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Effects of music tempo on perceived exertion, attention, affect, heart rate, and performance during isometric strength exercise

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ABSTRACT

This study examined the effects of slow and fast music tempi on effort-related thoughts, rating of perceived exertion (RPE), affect, heart rate, and performance during isometric strength exercises. Participants were randomly assigned to one of three conditions (no-music control, fast-tempo music, and slow-tempo music) and performed two isometric strength exercises (wall-sit and plank). RPE, attention allocation, and affect were measured during each exercise task. Participants in both the fast- and slow-tempo music conditions maintained a dissociative state for longer than those in the no-music control condition during the wall-sit exercise; however, this effect did not manifest during the plank exercise. Neither music condition influenced HR, RPE, time to volitional exhaustion, or affect. Within the first few minutes of exercise, participants exhibited an increase in HR and perceived exertion, as well as a corresponding shift towards associative attention and a high arousal state. The results are discussed with reference to potential underlying mechanisms and current theories pertaining to RPE, attention allocation, and affect.

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KEYWORDS
Exercise; fatigue; performance; psychology; strength

In recent years, listener-directed streaming services (e.g., Pandora, Spotify, Apple Music) have increased in popularity and offer individualized external stimuli to exercisers before, during, and after exercise. The individualization and customization of streaming services provides exercisers with music spanning a wide range of tempi, motivational qualities, and lyrics. Given the ubiquity of musical stimuli in exercise settings, it is imperative to determine how musical characteristics (e.g., tempo) influence psychological and performance outcomes for different exercise modalities (Karageorghis et al., 2018; Rejeski, 1985).

Different musical characteristics, such as tempi, motivational qualities, lyrics, and volume, have been associated with a greater tolerance for aerobic exercise (Karageorghis & Priest, 2012a, 2012b). Listening to music while exercising improves performance during running, cycling, and treadmill tasks (see Karageorghis & Priest, 2012a, 2012b for a review). Collectively, such findings support a social-cognitive model (Tenenbaum, 2001), which proposes that a high rating of perceived exertion (RPE) results in an attentional shift towards association with somatic sensations. Therefore, during exercise at high levels of perceived exertion, dissociative attention cannot be maintained, and attention shifts from a dissociative to an associative mode.

For most exercisers, dissociative attention accompanies positive thoughts and affect (e.g., pleasantness), while associative attention accompanies negative somatic-focused thoughts and feelings of fatigue (Balagué et al., 2015; García et al., 2015). Thus, a sustained state of dissociation during exercise is critical for exercise enjoyment, leading to greater adherence and tolerance. Studies support these theoretical assumptions for both aerobic and anaerobic exercise (Balagué et al., 2015; Hutchinson et al., 2018). Furthermore, exercisers report less associative attention and more dissociative attention while listening to music during exercise. This attentional shift results in more pleasant affective responses, particularly at submaximal exercise intensities (Dyrlund & Wininger, 2008; Karageorghis et al., 2013; Karageorghis & Jones, 2014). Although the effects of music on different aspects of exercise (e.g., performance, attention, affect, motivation) have been examined for aerobic exercises (e.g., running, cycling), there is a dearth of research examining the effects of music on functional or isometric strength tasks.

Few studies have examined the effects of music on isometric exercises (Bigliassi et al., 2018; Crust, 2004) or functional strength tasks (Bartolomei et al., 2015; Biagini et al., 2012). Music played during a portion of, or during the entire isometric task, resulted in longer contractions than music playing only prior to the exercise (Crust, 2004). Notably, the study's power and generalizability are limited by its small, all-male sample ($N = 9$). More recently, Bigliassi et al. (2018) found that compared to a no-music condition, attending to music increased dissociative attention and positive affect, but did not influence overall exertion during an isometric grip task. Importantly, the grip task required little effort and used small muscle groups, eliciting a very low level of exertion. Additionally, the isometric grip strength task, while easily measurable, is not commonly performed by exercisers and is thus limited in terms of external validity.

Findings from studies using functional strength tasks indicated that the presence of self-selected music increased muscular endurance and power, but failed to influence muscular

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strength (Bartolomei et al., 2015; Biagini et al., 2012). Music decreased RPE and increased feelings of vigour, fatigue, and tension during muscular power exercises; however, these changes were not present during muscular endurance exercises (Biagini et al., 2012). While the studies of Bartolomei et al. (2015) and Biagini et al. (2012) used functional strength tasks with greater external validity compared to previous research (i.e., bench press, squat jumps), these studies included only male participants, lacked appropriate restrictions and/or guidelines for the music selection, and used tasks in which performance criteria may be subjective. For example, participants in Bartolomei et al.'s (2015) study were allowed to adjust the music volume throughout the study, and the only guideline for music selection was a tempo above 120 bpm. Biagini et al. (2012) provided no guidelines for music selection. Additionally, the performance criteria for dynamic strength tasks, such as those used by Bartolomei et al. (2015) and Biagini et al. (2012), may be more subjective than the criteria used for static strength tasks. Therefore, functional (i.e., conventional) isometric tasks help address issues regarding external validity and standardization of performance criteria. To our knowledge, no study has examined the effects of music on HR, attentional focus, affect, and time to volitional exhaustion during functional isometric strength exercise. Additionally, several studies have examined the potential moderating effects of various components of music (e.g., tempo, volume, lyrics, motivational quality) to determine their effects on exercisers. However, this literature has been mostly limited to studies of running and cycling tasks.

