Music Enhances Performance and Perceived Enjoyment of Sprint Interval Exercise

MATTHEW J. STORK[1], MATTHEW Y. W. KWAN[2], MARTIN J. GIBALA[1], and KATHLEEN A. MARTIN GINIS[1]

[1]*Department of Kinesiology, McMaster University, Hamilton, Ontario, CANADA; and* [2]*Department of Family Medicine, McMaster University, Hamilton, Ontario, CANADA*

ABSTRACT

STORK, M. J., M. Y. W. KWAN, M. J. GIBALA, and K. A. MARTIN GINIS. Music Enhances Performance and Perceived Enjoyment of Sprint Interval Exercise. *Med. Sci. Sports Exerc.*, Vol. 47, No. 5, pp. 1052–1060, 2015. **Introduction**: Interval exercise training can elicit physiological adaptations similar to those of traditional endurance training, but with reduced time. However, the intense nature of specific protocols, particularly the "all-out" efforts characteristic of sprint interval training (SIT), may be perceived as being aversive. The purpose of this study was to determine whether listening to self-selected music can reduce the potential aversiveness of an acute session of SIT by improving affect, motivation, and enjoyment, and to examine the effects of music on performance. **Methods**: Twenty moderately active adults (22 ± 4 yr) unfamiliar with interval exercise completed an acute session of SIT under two different conditions: music and no music. The exercise consisted of four 30-s "all-out" Wingate Anaerobic Test bouts on a cycle ergometer, separated by 4 min of rest. Peak and mean power output, RPE, affect, task motivation, and perceived enjoyment of the exercise were measured. Mixed-effects models were used to evaluate changes in dependent measures over time and between the two conditions. **Results**: Peak and mean power over the course of the exercise session were higher in the music condition (coefficient = 49.72 [SE = 13.55] and coefficient = 23.65 [SE = 11.30]; $P < 0.05$). A significant time by condition effect emerged for peak power (coefficient = −12.31 [SE = 4.95]; $P < 0.05$). There were no between-condition differences in RPE, affect, or task motivation. Perceived enjoyment increased over time and was consistently higher in the music condition (coefficient = 7.00 [SE = 3.05]; $P < 0.05$). **Conclusion**: Music enhances in-task performance and enjoyment of an acute bout of SIT. Listening to music during intense interval exercise may be an effective strategy for facilitating participation in, and adherence to, this form of training. **Key Words:** SPRINT INTERVAL TRAINING, MUSIC, EXERCISE PERFORMANCE, EXERCISE BEHAVIOR

The pervasiveness of sedentary lifestyles and physical inactivity has become a widespread public health concern (5,27). In fact, physical inactivity has been depicted as "the biggest public health problem of the 21st century" (5). Consequently, it has become a challenge for the public health sector to find effective ways to increase physical activity (PA) and to decrease sedentary behavior (4). A perceived lack of time has consistently been cited as one of the most common reasons why people do not participate in PA on a regular basis (e.g., [34,36]). However, recent evidence suggests that interval exercise training is a potential strategy for combating this barrier to PA (16,17,27,38).

Interval training refers to exercise that typically involves brief, repeated bursts of relatively intense exercise that are separated by periods of rest (16,38). Relatively short-term studies have shown that interval training can induce physiological and health-related adaptations similar to those of traditional moderate-intensity continuous exercise, yet with reduced time commitment in both healthy and diseased individuals (16,17,38). For example, Burgomaster et al. (7) compared two groups of previously sedentary individuals who performed either 6 wk of Wingate-based interval training (which involved brief, repeated 30-s cycling efforts 3 $d \cdot wk^{-1}$) or traditional endurance training (which involved 40–60 min of continuous moderate-intensity cycling 5 $d \cdot wk^{-1}$). Both protocols elicited similar increases in cardiorespiratory fitness and mitochondrial capacity markers despite the fact that subjects in the interval group performed 90% less total exercise over a total training time commitment that was only one third of the other group. Other low-volume interval training protocols have also been shown to improve body composition (18), enhance glycemic control indices in people with type 2 diabetes (28), and improve vascular function markers in people with coronary artery disease (11). A recent systematic review and meta-analysis (38) suggested that interval training may even be superior to moderate-intensity continuous training in improving cardiorespiratory fitness. For those who cite

Address for correspondence: Matthew J. Stork, Health and Exercise Psychology Laboratory, Department of Kinesiology, McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada L8S 4L8; E-mail: storkmj@mcmaster.ca.
Submitted for publication June 2014.
Accepted for publication August 2014.

0195-9131/15/4705-1052/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000000494

lack of time as a barrier, interval training makes PA participation more feasible because it is time-efficient (16,38) and can be more easily incorporated into one's daily schedule (27).

One of the most time-efficient forms of interval training is sprint interval training (SIT) (38). A typical SIT protocol consists of four to six 30-s "all-out" bouts separated by 4 min of recovery (16). One commonly used version of SIT consists of each 30-s bout being completed according to the Wingate Anaerobic Test (WAnT) protocol of Bar-Or (2). Although the time efficiency of SIT suggests that it may be a promising option for improving PA levels, the potentially strenuous nature of SIT may be a deterrent, as people tend to avoid exercise behaviors that they find aversive (13,31).

