 = 0.01$). Contrasts for condition revealed that, over the course of the SIT trial, peak power output was higher in the music condition when compared to the podcast ($p = .02$, $\eta_p^2 = 0.23$) and no-audio ($p = .01$, $\eta_p^2 = 0.25$) controls. Contrasts for time indicated that peak power output decreased from sprint 1 to sprint 2 ($p = .05$, $\eta_p^2 = 0.16$) and sprint 3 ($p = .009$, $\eta_p^2 = 0.26$) across all conditions.

Mean power. A 3 (Condition) × 3 (Time Points: sprint 1, sprint 2, sprint 3) RM ANOVA on mean power output showed only a significant main effect of time, $F(1.42, 32.65) = 18.25$, $p < .001$, $\eta_p^2 = 0.44$. None of the other main effects or interactions were significant (ps > .025). Contrasts for time indicated that mean power output significantly decreased from sprint 1 to sprint 2 ($p < .001$, $\eta_p^2 = 0.44$) and sprint 3 ($p < .001$, $\eta_p^2 = 0.49$) across all conditions.

Post-Experimental Measures

Using Pillai's trace, there was a significant omnibus effect of condition, $V = 0.97$, $F(4, 92) = 21.82$, $p < .001$, $\eta_p^2 = 0.49$.

Liking. Mean liking scores differed across conditions, $F(2, 46) = 21.50$, $p < .001$, $\eta_p^2 = 0.48$. Scores were higher during the music condition ($M = 7.83$, $SD = 1.76$) when compared to the podcast ($M = 5.67$, $SD = 2.41$; $p = .004$, $\eta_p^2 = 0.32$) and no-audio ($M = 3.75$, $SD = 1.92$; $p < .001$, $\eta_p^2 = 0.69$) controls.

Motivation. Mean motivation scores differed across conditions, $F(2, 46) = 71.63$, $p < .001$, $\eta_p^2 = 0.76$. Scores were higher during the music condition ($M = 8.04$, $SD = 1.12$) when compared to podcast ($M = 3.21$, $SD = 1.84$; $p < .001$, $\eta_p^2 = 0.83$) and no-audio ($M = 3.00$, $SD = 1.74$; $p < .001$, $\eta_p^2 = 0.84$) controls.

In addition to the inferential statistics provided herein, a fully comprehensive set of data and statistics are available from the first author (MJS).

Discussion

The purpose of this study was to examine the psychological, psychophysical, and physiological effects of researcher-selected motivational music applied to a low-volume SIT protocol performed by insufficiently active adults. The main findings were that, listening to motivational music during SIT led to greater post-exercise enjoyment of SIT, elevated HR responses, and enhanced peak power output when compared to podcast or no-audio controls. Further, affective responses tended to be more positive over the course of the SIT trial in the music condition when compared to the control conditions. The present findings provide novel and important implications regarding the application of music during SIT for people who are insufficiently active.

Affective Responses

Consistent with H_1 and the results of previous studies (e.g., Hutchinson et al., 2011; Stork et al., 2015), affective responses were more positive over the course of the SIT trial in the music condition compared to the no-audio control. Although affect tended to be more positive in the music condition compared to the podcast control, these differences did not reach statistical significance ($p > .05$). Thus, H_1 was only partially supported. The present findings suggest that listening to motivational music during a low-volume SIT protocol has the potential to induce more positive affective responses, even for less active individuals. This has meaningful implications given that many researchers have suggested that the positive effects of music on core affect may contribute to improved exercise adherence (see e.g., Clark, Baker, & Taylor, 2016; Karageorghis & Priest, 2012b).

The finding that affective responses tended to be more positive throughout the music condition in comparison to the control conditions is intriguing given that participants also exhibited elevated HR and greater peak power in the music condition. Ostensibly, an increase in physical exertion during the music condition should have elicited more negative in-task affective states. However, *peak* power only represents the initial burst of power output during a WAnT sprint, and there were non-significant ($p > .05$) between-condition differences in *mean* power. Thus, brief increases in peak power alone may not have been sufficient to elicit more negative affective states during SIT. This finding concurs with previous findings showing increases in peak and mean power output while listening to music during single (Hutchinson et al., 2011) and repeated WAnT sprints (Stork et al., 2015), with no cost to in-task affect.

