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CARDIOVASCULAR RESPONSES TO MUSIC TEMPO DURING STEADY-STATE EXERCISE

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ABSTRACT

Birnbaum L, Huschle B, and Boone T. Cardiovascular responses to music tempo during steady-state exercise. ***JEP****online* 2009; 12(1):50-56. This study compared the effects of fast and slow music on cardiovascular and hemodynamic responses during submaximal treadmill exercise. Six males and five females completed three, 15-minute steady-state exercise sessions jogging at 5.5 mph at 0% grade while listening to fast music (Treatment 1), slow music (Treatment 2), and no music (Control). An ANOVA with repeated measures was used to compare the three conditions, and a post hoc Scheffe test was performed to determine which groups differed ($p<.05$). Oxygen consumption (VO_2), cardiac output (Q), stroke volume (SV), minute ventilation (V_E), and frequency of breaths (F_b) significantly increased while listening to fast music compared to the slow music and no music. Systemic vascular resistance (SVR) significantly decreased while listening to fast music compared to slow music and no music. These findings suggest that listening to fast music during steady-state treadmill exercise produces cardiovascular and respiratory responses that are significantly different from how the body responds to the same exercise intensity when listing to slow or no music. The data indicate that listening to fast music decreased the subjects' cardiovascular efficiency since the subjects were able to perform the same steady-state treadmill exercise with either slow music or no music with a lower SV, Q, and VO_2.

Key Words: Music Cadence, Oxygen Consumption, Cardiac Output, Hemodynamic Responses, Submaximal Exercise.

INTRODUCTION

While music has been used as therapy for centuries (1,2), it has only recently been used to augment athletic performance (3). In fact, it has become common practice to listen to music while exercising. Reasons for doing so may include improved athletic performance or simply a more enjoyable recreational experience.

Several investigators have examined the physiological effects of music, and a few have studied music tempo specifically. It has been asserted that fast tempo music helps runners psychologically (4) and that sedative music elicits a relaxation response (5). However, studies that have measured physiological responses to music of different tempos have not observed consistent results. Edworthy and Waring (6) found a significant increase in heart rate (HR) while listening to fast music during exercise compared with listening to slow music. Conversely, Schwartz, Fernhall, and Plowman (7) did not find any difference in exercise HR. Interestingly, Yamamoto, Ohkuwa, Itoh, Kitoh, Terasawa, Tsuda et al. (8) reported significantly lower plasma norepinephrine concentrations in subjects listening to slow music, but other studies have not shown physiological decreases while listening to slow, sedative music during exercise (4,9).

The contradictory findings may be due in part to variations in experimental design, such as differences in exercise mode, intensity, and duration. The type of music selected and the manner in which it was selected have also varied among the studies. Additionally, subjects differed in age, health and physical conditioning.

Another issue of concern with previous studies on music tempo and exercise is the relative lack of physiological variables measured. Most studies have measured only two to three variables, such as HR, systolic blood pressure (SBP), or rating of perceived exertion (RPE). It seems apparent that if more variables are examined, a more comprehensive assessment of the physiological responses to music can be ascertained.

Given the limited physiological evaluation of the effects of music on exercise in previous studies as well as the mixed findings, this study sought to acquire a better understanding of the cardiovascular responses to fast and slow music during steady-state treadmill exercise.

METHODS

Subjects

Eleven healthy college-aged students volunteered to participate in this investigation. None of the subjects was on any medication. After reporting to the laboratory, the subjects' body weight and height were determined in a standardized fashion. Their characteristics are in Table 1. Prior to testing, each subject gave written informed consent to participate. All subjects understood they could withdraw from the study at any time. This study was approved by the Human Subjects Review Board of St. Scholastica. All subjects were instructed to refrain from eating or consuming caffeine for 4 hours prior to testing and to abstain from exercising for 24 hours prior to testing. Each testing session took place at approximately the same time of day for each subject and sessions were separated by at least 48 hours.

Experimental Protocol and Calculations

The research design consisted of three experimental conditions while jogging at 5.5 mph at 0% grade. Each subject was tested three times under the same laboratory conditions. Treatment 1 (Fast Music) consisted of listening to four fast-paced popular songs. For Treatment 2 (Slow Music), the subjects listened to four slow songs (Table 2).

Table 1. Subject characteristics (M ± SD).

N	Gender	Height (cm)	Weight (kg)	Age (yr)
6	Male	181 ± 5	96 ± 18	23 ± 2
5	Female	162 ± 8	65 ± 22	23 ± 1
11	Total	172 ± 12	82 ± 25	23 ± 1

Table 2. Music selections.