Increasing research has focused on the role of affective variables (e.g., mood states, perceived enjoyment) as key motivators for PA participation (3,13,31). In particular, it has been suggested that feelings during exercise, or affective responses to exercise, may predict future exercise intentions, behavior, and adherence (26,39,40). Indeed, American College of Sports Medicine guidelines (1) state that exercise-induced feelings of fatigue and negative affect "can act as a deterrent to continued participation." Furthermore, it is believed that exercising at intensities beyond the ventilatory threshold (VT) leads to increased physiological stress and more negative affect (12,13)—changes that can be explained by the dual-mode theory of Ekkekakis (12). According to this theory, affective responses to acute exercise are influenced by the metabolic cost associated with exercise intensity (12). As exercise intensity increases beyond VT, lactate levels accumulate at a higher rate than they can be removed (12). With a lack of oxygen supply and a buildup of lactate, free nerve endings are stimulated, respiration becomes faster and heavier, and fatigue sets in (12). As a result, interoceptive stimuli reach the affective centers of the brain via oligosynaptic subcortical pathways, and affective valence inevitably becomes more negative (12). Given that SIT protocols are performed above VT, exercisers may have more negative affective responses to SIT, which may compromise future adherence. Thus, interventions aimed at improving affective responses to SIT are required.

A large body of research has shown that listening to music during exercise not only increases affect, improves enjoyment, regulates arousal, reduces perceived exertion, and improves motivation but also enhances exercise performance (e.g., [14,20,30,42]). In addition, it has been suggested that the positive impact of music on affective states can actually lead to increased adherence to exercise (23,30). Given that music is readily available and easy to incorporate, listening to music during SIT exercise may have psychological and performance benefits. However, most research studies of music and exercise have investigated continuous aerobic exercise performed at *submaximal* intensities, and there has been limited and conflicting research on the influence of music during high-intensity, maximal, or *supramaximal* exercise protocols (9,20,22). Although there is evidence to suggest that appropriately selected music can elicit psychological and physiological benefits during high-intensity exercise, some of these benefits may be less evident at supramaximal intensities (20,22). For example, music does not seem to reduce RPE during exercise intensities above VT (e.g., [9,20]), but it can reduce RPE during exercise performed below VT (e.g., [30]).

Some studies have shown improvements in affect, motivation, or performance with listening to music before or during a *single* 30-s WAnT bout (8,9,14,20,21). However, it has been suggested that the initial effects of music may diminish during prolonged exercise at this intensity (20) because heightened physiological states begin to dominate the processing capacity of the nervous system (33,35). In order to determine whether this is true, the effects of music during a prolonged supramaximal exercise protocol must be evaluated.

To our knowledge, the psychological effects of music and their subsequent influence on performance have not been evaluated using an intermittent high-intensity exercise protocol. Thus, the purpose of this study was to determine whether listening to self-selected music can reduce the potential aversiveness of an acute session of SIT by improving affect, motivation, and enjoyment, and to examine the effects of music on performance and perceived exertion. It was hypothesized that a SIT protocol performed with music would improve peak and mean power output and would lead to more positive affect, greater motivation, and higher ratings of exercise enjoyment as compared to a SIT protocol performed without music, whereas RPE would remain the same for both conditions. In addition, significant time–condition effects were anticipated such that power output, affect, and task motivation (TM) would be higher in the music condition after the first WAnT bout during the protocol, but these differences would diminish over subsequent WAnT bouts as fatigue sets in and as the negative physiological effects of exercise predominate the psychological benefits of music (33,35). It was also hypothesized that enjoyment would be significantly greater in the music condition.

METHODS

Participants

Twenty participants (10 men and 10 women) with a mean age of 22.5 yr (SD = 4.3 yr; range, 18–30 yr) were recruited from McMaster University and the surrounding community. Power calculations *a priori* indicated that a sample size of 20 would be required to achieve 80% power (α = 0.05) to detect an effect size (ES) of 1.80 on the primary outcome measure of affect (10). This is consistent with the ES for affect reported in a previous study (20), where differences in affect, TM, and performance of a single WAnT bout with music versus no music were evaluated. All participants were healthy and moderately active, as assessed by the International Physical Activity Questionnaire-Short Form (IPAQ-SF; https://sites.google.com/site/theipaq/questionnaire_links; median score = 2346 MET·min·wk^{-1}), and had a mean body mass of 64.8 ± 12.0 kg (men, 71.8 ± 10.6 kg; women, 57.8 ± 9.1 kg). Participants were excluded from the study if they had

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previously participated in SIT exercise, were elite athletes, had previously participated in a specific training program within the past 4 months, or had contraindications to exercise based on the Physical Activity Readiness Questionnaire (PAR-Q; http://www.csep.ca/cmfiles/publications/parq/par-q.pdf). The McMaster Research Ethics Board approved the study protocol. Participants were recruited through advertisements posted on campus and via E-mail. All participants provided written informed consent and received a Can$50 honorarium as compensation for their time and effort.