In all three conditions, a rebound to more positive affect was observed following the cessation of exercise (see Figure 1). This post-exercise "affective rebound" to more positive states is consistent with previous interval exercise research (e.g., Decker & Ekkekakis, 2017; Stork et al., 2018, 2015) and the predictions of the dual-mode model (Ekkekakis, 2003). Although the use of recuperative music during the 3 min cool-downs or post-exercise was not evaluated in the present study, future research may benefit from examining the effects of recuperative music on affective states post-exercise (see e.g., Karageorghis et al., 2018).

Exercise Enjoyment

In accord with H_2 and previous findings (Stork et al., 2015), post-exercise enjoyment of SIT was greater in the music condition compared to the control conditions. This finding is important given that enjoyment has been identified as a key moderator of the intention–behavior relationship (Rhodes & Quinlan, 2018), and a predictor of positive attitudes toward exercise (Martin Ginis et al., 2006; Stork & Martin Ginis, 2017) and exercise behaviour (Rhodes, Fiala, & Conner, 2009). Individuals who intend to participate in exercise because they enjoy it are more likely to sustain their exercise intentions and carry out their intended exercise behavior (Rhodes

& Quinlan, 2018). Moreover, the use of music during SIT has been shown to improve enjoyment and attitudes toward SIT, which may have important implications for strengthening intentions toward SIT (Stork & Martin Ginis, 2017). Therefore, if people who are insufficiently active are more likely to enjoy SIT exercise while listening to music, they may subsequently be more likely to engage in, and adhere to, SIT exercise again in the future (see e.g., Stork et al., 2015; Stork & Martin Ginis, 2017).

Perceived Exertion

Consistent with H_4 and previous findings (Stork et al., 2015), there were no differences in RPE across conditions. This finding is compelling given that, although participants achieved elevated HR responses and greater peak power output in the music condition, they perceived equal levels of physical exertion across conditions. These findings are also consistent with other studies that found that participants achieved higher power output during a single “all-out” WAnT sprint in a music condition compared to a no-music condition, despite non-significant differences in RPE between the two conditions (e.g., Chtourou, Jarraya, Aloui, Hammouda, & Souissi, 2012; Hutchinson et al., 2011). Collectively, such findings support the notion that music may not be as effective at influencing psychophysical states (i.e., RPE) at high exercise intensities because attentional processing is overwhelmed by afferent signals (e.g., Karageorghis & Priest, 2012a; Rejeski, 1985; Tenenbaum, 2001).

Heart Rate Responses

A novel finding of the current study was that HR was elevated in the music condition compared to the control conditions. Previous studies have documented increases in circulating levels of epinephrine (Yamamoto et al., 2003) and elevated HR responses (Eliakim, Meckel, Nemet, & Eliakim, 2007) when fast-tempo music was played prior to an “all-out” WAnT sprint, but such physiological responses were only detected during warm-up periods and music was not played during the WAnT performance in both studies. This is the first study to measure and report elevated HR responses over the course of a SIT protocol performed with music.

One possible explanation for the current findings can be linked to the biopsychomusicological concept of *entrainment*. This refers to the innate tendency for humans to alter the frequency of their biological rhythms, such as HR, toward that of musical rhythms (Karageorghis, 2016). Based on this concept, it is plausible that participants' HR increased in response to the fast-tempo music that was being played during SIT. Further, the fast-tempo music used, at 135–142 bpm, falls within the optimal tempo range for high-intensity exercise based on research examining the relationship between exercise HR and music-tempo preferences using cycle ergometry (e.g., Karageorghis et al., 2011). Additionally, considering that participants reported being highly motivated during SIT in the music condition, it is also possible that they were motivated to push themselves harder, which would have elicited higher HR. The additive effects of fast-tempo music and high levels of participant motivation may account for the heightened HR responses found in the music condition.

Power Output

Consistent with H_3 and the findings of previous studies (Hutchinson et al., 2011; Stork et al., 2015), peak power output was higher in the music condition when compared to the control conditions. Contrary to H_3, there were no differences in mean power output between the music condition and the two control conditions. While the non-significant mean power findings are inconsistent with the previous SIT study (Stork et al., 2015), they are consistent with other studies investigating the effects of fast-tempo music on a single WAnT sprint performance (e.g., Eliakim et al., 2007; Yamamoto et al., 2003). In the present study, it appears that music was particularly effective in terms of motivating participants only for an initial burst of power at the start of each 20 s sprint. Accordingly, during high-intensity activity, it is possible that the ergogenic effect of music diminishes as the exercise progresses and interoceptive cues overwhelm attentional processes (Hutchinson et al., 2011; Stork et al., 2015). Another plausible explanation for these findings is that the ergogenic effect of music during SIT may be reduced for individuals who are insufficiently active and have not been subjected to anaerobic forms of training. Such individuals are likely to be unaccustomed to the physiological effects of acidosis (Hutchinson et al., 2011).