Researchers examining musical characteristics in the exercise domain have predominately focused on tempo (i.e., the speed of the music in beats per minute; bpm) during aerobic exercise (see Karageorghis & Priest, 2012a, 2012b for a review). A few studies have examined the effects of tempo on isometric grip strength; however, no studies have employed functional strength tasks. Nearly all of the studies employing isometric tasks presented music prior to, rather than during, the task (Karageorghis et al., 2018, 1996; Pearce, 1981). Both Karageorghis et al. (1996) and Pearce (1981) found that participants exhibited greater grip strength after listening to stimulative music compared to sedative music. However, while Karageorghis et al. (1996) found that grip strength after sedative music was lower than a white noise control condition, Pearce (1981) found no differences between the sedative music and a no-music control condition. Furthermore, while Karageorghis et al. (1996) observed greater grip strength in the stimulative music condition compared to the white noise control condition, Pearce (1981) found no differences between the stimulative music and no-music conditions. Similarly, Karageorghis et al.'s (2018) study reported greater grip strength after listening to fast-tempo music compared to slow-tempo music; however, there was no difference between the slow-tempo music and a no-music control condition. Additionally, participants reported more positive affect, but not higher arousal, when listening to fast-tempo music compared to slow-tempo music or no-music.

One study presented music during an isometric task (Crust, 2004). Exposure to music during the entire task increased physical performance; however, similar carry-over effects of music played prior to the task were not evident, as was the case in the previously discussed studies (Crust, 2004). No strength-related studies have assessed the effects of music or music tempo on HR. However, the results from studies examining the relationship among music tempo, HR, and performance of aerobic tasks suggest that observed changes in HR are driven by changes in performance rather than by the music tempo alone (Copeland & Franks, 1991; Edworthy & Waring, 2006). Similarly, the effects of music tempo on attention have not been studied using strength exercises. Previous research has suggested both psychological and neurological mechanisms underlying performance differences across different music tempi (Bishop et al., 2014; Webster & Weir, 2005). Specifically, faster tempi have been associated with happiness (Webster & Weir, 2005) and activation of brain areas associated with processing emotion and motor control (Bishop et al., 2014). Furthermore, given the association between fast-tempo music and positive affect (Karageorghis et al., 2018; Karageorghis & Jones, 2014), fast-tempo music may facilitate dissociative attention leading to reduced RPE.

Overall, the existing research examining the association between music characteristics and functional strength and/or isometric exercise has been limited in scope and somewhat inconclusive. These studies suggest that music improves muscular endurance and grip strength performance (Bartolomei et al., 2015; Crust, 2004; Karageorghis et al., 2018), but not power-related exercise (Biagini et al., 2012). Only one study examined the effects of music on RPE during functional strength exercise, and found a reduction in RPE during power exercises but not during muscular endurance exercise (Biagini et al., 2012). Moreover, music failed to influence affective state during a strength endurance exercise (Biagini et al., 2012), but elevated affect during an isometric grip strength exercise (Karageorghis et al., 2018). Lastly, music increased dissociative attention during an isometric grip strength task (Bigliassi et al., 2018). To our knowledge, there are no studies that have measured the effects of music on physiological responses during strength exercises. Furthermore, no studies have examined the effects of music tempo on functional isometric strength exercises.

The current study aims to expand upon the research examining the effects of music tempo on strength performance. Specifically, the current study examined effects of music tempo on attentional focus, affect (arousal and pleasantness), RPE, and heart rate during isometric strength exercises (i.e., wall-sit and plank-hold) until volitional exhaustion. It is hypothesized that fast-tempo and slow-tempo music conditions will result in more dissociative attention, increased pleasantness and arousal, lower RPE scores, and a longer wall-sit and plank-hold compared to the no-music condition. It is also hypothesized that the fast-tempo music condition will result in a longer wall-sit and plank-hold, lower RPE, more dissociative attention, and more positive affect than the slow-tempo music condition.

Method

Participants

An *a priori* power analysis using G*Power 3.1.9.2 (Faul et al., 2007) indicated that based on a small-to-medium effect size of $f = 0.20$, using an $\alpha < .05$, and a power $(1 - \beta) = 0.80$, a sample size of 54 participants was required. Accordingly, 63 young adults (M = 25.0 years, SD = 4.4 years), who strength-trained twice a week for at least 1 month were recruited for the study. Participants were recruited via a research recruitment database of undergraduate students, email flyer, and word of mouth from a university in the south of the USA. All participants completed the PAR-Q to ensure that they did not require further advice from a doctor or qualified exercise professional before participating in physical activity. The additional nine participants were recruited in case participants could not complete both the baseline and experimental trials or could not complete at least 30 s of each trial, and to reduce the influence of outliers. Participants were stratified by sex, and then randomly assigned to one of three conditions: no-music control (N = 22; 11 males, 11 females), slow-tempo condition (N = 21; 11 males, 10 females) and fast-tempo condition (N = 20; 10 males, 10 females). Participants were stratified by sex to account for possible sex differences in performance on muscular strength and endurance tasks.