Study Design

This study used a crossover design, whereby each participant completed an acute session of SIT under two different conditions: music and no music. The order of the conditions was randomized and counterbalanced to control for temporal order and carryover effects. Participant randomization was stratified by gender.

Measures

Peak and mean power output. Power output during cycling (in watts) was measured using Velotron Wingate software (version 1.0.1; RacerMate) and recorded for each WAnT bout performed.

Perceived exertion. Borg's CR-10 (6) RPE scale (from "nothing at all" (0) to "absolute maximum" (10)) was used. The RPE scale has been established as a reliable and valid measure of physical exertion during exercise (6).

Affect. The Feeling Scale (FS) developed by Hardy and Rejeski (19) was used to measure affective states during and after WAnT bouts. This is an 11-point bipolar single-item scale that ranges from "very good" (+5) to "very bad" (−5) along a pleasure–displeasure continuum. FS score has been established as a reliable and valid measure of exercise-related affective states (19).

Task motivation. A single-item 10-point Likert scale ranging from "not at all motivated" (0) to "extremely motivated" (10) was used to measure TM (20). This was the same scale used to measure TM after a WAnT exercise protocol in a previous study (20).

Perceived enjoyment. Perceived enjoyment of SIT protocols was measured using an adapted version of the Physical Activity Enjoyment Scale (PACES) (3,25). This scale has 11 negative items and 7 positive items that participants rated on a seven-point bipolar scale (ranging from 1 to 7) to indicate how they felt about the exercise they had just completed. The internal consistency was acceptable at each administration (Cronbach's $\alpha > 0.90$).

Music. The six-item Brunel Music Rating Inventory-2 (BMRI-2) was used to measure the motivational components of music tracks played during exercise (24). The BMRI-2 is a tool that has been used to select and standardize music played during experimental exercise protocols (24). Participants rated each item on a seven-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (7).

Procedural Overview

Each participant made a total of five visits to the laboratory over the course of approximately 4 wk. During the first two visits, participants were familiarized with the testing protocols and materials. All exercise sessions were performed on the same stationary cycle ergometer (Velotron Dynafit Pro; RacerMate). This cycle ergometer was set up directly facing a wall and enclosed by two temporary walls in order to reduce the potential for external distractions. On the third and fourth visits, participants completed two experimental trials (one trial for each condition). The fifth visit was used as a short follow-up assessment. To eliminate the effects of exercise fatigue and to minimize any differences between participants or between experimental trials, laboratory visits were spaced approximately 7 d apart, and participants were instructed to maintain consistent dietary and sleep habits and to avoid any PA for the entire day preceding the experimental trials. In order to reduce diurnal variation in WAnT performance, efforts were made to schedule participants at the same time of day for their third and fourth visits to the laboratory, and experimental trials in the early morning (i.e., before 10:00 a.m.) or later in the evening (i.e., past 5:00 p.m.) were avoided.

Protocol

Familiarization 1 (visit 1). During the first visit, participants completed the written consent form, the PAR-Q, and the IPAQ-SF. After this, participants were instructed to write a list of six songs (ranked in order by preference) that they would enjoy listening to while exercising. These songs were used to create a personalized music playlist for each participant. Next, the RPE scale, FS, and TM scale were explained and reviewed with the participants. Each participant's height and weight were then measured using a standardized scale (500KL Eye Level Digital Scale; Health o meter). These measurements were used to calibrate the resistance applied by the cycle ergometer during the exercise protocol. Participants were instructed on how to set up the seat and bar handles on the ergometer. These settings were recorded and used for all subsequent visits to the laboratory. Participants were then asked to complete a single 30-s "all-out" WAnT bout according to the protocols of Bar-Or (2).

Participants began with a 2-min warm-up, pedaling lightly at a set resistance of 50 W. At exactly 1 min and 30 s into the warm-up, participants verbally reported a number to represent how they felt *at that moment* in time according to the RPE scale, FS, and TM scale. After the warm-up, participants were given a 30-s warning before the start of their "all-out" WAnT bout and were instructed to start increasing their pedaling rate. Participants were given a verbal 10-s countdown until their "all-out" bout began. During the 10 s leading up to the sprint, the ergometer resistance was dropped to 0 W, and pedaling was unloaded for those 10 s. As soon at the countdown finished, participants were verbally prompted to begin the "all-out" bout when they heard the word "Go!" Participants were asked to perform the 30-s "all-out" bout as fast as

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they possibly could against a set resistance of 7.5% of their body weight. During the bout, the experimenter provided the same verbal script to every participant (consisting of non-motivational updates of time remaining). Immediately after the "all-out" bout, participants were asked to verbally indicate a number to represent how they felt *during* the exercise according to the RPE scale, FS, and TM scale. This protocol was followed for each "all-out" WAnT bout performed in all subsequent exercise sessions. Once participants had finished the exercise bout, they completed the PACES.

Familiarization 2 (visit 2). For the second familiarization visit, participants were asked to complete a total of four 30-s "all-out" WAnT bouts, with 4 min of rest in between each bout. The experimenter ensured that participants clearly understood the instructions and each of the scales before the exercise trial began.