It has been suggested that applying music to SIT can elicit both pre-task (warm-up and rest periods) and in-task (during sprints) effects, and these additive effects may explain why the impact of music can persist over the course of multiple sprint bouts (Stork et al., 2015). Notwithstanding, unlike the previous study that implemented a traditional 4 × 30-s SIT protocol with a 2-min and 30-s warm-up and 4-min rest periods (Stork et al., 2015), the present study implemented a lower-volume SIT protocol with fewer sprint bouts (3) and shorter warm-up (2 min), sprint (20 s), and rest (2 min) durations. It may be that the reduced duration of the warm-up and rest periods reduced the potency of the music pre-task. In addition, fewer sprint bouts and shorter sprint durations may have limited the opportunity for the ergogenic effects of music to come into force.

Practical Implications

Based on the findings from this study, listening to music during interval exercise can be recommended for insufficiently active individuals. The present findings showed that music has the potential to evoke more positive affect and higher enjoyment; two outcomes that have been independently linked to increased exercise adherence (Karageorghis & Priest, 2012b; Stork et al., 2015; Stork & Martin Ginis, 2017). Further, music was also found to increase physical exertion during SIT, as reflected by elevated HR and greater peak power in the music condition. Thus, the application of music to interval exercise may be a practical strategy to help insufficiently active people get more out of their workout and can be used to encourage continued participation in interval-type exercise. For example, if an individual was interested in trying interval exercise for the first time, they might benefit from listening to music with a fast tempo (~135–142 bpm; cf. Karageorghis et al., 2011), from a genre of their preference, while completing the exercise.

Strengths and Limitations

There are several strengths associated with the present study. This is the first study to examine the psychological, psychophysical, and physiological effects of motivational music during a low-volume 3 × 20-s SIT protocol among insufficiently active adults. The study builds upon previous work (Stork et al., 2015), but provides novel contributions by replicating findings using a different participant sample and SIT protocol, and by accounting for previously stated limitations. Specifically, researcher-selected music with high motivational ratings (both a priori *and* post hoc) and with a standardized epoch and tempo was applied during SIT. In addition, a non-musical audio control condition (i.e., podcast) was included, and continuous HR data were collected throughout each of the exercise trials. Further, the application of music in this study was novel because participants were provided with the option to select which genre they preferred, and analysis of post-experiment items indicated that the music was perceived as being highly motivating and well-liked by participants. The present study followed rigorous methodology in order to mitigate potential confounds and to tease out the effects of the music intervention: interactions with participants were scripted for all laboratory visits; two familiarization trials were used; experimental visits were separated by a minimum of 2 days;

participants were familiarized with and reminded about the differences between the scale measures at the start of each laboratory visit; diurnal variation between experimental trials was controlled for; an effort was made to conceal the true purpose of the study by not informing participants that music or audio stimuli would be played during the study.

This study has a few limitations that are worth noting. While a podcast about the history of consumerism was selected for the podcast control condition owing to its non-musical and relatively impartial attributes, it was not possible to standardize individual responses to it. Accordingly, it is possible that the podcast may have elicited unintended (positive or negative) psychological or physiological responses from participants during the SIT protocols. However, this possibility seems unlikely given that the post-experiment measures indicated that, as anticipated, the music condition was superior to the podcast control condition in terms of liking (M = 7.83 vs. M = 5.67 out of 10, respectively) and motivation (M = 8.04 vs. M = 3.21 out of 10, respectively).