Instrumentation

Participant survey

The participant survey consisted of eight questions regarding age, sex, experience in strength training (i.e., frequency and duration of strength training) and adherence to guidelines required to participate in the experiment (e.g., food and alcohol intake, exercising prior to experiment, etc.).

The physical activity readiness questionnaire for everyone

(PAR-Q+; Warburton, Jamnik et al., 2011). The PAR-Q+ is the first of a two-part risk stratification and physical activity participation clearance strategy. The PAR-Q+ has a very high test-retest reliability (r = 0.99; Warburton, Bredin et al., 2011). The PAR-Q was used to ensure that participants did not require further advice from a doctor or qualified exercise procession before participating in physical activity.

Attention scale

(AS; Tammen, 1996). The AS is a single item 10-point scale that measures attention throughout a task. The scale response ranges from 0 (*dissociative attention – external thoughts, surroundings, music*) to 10 (*associative attention – internal thoughts, breathing, muscles)*. The single-item scale has been determined to be both an effective and valid measure of attention during exercise (Baden et al., 2005; Tenenbaum et al., 2007), and immediately following exercise (Masters & Ogles, 1998).

Affect grid

(AG; Russell et al., 1989). The AG measures overall pleasantness and arousal throughout a task. The pleasantness scale ranges from 1 (*unpleasant*) to 9 (*pleasant*), and the arousal scale ranges from 1 (*sleepiness*) to 9 (*high arousal*). Russell and Mehrabian (1977) reviewed 42 self-report affect scales and found that affect could be predicted on most scales via participants' scores on the dimensions of pleasure–displeasure, arousal–sleepiness, and dominance–submissiveness scales. The dominance–submissiveness scale accounted for the least amount of variance, thus supporting the use of only two dimensions in the AG. Subsequently, the AG has been used in dozens of experimental studies and practices (e.g., Karageorghis et al., 2018).

Rating of perceived exertion

(RPE; Borg, 1982). The RPE scale is a 15-point category-ratio scale ranging from 6 (*very, very light [rest]*) to 20 (*maximum exertion)*, measuring perceived exertion during a task. The higher the RPE score, the higher the rating of perceived exertion during a task. The RPE scale has high temporal stability (r > .83) and intra-test (r = 0.93) reliability and has been shown to correlate strongly with physiological measures including heart rate (Borg, 1998; Borg & Kaijser, 2006).

Commitment check

To measure participant commitment to the exercise tasks the participants indicated how much effort they invested in the exercise task from 1 (*none*) to 10 (*very much*), and how hard they tried while completing the task, from 1 (*not at all*) to 10 (*very hard*).

Music enjoyment scale (MES)

To measure how much participants enjoyed the music, they rated their enjoyment using a single-item scale ranging from 1 *(I did not like it at all)* to 10 *(I liked it very much)*.

Apparatus

The Polar T31 HR monitor system (Polar Electro Inc., 1977) was used to measure the participants' HR during exercise via a sensor strap worn around the chest. The HR was displayed on a watch held by the researcher. Music was played on a laptop computer (Lenovo Yoga 2 Pro; Lenovo Group Ltd., 1984) using an iHome speaker (iHome iM59WC; iHome, 2005).

Exercises

Wall-sit

To perform the wall-sit, the participant was asked to place her/his feet slightly wider than shoulder-width apart and lean against the wall. With her/his back flat on the wall, the participant was instructed to bend her/his knees, walk her/his feet out, and lower towards the floor until her/his knees reached a 90° angle (see Figure 1(a)). The exercise was held until the point of voluntary exhaustion (i.e., getting out of the exercise) or when the participant could no longer hold the correct position (i.e., the knees could no longer maintain a 90° angle).

Plank-hold

To perform the plank-hold, the participant was instructed to hold a plank position supported by the feet and elbows (Figure 1(b)). The exercise was held until voluntary exhaustion (e.g., getting out of the exercise) or the participant could no longer hold the correct position (e.g., dropping the hips towards the floor, creating an arch in the back, or raising the buttocks upward, creating a pike in the hips).

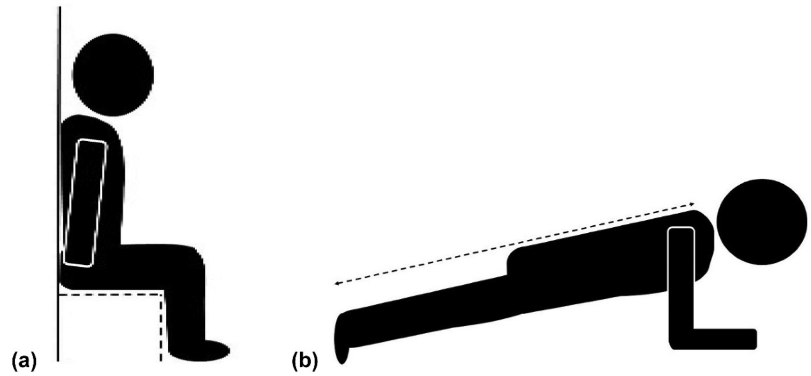

Figure 1. Depiction of the (A) wall-sit and (B) plank-hold exercises.