Immediately after each "all-out" bout, participants were given the option to stay on the bike or to step off the bike during the 4-min rest period. If they elected to remain on the bike, they were allowed to pedal very lightly, without physically exerting themselves any more than a 0.5 on the RPE scale. If they stepped off the bike, participants were asked to stay within the designated resting area and could walk around, stretch, or sit. At precisely 3 min into each rest period, participants were instructed to get back on the bike and to indicate their FS and TM scores at that moment in time. After this, participants were allowed to begin pedaling lightly and were then given a 30-s warning before the start of the next "all-out" bout of exercise. As done previously, participants were asked to gradually increase their pedaling rate during this time and were given a 10-s countdown leading up to their next "all-out" bout. FS and TM scores were also reported 3 min after the fourth bout of exercise.

Experimenters only interacted with participants to provide instructions, take measures, and ensure their safety during the procedure. To control for any motivational influence by the experimenter, all participants were provided with the same scripted set of instructions and feedback throughout each trial. After the completion of the SIT session, participants completed the PACES.

Experimental protocols (visits 3 and 4). All participants completed one SIT session in the music condition and one SIT session in the no-music condition. The only difference between these two trials was the absence or presence of music being played. Both SIT conditions were performed according to the exact same protocols as laboratory visit 2; however, participants were asked to rest for an additional 60 min after the exercise. During this time, participants were allowed to relax or read quietly but were instructed to refrain from using electronics. Measures of FS and PACES were also taken at 30 and 60 min postexercise.

Music condition. Music was played from speakers at a volume of 80 dB. The music was played from speakers (as opposed to headphones or ear buds) in order to allow for interactions between the participants and the experimenters, when necessary. Based on song order and the duration of each song selected during laboratory visit 1, a personalized music playlist (lasting a total of 16 min 30 s) was created for each participant. This playlist was designed to last the entire length of the SIT protocol, including the warm-up and rest periods. The last song on each list was trimmed in order for the playlist to fit within the duration of the SIT protocol. All songs were downloaded from Apple's iTunes Store, and the playlists were created using Apple's iTunes program (Apple Inc., 2013). As all songs were self-selected, there was a wide range of music selections (e.g., pop, rock, instrumental, rap, and hip-hop).

Follow-up visit (visit 5). Participants were asked to complete a measure of their enjoyment of SIT in general (i.e., PACES) and to indicate their interest in listening to music during SIT in the future. Participants also rated the music that they exercised to during the protocol, using the BMRI-2.

Statistical Analyses

Data collected at visits 3 and 4 were analyzed to test the hypothesis that power output, affect, TM, and perceived enjoyment would be higher in the music condition than in the no-music condition. Mixed-effects models were used to examine differences between the music condition and the no-music condition for each of the dependent measures, estimating change within individuals over time and accounting for correlations within and between subjects (repeated measures). This allows for simultaneous examination of the effects of group and individual-level variables on individual-level outcomes. Each dependent variable (i.e., peak and mean power, FS score, TM score, and PACES score) was included in multivariate analyses with two models being specified. The first model started by examining changes in dependent variables over time and potential for gender and manipulation order differences. Condition (music or no music) and an interaction term for time–condition were subsequently entered into model 2. In these analyses, time was modeled as a linear variable to determine whether the dependent variable remained constant or varied over time. A random intercept at the participant level and a random slope for time were included in each analysis. The interaction term in model 2 was calculated to test whether the effect of music on SIT changed over time. Where appropriate, gender, FS and TM scores at warm-up, condition order, differences in peak power from bout 1 to bout 4, BMRI-2, and RPE were included in the models as covariates. SAS version 9.3 was used for these analyses, and significance was set at $P < 0.05$.

RESULTS

Peak Power Output

Main effects for time (estimate = −18.51 [SE = 4.18]; $P < 0.01$), gender (estimate = −159.66 [SE = 47.24]; $P < 0.01$), and condition (estimate = 49.72 [SE = 13.55]; $P < 0.01$) were found for peak power across all four bouts of the SIT sessions (Table 1). Peak power significantly decreased over the course of the exercise sessions and was greater for men than for women. The significant main effects for time and condition were superseded by a significant time–condition

TABLE 1. Mixed-effects models predicting power output.

	Peak Power		Mean Power	
	Estimate (SE)	P	Estimate (SE)	P
Intercept	549.50 (42.64)	<0.01**	502.97 (29.11)	<0.01**
Time	−18.51 (4.18)	<0.01**	−25.10 (3.48)	<0.01**
Condition (music)	49.72 (13.55)	<0.01**	23.65 (11.30)	0.04*
First condition (no music first)	37.68 (47.24)	0.49	−53.78 (29.34)	0.07
Gender (female)	−159.66 (47.24)	<0.01**	−138.77 (31.07)	<0.01**
RPE	3.61 (2.69)	0.18	−0.61 (2.23)	0.79
BMRI-2	37.66 (25.35)	0.14	35.48 (16.33)	0.03*
Time–condition	−12.31 (4.95)	0.01*	−6.04 (4.12)	0.15

Values are derived from model 2 once all variables had been entered into the model.
*Significant at $P < 0.05$.
**Significant at $P < 0.01$.

interaction (estimate = −12.31 [SE = 4.95]; $P < 0.05$) (Table 1), indicating that, as predicted, peak power was higher during the early WAnT bouts in the music condition. In addition, this interaction indicates that differences in peak power between conditions were greatest for bout 1 and became increasingly smaller until bout 4, where differences in peak power between conditions were no longer evident (Fig. 1a).