Treatment 1 (Fast Music)	Treatment 2 (Slow Music)
Low - Flo Rida featuring T-Pain	Here's to the Night - Eve 6
Don't Stop the Music - Rihanna	Superman - Five for Fighting
See You Again - Miley Cyrus	Only Time - Enya
Paralyzer - Finger Eleven	Running - No Doubt

Oxygen consumption and ventilation.

Using headphones, the subjects listened to music from an Insignia MP_3 player. A Trackmaster, Jas Fitness Systems treadmill was used for the submaximal treadmill test. A MedGraphics $CardiO_2$ metabolic analyzer, which was calibrated before each test, was used to measure the subjects' steady-state oxygen consumption (VO_2), expired carbon dioxide (VCO_2), frequency of breaths (F_b), and minute ventilation (V_E). Respiratory exchange ratio was determined by dividing VCO_2 by VO_2. The two treatments (Fast Music and Slow Music) and the control (No Music) sessions were applied in random order after a 5-minute rest period. Subjects jogged on the treadmill at 5.5 mph for 15 minutes while listening to the music the entire time. This speed was chosen because it approximated 85% of the subjects' maximum heart rate. The exercise intensity (percent) was consistent with the subjects' earlier indications of their exercise intensity.

Heart rate and blood pressure.

Using a Polar HR monitor to determine heart rate (HR), the subjects' HR responses were collected during 6 consecutive minutes starting at minute 7 of exercise. Systolic blood pressure (SBP) was determined as the appearance of Korotkoff sounds, while the point of disappearance of these sounds was considered to be the diastolic blood pressure (DBP). Systemic vascular resistance (SVR) was estimated by dividing MAP [DBP + .33 (pulse pressure)] by cardiac output (Q). Blood pressure was collected during minute 13.

Cardiac output.

The indirect Fick principle was used to estimate Q at steady-state exercise. This method allows for the noninvasive estimation of exercise Q. Carbon dioxide production (VCO_2) was determined from measurements of expired ventilation and mixed expired carbon dioxide (CO_2) concentration. Systemic arterial CO_2 tension ($PaCO_2$) was derived from the end-tidal CO_2 tension ($P_{ET}CO_2$). Mixed venous CO_2 tension (P_VCO_2) was determined with a CO_2 rebreathing technique, as previously described by Defares (10). The subjects were disconnected from the non-breathing value and connected to an anaesthetic bag to rebreathe a 4% concentration of CO_2. Each subject was instructed to breathe at a rate of 40 breaths/min in time with one of the investigators (BH), completely emptying the bag on inspiration and filling it on expiration. A Medical Graphics $CardiO_2$ metabolic analyzer was used to graphically examine the CO_2 signal generated during the rebreathing to ensure that a satisfactory CO_2 partial pressure had been achieved.

Cardiac output was calculated from the measurements of VCO_2 and the estimated $PaCO_2$ and P_VCO_2 (i.e., Q = $VCO_2 \div P_VCO_2 - PaCO_2$). This method correlates well [r = 0.96, 95% confidence interval (CI) of the different -0.37 to +0.47 L/min] with Q measurements made by thermodilution [11]. Cardiac output was collected at minute 15, which was followed by the subject's rating of the exercise intensity using the Borg's 6-20 scale of perceived exertion. Stroke volume was calculated by dividing Q by HR. Arteriovenous oxygen difference (a-vO_2 diff) was calculated by dividing VO_2 by Q. Myocardial oxygen consumption (MVO_2) in mL/100 gm LV/min was calculated using the equation: MVO_2 = 0.14 (DP) – 6.3, in which double product (DP) was calculated by multiplying the subjects' exercise HR x SBP x 0.01.

Statistical Analysis

Analysis of variance (ANOVA) with repeated measures was used to determine if there were any significant differences in the dependent variables (VO_2, Q, SV, HR, a-vO_2 diff, SBP, DBP, MAP, SVR, MVO_2, VCO_2, V_E, F_b, T_v, RER, and RPE) across the three exercise conditions. A probability of $p<0.05$ was used to determine statistical significance. When statistical significance was found, a post hoc Scheffe test was performed ($p<0.05$) to determine where the difference occurred.