Given that this study involved multiple statistical analyses and the measurement of several dependent variables (some of which were conceptually linked or statistically correlated), we acknowledge the risk for type 1 error. To mitigate such risks, we conducted multivariate analyses (i.e., MANOVAs) and used Bonferroni-corrected p values where appropriate. We also decomposed significant main effects using simple contrasts. While this approach aligned with our use of directional hypotheses (Field, 2013), the simple contrasts did not allow for comparisons between the two control conditions (i.e., podcast and no audio) or between all specified time points for some analyses (e.g., sprint 2 vs. sprint 3). These other comparisons were not central to our research questions and, moreover, the study was not adequately powered for these additional analyses. Investigators may wish to address research questions pertaining to these comparisons in future studies. For example, studies that investigate the effects of music on affective responses to SIT can test differences at specific time points of the SIT protocol that are considered sensitive to change or the most consequential (e.g., positive or negative peaks, end states; Decker & Ekkekakis, 2017; Stork et al., 2017).

Given that this was an acute study of the effects of music during SIT, we cannot determine if the effects of music during SIT were, in part, due to novelty effects or would persist over time. Future studies might employ longitudinal designs to assess the longer-term effects of music on SIT. Likewise, the SIT trials for this study were completed in a tightly controlled laboratory environment, therefore researchers are encouraged to examine the effects of music in more ecologically valid settings.

Conclusions

While SIT may be one of the most time-efficient forms of exercise and has been shown to provide meaningful health benefits, its “all-out” intensity can induce feelings of displeasure during exercise, which may discourage future participation (e.g., Stork et al., 2017). The use of music has the potential to enhance people’s psychological and physiological responses to SIT. The current study found that listening to researcher-selected music during low-volume SIT led to greater enjoyment and enhanced power output among insufficiently active adults. Further, HR responses were elevated, and affective responses tended to be more positive over the course of the SIT trials performed with music when compared to two control conditions (podcast and no-audio). The findings indicate that the psychological and physiological benefits of listening to music during SIT can be experienced by people deemed to be insufficiently active. Collectively, the application of music during SIT has the potential to enhance feelings of pleasure, improve enjoyment, and elevate performance of SIT for adults who are insufficiently active, which may ultimately lead to better adherence to this type of exercise.

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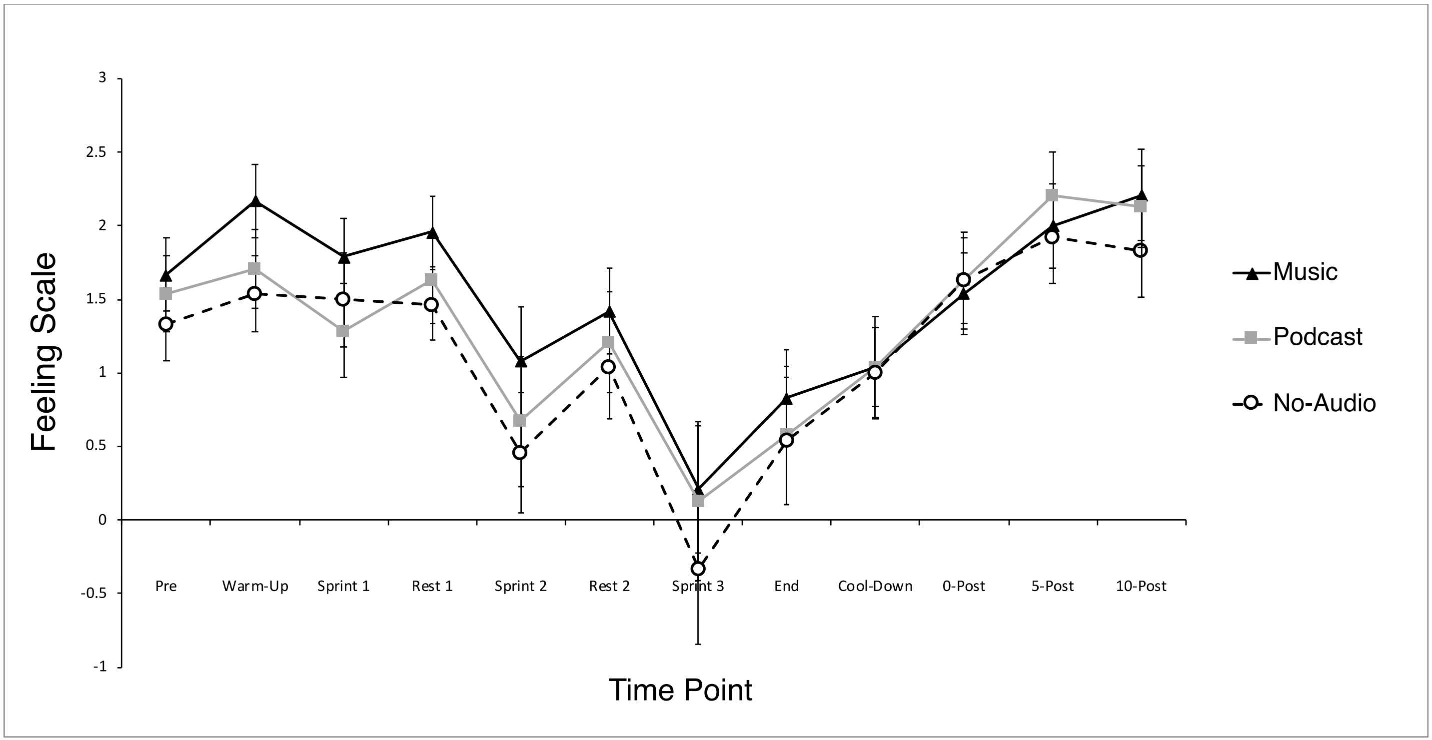