Mean Power Output

Significant main effects for time (estimate = −25.10 [SE = 3.48]; $P < 0.01$), gender (estimate = −138.77 [SE = 31.07]; $P < 0.01$), and condition (estimate = −23.65 [SE = 11.30]; $P < 0.05$) were found for mean power across all four bouts (Table 1). Mean power significantly decreased over the course of the exercise sessions and was greater for men than for women. As hypothesized, mean power was consistently higher in the music condition than in the no-music condition. However, the time–condition interaction was not significant (estimate = −6.04 [SE = 4.12]; $P = 0.145$) (Table 1), suggesting that mean power decreased at a similar rate over time in both conditions. Figure 1b shows the estimates of mean power across all four bouts and for each condition.

Perceived Exertion

As predicted, RPE was not significantly different between conditions ($P > 0.05$).

Affective Responses

Two separate equations and slopes were derived for FS measures: one for the change in FS score across all four bouts and one for the change in FS score across all four rest periods. A significant main effect for time was found for both of these equations (estimate = −0.71 [SE = 0.16] and estimate = −0.68 [SE = 0.17]; $P < 0.01$) (Table 2). FS score decreased across all four bouts and across all four rest periods; but, contrary to hypothesis, there was no significant difference in FS score (during bouts or rest) between conditions. Nevertheless, participants in the music condition tended to report higher FS ratings across all time points during bouts and rest periods and at 30 min postexercise (Fig. 2a).

Motivational Responses

Two separate equations and slopes were derived for the TM measures: one for the change in TM across all four bouts and one for the change in TM across all four rest periods. A significant main effect for time was found for both of these equations (estimate = −0.48 [SE = 0.14] and estimate = −0.56 [SE = 0.14]; $P < 0.01$) (Table 2). TM decreased across all four bouts and across all four rest periods. Contrary to hypothesis, there was no significant difference in TM (during bouts or rest) between conditions. However, participants in the music condition tended to report higher TM ratings across all time points during bouts and rest periods (Fig. 2b).

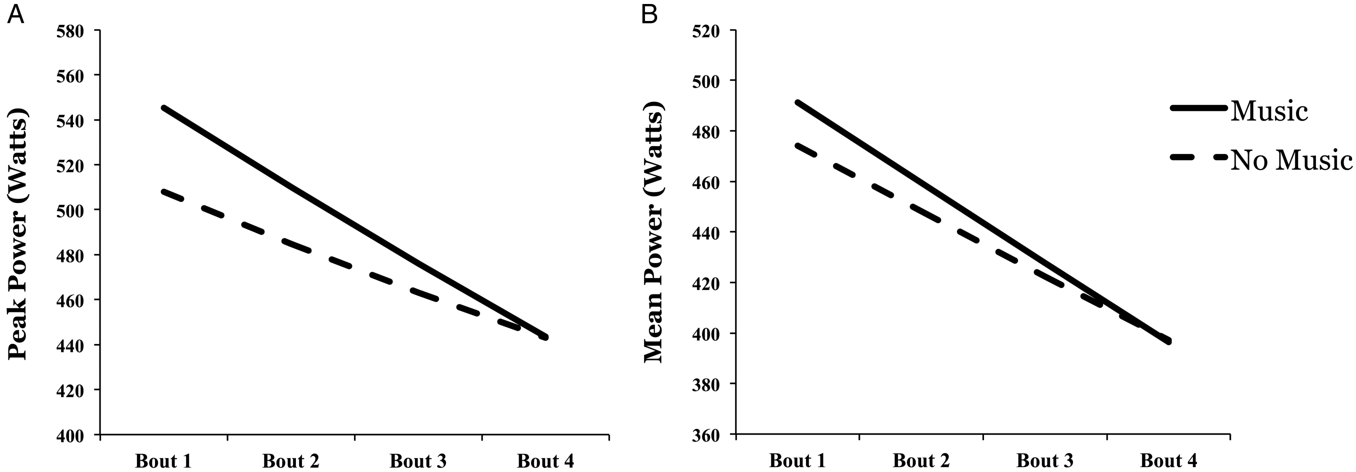

FIGURE 1—Mixed-effects models for peak (a) and mean (b) power output during the music condition and the no-music condition across the four exercise bouts. Lines represent estimates based on equations derived from the models.

TABLE 2. Mixed-effects models predicting FS and TM scale.