Music selection

To ensure familiarity, all music selections were from the Billboard Hot 100 Chart in the 6 months prior to the study's start date. Ten songs from a variety of genres were selected and then edited to allow the same song to be used in both music conditions. The fast-tempo music selections were edited to maintain a tempo of 120 bpm in line with Karageorghis et al.'s (2006) recommendations, and the slow-tempo music was edited to maintain a tempo of 90 bpm to ensure it could be differentiated from the fast-tempo selection. Songs ranged 145–285 s in length, and the volume was kept constant for each track at 75 dBA.

Procedure

Upon arriving at the laboratory, the procedures were explained to the participant and s/he was asked to complete the participant survey. If the participant met inclusion criteria, s/he signed the consent form. The institutional review boards at Auburn University and Florida State University approved the study. Participants were stratified by sex and then randomly assigned (via a random number generator) to one of three conditions: control, fast-tempo, or slow-tempo music. Having been assigned to a condition, each participant completed a no-music baseline trial and an experimental trial consistent with their group assignment (see Figure 2).

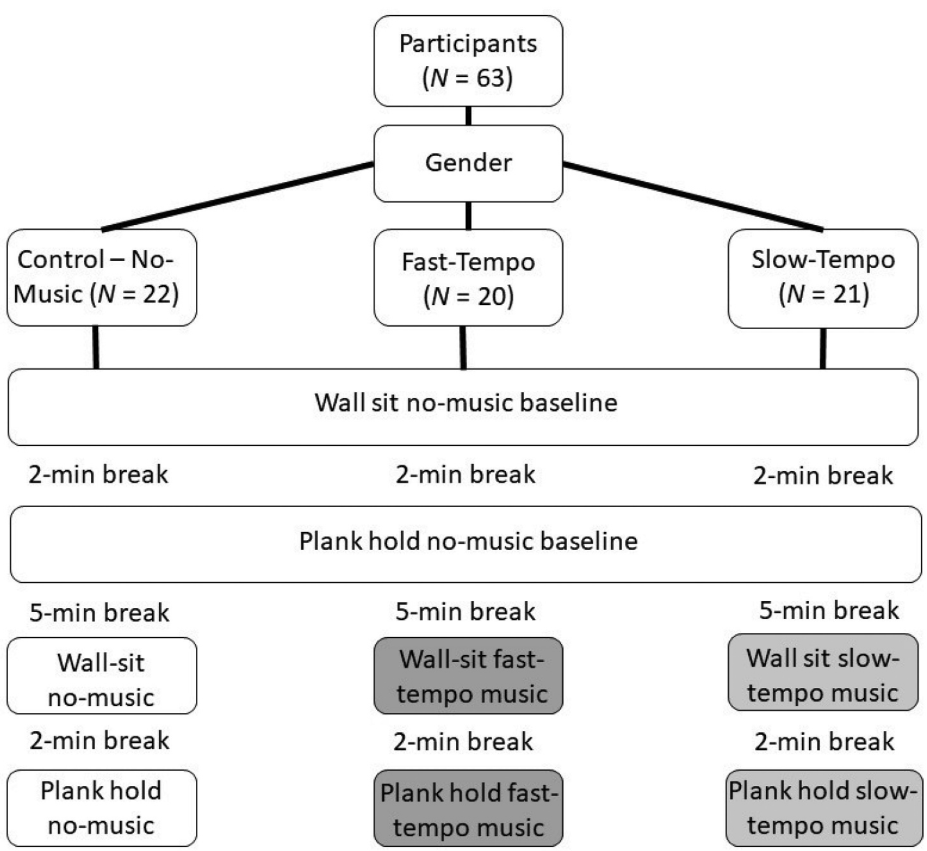

Figure 2. The study design.

Throughout the experiment, the participant wore a HR monitor around her/his chest, which transmitted HR to the receiver unit held by the researcher. Baseline HR was measured before the exercise bout. During the exercise bout, HR was recorded every 10 s. HR was monitored for safety and to measure the intensity of the isometric exercise. HR has been used to measure exercise intensity during isometric tasks (Petrofsky & Lind, 1975; Smolander et al., 1998). RPE and attention were assessed every 30 s throughout each trial and at the cessation of each trial.

Baseline trial

Each participant completed each exercise (wall-sit and plank-hold) once with no-music. Participants were positioned so that visual and other audio distractions were minimized (i.e., they faced a blank wall in a quiet area). The researcher demonstrated and verbally explained each exercise and allowed the participant to practice each exercise and ask questions prior to beginning the experiment. Participants were instructed to hold the wall-sit for as long as possible. After performing the wall-sit, participants were given a 2-min break and then asked to perform a plank-hold for as long as possible. The researchers verified the form for both exercises. Once the participant could no longer maintain correct form, the researcher instructed the participant to stop and then data collection for the baseline trial was terminated. After finishing the baseline trial, participants were given a 5-min break before beginning the experimental trial (see Figure 2).