Figure 1. Feeling Scale responses (*M* ± *SE*) before, during, and following the music, podcast, and no-audio trials, plotted over time. 0-Post = 0 min post-exercise; 5 Post = 5 min post-exercise; 10-Post = 10 min post-exercise.

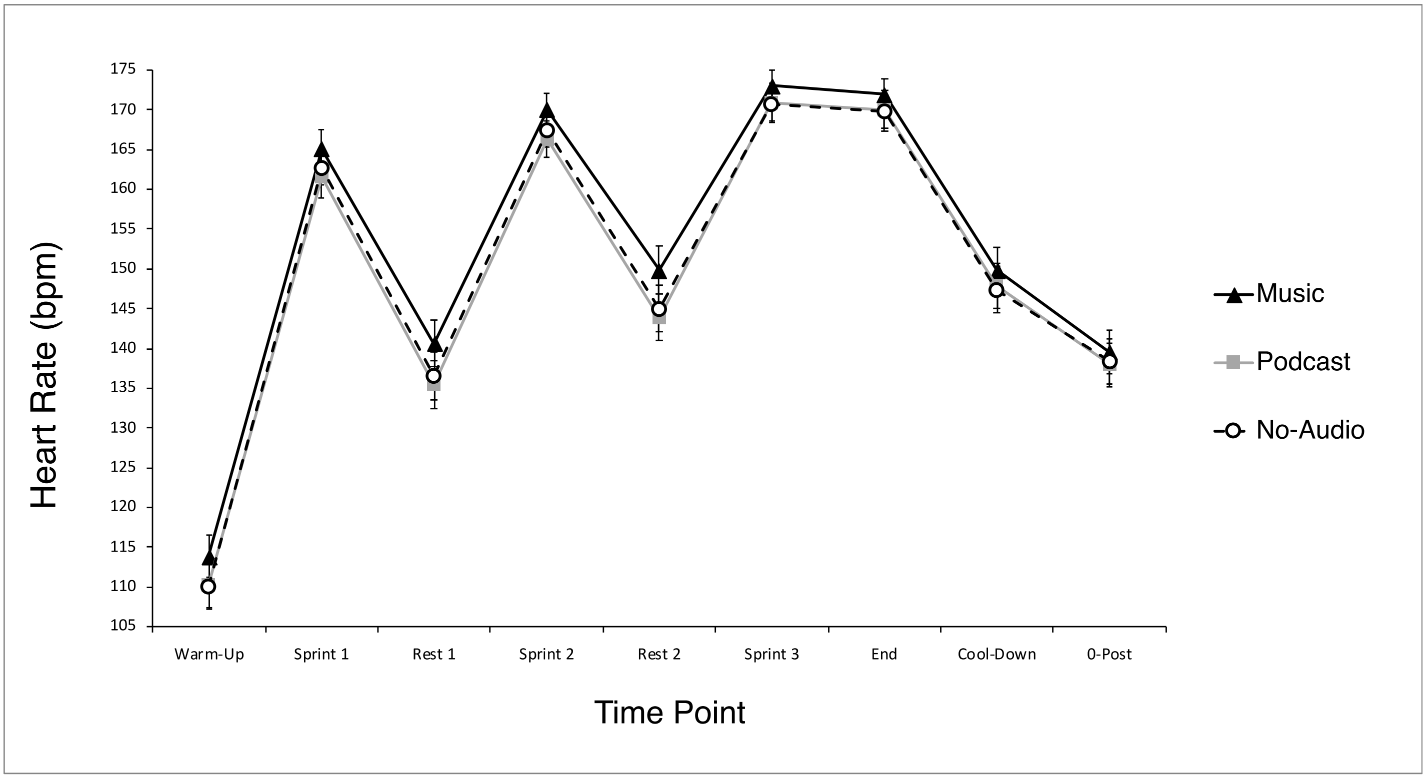

Figure 2. Heart rate responses (*M* ± *SE*) during the music, podcast, and no-audio trials plotted over time. The presented heart rate values