	FS Bout		FS Rest		TM Bout		TM Rest	
	Estimate (SE)	*P*	Estimate (SE)	*P*	Estimate (SE)	*P*	Estimate (SE)	*P*
Intercept	4.13 (0.95)	<0.01**	3.75 (0.95)	<0.01**	8.79 (0.71)	<0.01**	7.99 (0.71)	<0.01**
Time	−0.71 (0.16)	<0.01**	−0.68 (0.17)	<0.01**	−0.48 (0.14)	<0.01**	−0.56 (0.14)	<0.01**
Condition (music)	0.17 (0.56)	0.76	0.32 (0.56)	0.57	0.00 (0.49)	0.98	0.21 (0.49)	0.67
First condition (no music first)	−0.74 (0.78)	0.34	−1.16 (0.78)	0.14	−0.87 (0.49)	0.08	−0.93 (0.49)	0.06
Gender (female)	−0.23 (0.77)	0.77	−0.35 (0.80)	0.66	0.27 (0.49)	0.58	0.50 (0.49)	0.31
RPE	−0.11 (0.11)	0.30	−0.04 (0.10)	0.73	−0.15 (0.09)	0.09	−0.04 (0.08)	0.65
BMRI-2	0.77 (0.43)	0.08	0.62 (0.41)	0.13	0.96 (0.27)	0.03*	0.46 (0.27)	0.09
FS score during warm-up	0.14 (0.18)	0.44	0.00 (0.19)	0.99	−0.10 (0.15)	0.51	−0.15 (0.15)	0.32
TM score during warm-up	0.27 (0.15)	0.07	0.53 (0.15)	<0.01**	0.68 (0.12)	<0.01**	0.85 (0.12)	<0.01**
Time–condition	0.01 (0.19)	0.97	−0.02 (0.21)	0.93	0.07 (0.18)	0.67	0.00 (0.17)	0.98

Values are obtained from model 2 once all variables had been entered into the model.
Bout refers to measurement taken during each WAnT bout. Rest refers to measurement taken during each rest period after each bout.
*Significant at $P < 0.05$.
**Significant at $P < 0.01$.

Perceived Enjoyment

Significant main effects for time (estimate = 2.08 [SE = 0.99]; $P < 0.05$) and condition (estimate = 7.00 [SE = 3.05]; $P < 0.05$) were found for perceived enjoyment immediately after exercise and at 30 and 60 min postexercise (Table 3). No other effects were significant. In support of the hypothesis, perceived enjoyment significantly increased over time and was consistently higher in the music condition (Fig. 3).

Follow-up Music Preference

After completion of all study protocols, 19 of 20 (95%) participants reported that exercise performed in the music condition was more enjoyable than exercise performed in the no-music condition. Furthermore, 20 of 20 (100%) participants reported that if they were to participate in SIT in the future, they would listen to music while doing it.

Brunel Music Rating Inventory-2

BMRI-2 scores ranged from a mean score of 2.43 to 6.83 of a possible 7 ($\bar{X}$ = 5.62 ± 0.97), indicating that not all participants had high motivational ratings of the music that they selected. To account for this variability, we included BMRI-2 scores as a covariate in the models for power output, FS score, and TM score, as reported above.

DISCUSSION

The primary finding of the present study was that music improved the enjoyment of SIT while enhancing acute exercise performance. To our knowledge, this is the first study to demonstrate both the psychological and the physiological benefits of listening to self-selected music during a SIT protocol.

Performance

Consistent with our hypotheses, peak and mean power output were higher in the music condition versus the no-music condition (Table 1, Fig. 1). These findings are supported by previous research, which found that listening to music before or during a *single* 30-s WAnT bout can significantly increase power output (8,9,14,20,21). However, these studies did not evaluate the effects of music before or during the performance of *multiple* WAnT bouts, which is characteristic of interval type training. In fact, one study (20) suggested that, in order to determine whether this "initial burst of power" continues to diminish over time, performance needs to be evaluated on a progressive or interval exercise task. Our data are the first to illustrate that the ergogenic effects of music can persist over the course of repeated intervals. Furthermore, our data also show that this relative effect does appear to diminish over the course of the SIT session (Fig. 1). This observation is consistent with the notion that music may not be able to offset the