Experimental trial

For the control condition, the experimental trial followed the exact same protocol as described for the baseline trial. For the fast-tempo and slow-tempo music conditions, participants were exposed to fast or slow-tempo music during the experimental trial, respectively, but otherwise followed the same protocol as described for the baseline trial (see Figure 2). Immediately after the task completion, each participant completed the commitment check and the music enjoyment scale (only if s/he had been exposed to music during her/his experimental trial).

Statistical analyses

Following screening for data entry errors and outliers, the exercisers' HR, RPE, and attention scores were normalized into three within-subject time points: first third, second third, and completion. A series of 3 (Condition: no-music, slow-tempo, fast-tempo) × 3 (Time Point) × 2 (Trial: baseline and experimental trial) mixed-model repeated measures analysis of variance (RM ANOVA) were conducted on HR, RPE, and attention allocation rating for each exercise. Huynh-Feldt corrections were applied to all RM ANOVAs if the assumption of sphericity was violated. Three (Condition) × 2 (Trial) mixed-model RM ANOVAs were conducted on time until volitional exhaustion for each exercise separately. One-way ANOVAs were performed on the pleasantness and arousal ratings for each exercise. The assumptions of RM ANOVA (e.g., normality, sphericity, homogeneity of variance) and one-way ANOVA (e.g., normality, homogeneity of variance) were examined. To account for multiple comparisons, Bonferroni-adjusted alpha level of .008 (.05/6) was used to determine statistical significance. Only main effects of condition and condition interactions are reported, as they represent the hypothesized effects. Post hoc analyses using least significant difference (LSD) were conducted where applicable and Cohen's *d*s were calculated to estimate the size of significant effects.

Results

Manipulation checks

Commitment check

All participants indicated that high effort ($M = 8.60$, $SD = 1.25$) and hard work ($M = 8.73$, $SD = 1.48$) were invested in the exercise tasks. Level of effort investment, $F(2, 60) = 0.72$, $p = .493$, and indication of work level $F(2, 60) = 0.42$, $p = .662$ did not differ across the three conditions.

Music enjoyment

Overall, the music was well liked, as indicated by the average music enjoyment rating ($M = 7.05$, $SD = 2.42$). There were no differences in music enjoyment between the two music conditions, ($t_{39} = -0.12$, $p = .902$).

Task analysis

Heart rate

There was no main effect of experimental condition on HR for wall-sit, $F(2, 55) = 2.48$, $p = .093$, $\eta^2 = .07$, or plank-hold, $F(2, 55) = 1.63$, $p = .205$, $\eta^2 = .05$. Additionally, the Condition × Time and Condition × Trial interactions were not significant for the wall-sit, $F(2.69, 73.96) = 0.08$, $p = .962$, $\eta^2 < .01$; $F(2, 55) = 0.74$, $p = .481$, $\eta^2 < .01$, or the plank-hold $F(3.70, 101.71) = 0.20$, $p = .927$, $\eta^2 < .01$; $F(2, 55) = 1.63$, $p = .896$, $\eta^2 < .01$. Finally, the Condition × Time × Trial interaction was not significant for the wall-sit, $F(3.64, 100.14) = 0.87$, $p = .475$, $\eta^2 < .01$, or plank-hold, $F(3.52, 96.79) = 0.23$, $p = .900$, $\eta^2 < .01$ (see Table 1).

Rating of perceived exertion

There was no main effect of experimental condition on RPE for wall-sit, $F(2, 60) = 0.75$, $p = .479$, $\eta^2 = .02$, or plank-hold, $F(2, 60) = 1.45$, $p = .242$, $\eta^2 = .03$ exercises. Again, the Condition × Time and Condition × Trial interactions were not significant for the wall-sit $F(2.42, 72.58) = 0.39$, $p = .719$, $\eta^2 < .01$; $F(2, 60) = 0.11$, $p = .900$, $\eta^2 < .01$, or plank-hold, $F(2.45, 73.58) = 0.76$, $p = .497$, $\eta^2 < .01$; $F(2, 60) = 1.62$, $p = .207$, $\eta^2 < .01$. Finally the Condition × Time × Trial interaction was not significant for the wall-sit, $F(3.52, 105.62) = 2.86$, $p = .033$, $\eta^2 < .01$, or plank-hold, $F(3.39, 101.59) = 0.29$, $p = .854$, $\eta^2 < .01$ (see Table 1).

Attention

There was no main effect of experimental condition on attention for the wall-sit, $F(2, 60) = 0.15$, $p = .862$, $\eta^2 < .01$, or plank-hold, $F(2, 60) = 1.09$, $p = .343$, $\eta^2 = .02$. There was a significant Condition × Trial interaction for the wall-sit, $F(2, 60) = 5.67$, $p = .006$, $\eta^2 = .02$, but this interaction was not significant for the plank-hold, $F(2, 60) = 1.20$, $p = .308$, $\eta^2 < .01$. During the wall-sit

Table 1. Descriptive statistics for HR, RPE, and Attention during baseline and experimental trials (*M* [*SD*]).