correspond with the following time points of the protocol: Warm-up = 1:00 min, Sprint 1: 2:20 min, Rest 1 = 3:45 min, Sprint 2 = 4:40 min, Rest 2 = 6:05 min, Sprint 3 = 7:00 min, End = 7:20 min, Cool-down = 8:30 min, 0-Post = 10:00 min. 0-Post = 0 min post-exercise.

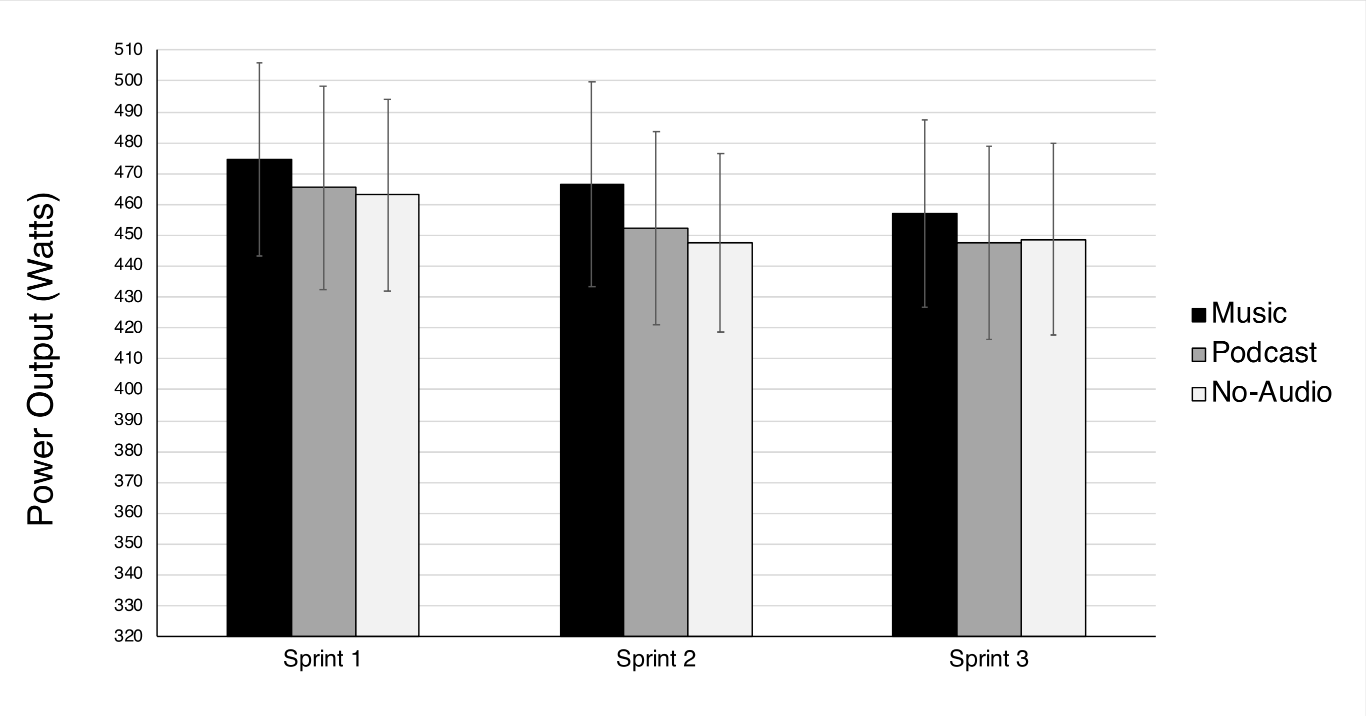

Figure 3. Peak power output (*M* ± *SE*) across each sprint during the music, podcast, and no-audio trials.