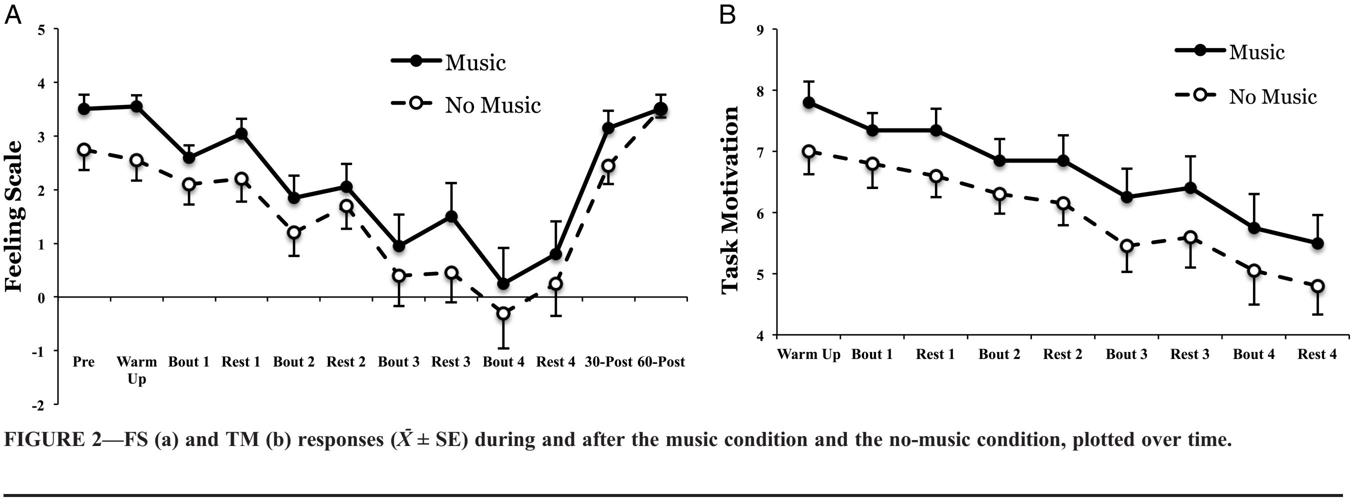

FIGURE 2—FS (a) and TM (b) responses ($\bar{X}$ ± SE) during and after the music condition and the no-music condition, plotted over time.

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TABLE 3. Mixed-effects models predicting perceived enjoyment.

	PACES	
	Estimate (SE)	*P*
Intercept	80.52 (5.88)	<0.01**
Time	2.08 (0.99)	0.04*
Condition (music)	7.00 (3.05)	0.02*
First condition (no music first)	−5.21 (6.36)	0.41
Gender (female)	1.91 (6.36)	0.76
Time–condition	−0.10 (1.41)	0.94

Values are obtained from model 2 once all variables had been entered into the model.
*Significant at $P < 0.05$.
**Significant at $P < 0.01$.

physiological demands of exercise (e.g., acidosis), which eventually outweigh the psychological benefits of music as the exercise persists and as fatigue sets in (20,33,35).

The performance response observed in the present study is unlike that typically seen after several weeks of interval exercise training. For example, researchers (29) reported increased peak and mean power during a repeated WAnT task (identical to the SIT protocol used in the current study) after 7 wk of SIT, but this improvement in performance was only found for the latter bouts of exercise (i.e., bouts 2–4). In contrast, we found performance differences in the earlier bouts, indicating that music has the potential to elicit an immediate and unique performance benefit during acute SIT exercise. An explanation for this effect is not immediately clear. We did not include invasive measurements in this study (e.g., needle blood sample of epinephrine) to examine potential physiological mechanisms, but it is possible that elevated arousal or motivation from the music may have facilitated these effects.

Specifically, pretask music has been shown to promote optimal arousal levels and to assist in the preparation of a short bout of high-intensity cycling exercise (8,9,14,21,42). Furthermore, studies have shown increased circulating levels of epinephrine and heart rate when stimulating music was played before an all-out WAnT protocol, in comparison to slow music or a no-music control (14,42). It has also been suggested that, leading up to exercise, participants may experience "segmentation," where particular segments of musical pieces that are yet to be played are anticipated by the participant, resulting in a heightened state of arousal and a conscious trigger for increased work output (22,23,32). In the context of the present study, it is possible that the music being played during the 2-min and 30-s warm-up elicited a heightened (and optimal) state of arousal leading into the first WAnT bout. Given that participants self-selected their songs, the "segmentation" effect may have been in play. That is, participants may have anticipated the upcoming motivational segments of the music that they selected, and this may have "psyched up" or energized participants, causing them to increase their work output. Furthermore, given the intermittent nature of the SIT protocol and the continuous play of music during rest periods, the music would have had both pretask and in-task effects for each of the WAnT bouts. This may have created additive effects for each of the four bouts and may partially explain why the effects of music persisted for multiple WAnT bouts.

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Perceived Exertion

A compelling finding was the lack of difference in RPE between conditions. Although participants reported physically exerting themselves equally as hard in both conditions, they achieved greater power output in the music condition. Interestingly, other studies have reported similar findings where individuals showed higher work outputs when music was played before or during a WAnT bout (in comparison to a no-music control), despite having no significant differences in RPE between the music condition and the no-music condition (9,20). This is consistent with the notion that music may be less influential at altering psychophysical states (e.g., RPE) at exercise intensities exceeding VT due to the dominance of physiological cues in attentional processing (33,35).

Affect and Motivation

Differences in affect and TM between the two conditions were not statistically significant across the four bouts. These finding are inconsistent with the hypotheses and are at odds with a previous study (20). However, trends toward more positive FS scores and higher TM scores in the music condition were still evident (Fig. 2). This suggests that our study was underpowered to detect significant differences in these variables. This is likely due to the fact that our power calculations were based on a very large ES. Additional studies powered to detect modest effects are needed to evaluate the influence of music during SIT.

Interestingly, the objective increase in workload in the music condition occurred at no cost to in-task affect (i.e., affect was not rated more negatively in the music condition even though the workload was greater). This finding is consistent with previous research (15,20). It appears that, in these cases, the enhancement of affective states from music was independent of workload.