	Control			Fast-Tempo			Slow-Tempo		
	First Third *M (SD)*	Second Third *M (SD)*	Last Third *M (SD)*	First Third *M (SD)*	Second Third *M (SD)*	Last Third *M (SD)*	First Third *M (SD)*	Second Third *M (SD)*	Last Third *M (SD)*
Heart Rate									
Wall Sit Baseline	107.55 (20.83)	113.20 (23.50)	120.40 (24.60)	113.06 (14.83)	118.39 (17.74)	125.22 (19.22)	97.85 (14.97)	102.30 (22.92)	108.20 (28.37)
Wall Sit Trial 1	115.45 (20.93)	123.40 (21.63)	130.65 (22.58)	121.39 (19.64)	126.61 (18.66)	134.44 (19.96)	107.55 (19.00)	117.00 (24.75)	125.25 (27.36)
Plank Hold Baseline	104.80 (19.18)	111.45 (19.98)	117.40 (26.91)	114.67 (15.98)	118.00 (15.44)	124.50 (15.61)	101.55 (23.24)	105.90 (23.51)	112.70 (26.93)
Plank Hold Trial 1	113.30 (20.29)	115.65 (21.36)	126.35 (21.45)	121.00 (14.35)	122.17 (15.87)	133.22 (14.30)	109.70 (24.34)	112.90 (26.82)	121.70 (28.70)
RPE									
Wall Sit Baseline	12.18 (1.84)	15.50 (2.30)	16.77 (2.25)	12.00 (2.25)	14.95 (2.68)	16.10 (3.01)	12.00 (2.10)	14.52 (1.81)	15.67 (1.96)
Wall Sit Trial 1	12.95 (2.24)	15.55 (2.28)	17.05 (2.54)	11.95 (2.37)	15.40 (2.09)	16.75 (2.20)	12.24 (2.61)	14.86 (1.80)	16.62 (1.83)
Plank Hold Baseline	12.59 (2.44)	15.59 (1.94)	17.23 (2.00)	11.60 (2.16)	15.10 (2.49)	16.70 (2.34)	12.24 (2.07)	15.29 (1.71)	16.67 (2.06)
Plank Hold Trial 1	13.59 (2.24)	16.32 (2.08)	17.36 (2.06)	12.05 (2.39)	15.35 (2.08)	16.65 (2.25)	12.67 (2.01)	15.19 (1.96)	16.33 (2.24)
Attention									
Wall Sit Baseline	3.95 (1.94)	6.36 (2.48)	7.27 (2.66)	4.40 (2.01)	6.45 (2.31)	7.65 (2.41)	5.29 (2.49)	6.57 (1.89)	7.81 (1.54)
Wall Sit Trial 1	4.77 (2.20)	6.59 (2.30)	7.77 (2.45)	3.75 (2.40)	5.95 (2.42)	7.05 (2.37)	4.19 (1.97)	5.86 (1.77)	7.33 (2.11)
Plank Hold Baseline	4.50 (2.41)	6.91 (2.07)	8.09 (1.87)	4.55 (2.33)	6.15 (2.23)	7.25 (2.17)	4.76 (1.97)	7.19 (1.47)	8.14 (1.49)
Plank Hold Trial 1	5.32 (2.71)	7.05 (2.54)	8.14 (2.46)	4.45 (2.19)	6.10 (2.15)	6.90 (2.17)	5.05 (1.63)	6.62 (1.66)	7.38 (2.20)

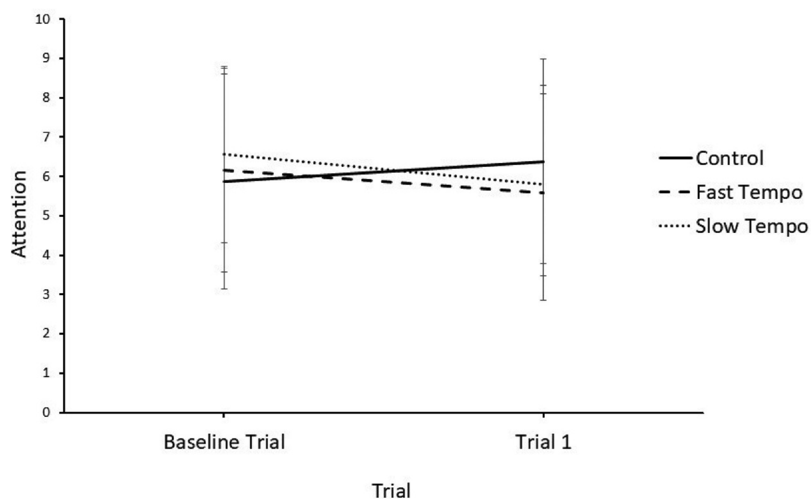

Figure 3. Depiction of the Condition × Trial interaction for attention during the wall-sit exercise.

exercise, the no-music control group became more associative during the experimental trial ($M = 6.38$, $SD = 2.60$) compared to the baseline trial ($M = 5.86$, $SD = 2.73$, $d = 0.20$), while both the fast-tempo and slow-tempo music groups became more dissociative during the experimental trial (fast-tempo: $M = 5.58$, $SD = 2.73$; slow-tempo: $M = 5.79$, $SD = 2.32$) compared to the baseline trial (fast-tempo: $M = 6.17$, $SD = 2.59$, $d = 0.22$; $M = 6.56$, $SD = 2.23$, $d = 0.34$). Figure 3 depicts the Condition × Trial interaction for attention during the wall-sit. The Condition × Time interaction was not significant for the wall-sit, $F(2.66, 79.78) = 0.74$, $p = .517$, $\eta^2 < .01$, or plank-hold, $F(2.48, 74.27) = 0.68$, $p = .538$, $\eta^2 < .01$. Finally, the Condition × Time × Trial interaction was not significant for wall-sit, $F(3.64, 100.14) = 0.97$, $p = .416$, $\eta^2 < .01$, or plank-hold, $F(3.52, 96.79) = 1.08$, $p = .363$, $\eta^2 < .01$ (See Table 1).

Time to volitional exhaustion

There was no main effect of experimental condition on time to volitional exhaustion for the wall-sit, $F(2, 60) = 0.81$, $p = .449$, $\eta^2 = .02$, or plank-hold, $F(2, 60) = 0.04$, $p = .956$, $\eta^2 < .01$. See Table 2 for descriptive statistics regarding time to volitional exhaustion.

Table 2. Descriptive statistics for time to volitional exhaustion.

	Wall Sit	
	Baseline Trial Time (s) *M (SD)*	Experimental Trial Time (s) *M (SD)*
Control	111.42 (49.04)	107.05 (40.01)
Fast-Tempo	137.88 (75.04)	107.76 (38.02)
Slow-Tempo	102.83 (44.04)	102.28 (39.63)
	Plank Hold	
	Baseline Trial (s) *M (SD)*	Experimental Trial (s) *M (SD)*
Control	111.32 (42.90)	95.05 (30.54)
Fast-Tempo	123.47 (39.57)	105.29 (33.97)
Slow-Tempo	121.56 (45.15)	104.17 (35.05)

Affect

Pleasantnes

There was no main effect of experimental condition on pleasantness, $F(2,60) = 1.98$, $p = .147$, $\eta^2 = 0.07$.

Arousal

Due to a violation of the assumption of normality, a Kruskal Wallis test was applied to arousal ratings (rather than a one-way ANOVA). The test indicated that arousal ratings did not vary across the experimental conditions, $\chi^2(2,60) = 1.99$, $p = .370$.

Discussion

The present study examined whether music tempo moderates the psychological effects associated with isometric strength exercise. We hypothesized that compared to a no-music condition, participants exposed to fast-tempo or slow-tempo music would persist longer, report lower RPE, become less associated with the task, and feel more positive affect and enjoyment. Furthermore, we expected that participants in the fast-tempo music condition would maintain lower RPE and attention scores, persist for a longer time, and report more positive affect than participants in the slow-tempo music condition. Participants in both the fast and slow-tempo music conditions maintained a dissociative state longer than those in the no-music control condition during the wall-sit exercise; however, this effect did not manifest during the plank exercise. Neither music condition influenced HR, RPE, time to volitional exhaustion, or affect.

The presence of music and different music tempi failed to increase time until volitional exhaustion during either of the isometric exercises compared to the no-music condition. These findings diverge from previous findings wherein music increased muscular endurance (Bartolomei et al., 2015; Biagini et al., 2012) and the duration of isometric weight holds (Crust, 2004). This discrepancy may be attributed to differences in the type of exercises, choice of music stimuli, the timing of when the music was played during the task, and the duration of exposure to music stimuli.

The current findings are in line with results from Biagini et al. (2012) and Bigliassi et al. (2018), who found that music did not affect RPE during a bench-press endurance or grip strength task, respectively. Biagini et al. (2012) reported very high RPE values during the bench press exercise ($M = 8.81$, $SD = 1.18$ [on a 1–10 scale]) and Bigliassi et al. (2018) reported low overall exertion (Control: $M = 3.15$, $SE = 0.31$; Music: $M = 2.89$, $SE = 0.28$ [on a 1–10 scale]) during the isometric grip strength task. In contrast, Biagini et al. (2012) reported moderate RPE values during the squat jump exercise ($M = 5.71$, $SD = 1.37$) and found an effect of music on RPE for this task. Thus, the lack of change in RPE from the baseline trial to the experimental trial for the music conditions in the present study may be attributed to the "somewhat hard" to "hard" RPE rating (on a 6–20 scale) for both the wall-sit ($M = 14.62$, $SD = 2.86$) and plank exercises ($M = 14.93$, $SD = 2.82$). Collectively, these results suggest that exercises at high or low RPE are resistant to manipulation via external stimuli such as music, while exercises at moderate levels of RPE are susceptible to manipulation.