Although FS scores significantly dropped over the course of the four bouts of exercise, a large rebound toward a more positive FS score was observed postexercise in both conditions (Fig. 2a). This "rebound effect" is consistent with previous research showing changes in affect during and after

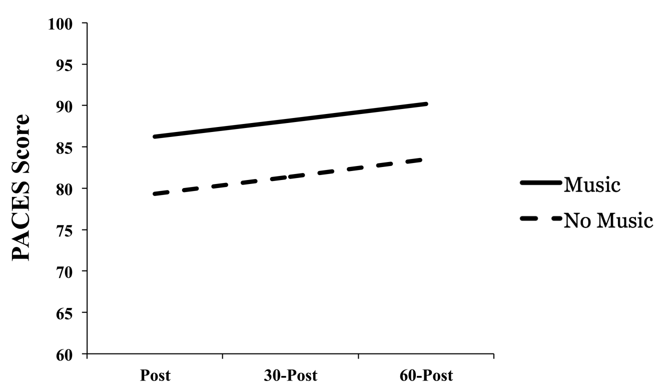

FIGURE 3—Mixed-effects models for perceived enjoyment (PACES) in the music condition and the no-music condition at three time points postexercise. Lines represent estimates based on equations derived from the models.

exercise performed at an intensity above VT (13,31). Although most research studies suggest that affect *during* exercise is a strong predictor of future exercise behavior, some evidence indicates that *postexercise* affect also plays a role [e.g., (26)]. Thus, even though participants experienced a decline in affective states during SIT, their rebound to more positive affective states postexercise (relative to their in-task affective states) could also influence their future SIT participation. It should be noted, however, that affect was not any higher posttask than it was pretask.

Perceived Enjoyment

In line with the hypotheses, perceived enjoyment of the SIT exercise was found to be significantly higher in the music condition than in the no-music condition across all three time points postexercise (Fig. 3). This is consistent with a previous study that found greater exercise enjoyment while listening to music in comparison to a verbal dialogue control (30). The current findings are promising given that exercise enjoyment has been advocated as an important predictor of exercise adherence (3,37). More specifically, it has been suggested that increasing the enjoyment of exercise has the potential to improve adherence to exercise in the long term (3). Thus, individuals may be more likely to participate in, and adhere to, SIT exercise if they listen to music while doing it. In support of this reasoning, all participants reported that they would listen to music during SIT if they were to participate in SIT in the future.

The perceived enjoyment of SIT improved over time in both conditions and was relatively high overall (mean scores >80 of a possible 126). Follow-up reports of general enjoyment of SIT were also high (mean of 92.3 of 126). This suggests that SIT may be more enjoyable than people are led to believe. Previous research has shown that intermittent exercise is perceived as being more enjoyable and less boring than traditional endurance exercise (3,41). Our study is the first to document exercise enjoyment following this specific SIT protocol.

Strengths and Limitations

The current study has several strengths. This was the first study to include psychological measures before, during, and after SIT; two familiarization trials were used; laboratory visits were separated apart by 7 d; laboratory setup, materials, and environment were carefully controlled for; interactions with participants during trials were scripted; and mixed-effects models were used to account for between-subject *and* within-subject errors in the data. In addition, a few limitations warrant mention. The study was underpowered to detect significant differences in some variables; music was self-selected, meaning there was variability in music characteristics (e.g., genre, tempo, and rhythm); because participants were young and healthy, the results may not be generalizable to older and less healthy populations; and measures of heart rate were not included to corroborate that participants were actually exercising at an "all-out" intensity.

As mentioned previously, BMRI-2 scores had high variability in this study, indicating that some participants did not have unanimously high motivational ratings of the music that they selected, and some participants may have been better at selecting music than others. Thus, it is possible that the music intervention may not have been motivational or stimulating enough to elicit a maximal response in all participants, and this may have partly contributed to the nonsignificant findings with FS and TM measures. Nevertheless, the positive effects of music were still evident in this study, as reflected in improved exercise performance and greater enjoyment in the music condition. These findings are encouraging, as it is possible that the music intervention used in this study could be improved upon to elicit even greater effects in future research.

CONCLUSION

SIT is a time-efficient alternative to traditional endurance exercise. However, the intensive nature of SIT has the potential to evoke negative feelings during exercise that can deter people from future participation. The present findings suggest that, although listening to self-selected music during SIT exercise does not significantly reduce such negative feelings during exercise, it makes the exercise more enjoyable overall and leads to improved performance. Our results also indicate that the ergogenic effects of music present during a single WAnT bout can persist for multiple WAnT bouts performed during SIT. Together, these findings suggest that the use of music during SIT can be used to enhance exercise performance and enjoyment. Thus, listening to music during SIT exercise may be an effective strategy for encouraging people to participate in, and adhere to, SIT exercise.

We would like to thank the Arts Research Board at McMaster University for funding this project and the Exercise Metabolism Research Laboratory at McMaster University for providing access to laboratory space and exercise equipment. We would also like to acknowledge Mark Reilly, Brian Long, Nate Morris, and Laura Tambosso for their assistance with data collection and the participants who volunteered their time and effort to this study. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

The authors declare no conflicts of interest.

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