Although music did not influence RPE in the present study, it did influence attentional processes (i.e., association/dissociation). During the wall-sit, both fast-tempo and slow-tempo music conditions encouraged dissociation during the experimental trial compared to the baseline trial. In contrast, participants in the no-music control condition showed an increase in associative attention during the experimental trial compared to the baseline trial (see Figure 3). The results for the plank-hold followed a similar pattern but were not statistically significant. These results are consistent with Dyrlund and Wininger (2008), who reported an inability to maintain a dissociative attentional state during high RPE exercises. These findings are also in line with previous research showing that the presence of music resulted in more dissociative attention during an isometric grip task (Bigliassi et al., 2018).

Music tempo did not influence perceptions of pleasantness ($M = 5.12$, $SD = 1.76$) and arousal ($M = 7.22$, $SD = 1.11$). These results differ from previous findings suggesting that music, especially fast-tempo music, was associated with more positive affect during an isometric grip strength task (Karageorghis et al., 2018). However, the present null results are consistent with the limited existing research on affect and functional strength exercises (Bartolomei et al., 2015; Biagini et al., 2012). In line with the RPE findings, affect is a psychological state which is difficult to influence when exercise intensity increases (Karageorghis et al., 2013).

Lastly, in the present study, music of both tempi failed to influence participants' HR. These results are consistent with previous findings for aerobic exercise showing no effect of music on HR (Boutcher & Trenske, 1990; Brownley et al., 1995), and that HR effects mirror performance effects (Copeland & Franks, 1991; Edworthy & Waring, 2006). The presence of music and the tempo of the music did not appear to affect HR during isometric strength exercises.

Although the participants did not completely return to their baseline HR between the two exercises, the HR increase was similar among the three conditions. Moreover, participants returned to their baseline HR before beginning the experimental trial.

Music had a greater effect on task performance, RPE, attention, and affect, when presented during periods of low-to-moderate exercise intensity (Tenenbaum, 2001). To attain ergonomic effects during high-intensity exercise, exercisers may consider extending music exposure. For example, attending to music prior to and during the exercise bout as well as throughout rest periods. This hypothesis is supported by research on an isometric grip strength task, where the presence of loud, fast-tempo music, prior to the task improved task performance and increased positive affect (Karageorghis et al., 2018, 1996).

In contrast to previous isometric studies, music tempo failed to affect any of the variables measured in the present study. However, previous studies used grip strength and provided music prior to the task. Therefore, it is likely that the difficulty of the task and timing of the music stimulus mediate the effect of music on physiological, performance, and psychological variables. Additionally, while cyclical, aerobic tasks (e.g., running, cycling, swimming), can be synchronized to music tempo, synchronizing isometric exercise is not possible. Therefore, music tempo might have a smaller influence on these variables during isometric exercise (Karageorghis & Priest, 2012a, 2012b).

A recent study using EEG to examine the neurophysiological mechanisms of the effect of music on exercise reported increased beta frequencies over central brain regions when music is present during exercise (Bigliassi et al., 2019). This increased beta activity may prevent the onset of fatigue during exercise (Bigliassi et al., 2019, 2016). Future studies using functional isometric tasks, such as those employed presently, are needed to further examine these neurophysiological mechanisms. Isometric tasks have similar external validity as dynamic exercise tasks (i.e., they are comparable to tasks commonly performed by exercisers) but limit movement that may contribute to movement artefact, which reduces the quality of EEG recordings.

One major limitation of the present study was that the exercise intensity was outside the suggested ranges of RPE values that may be sensitive to the effects of music (Tenenbaum, 2001). The high RPE values in the present study may have precluded possible effects of music. Though many participants did not reach maximal values of RPE, they continued the effort until voluntary exhaustion. To replicate these findings and reduce exercise intensity variability, follow-up studies on isometric exercise may limit participation to very fit individuals who do not require exercise modifications. In order to generalize to a broader population (e.g., including unfit participants or those requiring exercise modifications), future studies will need to ensure a similar level of intensity across all participants and within a range that may be more susceptible to the effects of music.

A second limitation was the selection of music. Although participants reported a high average music enjoyment rating, it may not have been the specific type of music that participants prefer to listen to during exercise. Future research should examine whether self-selected music exhibits the same pattern of results as those presently reported. The autonomy of music choice would also enhance external validity, increase participants' familiarity with the music, and ensure participant enjoyment of the music selection. Moreover, providing the participant autonomy in music selection may increase her/his intrinsic motivation during the exercise.

A third limitation is the lack of a counterbalanced experimental design, as all participants completed the wall-sit exercise prior to the plank-exercise. Therefore, it is possible that the results from the plank exercise were affected by the wall-sit exercise. However, sufficient rest was given between exercises to negate this possible effect.

In conclusion, both fast- and slow-tempo music promoted dissociation during the wall-sit, but not the plank exercise. Additionally, while the hypotheses of the present study regarding RPE, time to volitional exhaustion, and affect were not supported, the findings do have practical implications for exercisers. Playing music of different tempi during isometric strength exercises will not influence the exercisers' tolerance, RPE, or affect. Therefore, music should not be used as a primary means by which to lower RPE or improve affect during isometric exercise that is deemed to be "somewhat hard" or "hard" in RPE terms.

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