RESULTS

Cardiovascular responses to the three exercise conditions (Fast Music, Slow Music, and No Music) are presented in Table 3. The hemodynamic responses are given in Table 4, and respiratory responses can be found in Table 5. Listening to fast music (Treatment 1) while jogging produced greater VO_2, Q, SV, V_E, and F_b and a lower SVR compared to slow music (Treatment 2) and no music (Control). Other cardiovascular, hemodynamic, and respiratory variables did not change. The results indicate that listening to fast music while exercising produced significant central adjustments in the cardiovascular response to steady-state treadmill exercise. Listening to fast music also increased the work of the lungs. Interestingly, there was no difference in the BP to both treatments versus the control.

Table 3. Cardiovascular responses to fast, slow, and no music during submaximal treadmill exercise (M ± SD).

Cardiovascular Variables	Treatment 1 Fast Music (A)	Treatment 2 Slow Music (B)	Control No Music (C)	F value	Sig
VO_2 (L/min)	2.52 ± 0.69 A-B^ A-C^	2.39 ± 0.71	2.34 ± 0.61	8.186	.003*
Q (L/min)	21.5 ± 5.6 A-B^ A-C^	18.0 ± 3.4	18.3 ± 3.6	7.934	.003*
HR (bpm)	167 ± 16	165 ± 16	163 ±19	2.089	.158
SV (mL/beat)	130 ± 36 A-B^ A-C^	111 ± 25	113 ± 25	5.936	.010*
a-vO_2diff (mL/100 mL)	11.9 ± 2.2	13.1 ± 2.4	12.7 ± 1.4	1.981	.173
SVR (mmHg/L/min)	4.8 ± 1.2 A-B^ A-C^	5.7 ± 0.9	5.4 ± 1.0	3.584	.047*

*ANOVA, ($p<0.05$); ^Scheffe test, ($p<0.05$)

DISCUSSION

Based on the Fick equation (VO_2 = Q x a-vO_2 diff), the subjects' increase in VO_2 while listing to the fast music during exercise was due to the increase in Q, which resulted from the increase in steady-stead SV (Q = SV x HR). The increase in SV indicates that listening to fast music during exercise increases contractility of the heart. Increased ventricular contractility can be produced by activation of the sympathetic nervous system (SNS), increased catecholamine release from the adrenal medulla, and/or greater venous return via the Frank Starling mechanism (12). Since HR did not increase, it is reasonable to assume that the increased SV may also be associated with an increase in venous return (i.e., preload). This assumption is likely to be the case, given that greater skeletal muscle activity is linked to an increase in VO_2. In fact, the subjects' VO_2 was significantly increased while listing to fast music (as was caloric expenditure) versus slow music or no music during exercise. While the difference is not that large (189 kcal, Fast Music vs. 179 kcal, Slow Music), burning more calories during exercising at the same HR intensity should be of considerable interest to people concerned with weight management. To do so without an increase in HR is also an important finding for people with cardiovascular disease.

It might be argued that since a-vO_2 diff did not change across the three experimental conditions, the skeletal muscles could not have extracted more oxygen when the subjects were listening to fast music. Recall that a-vO_2 diff is the amount of O_2 in milliliters (mL) removed from a standard volume of arterial blood (100 mL or 1 L). Consequently, even though the muscle fibers did not extract more O_2 per 100 mL of blood, more blood was delivered to the muscles per unit time (increased Q), thus increasing VO_2.

Table 4. Hemodynamic responses to fast, slow, and no music during submaximal treadmill exercise (M ± SD).

Hemodynamic Variables	Treatment 1 Fast Music	Treatment 2 Slow Music	Control No Music	F value	Sig
SBP (mmHg)	151 ± 26	145 ± 19	143 ± 16	1.772	.196
DBP (mmHg)	73 ± 5	76 ± 5	74 ± 6	1.668	.220
MAP (mmHg)	97 ± 12	98 ± 9	96 ± 7	.537	.592
MVO_2 (mL/100 g LV/min)	29.1 ±7.4	27.1 ±4.8	26.8 ± 5.8	2.307	.125

The unchanged HR found in this study is in agreement with Brownley et al. (4). However, this finding is in contrast to the report by Edworthy and Waring (6) and Thornby, Haas, and Axen (13). They observed a significant increase in HR when their subjects listened to fast music while exercising. Their studies used different exercise protocols and different music selection processes, which may account for the contradictory findings. The lower SVR in the fast music group was caused by the higher Q since MAP did not change. The lower SVR allowed for a greater Q response without a significant increase in SBP (Table 4). Since neither HR nor SBP increased with fast music, the heart

Table 5. Respiratory responses to fast, slow, and no music during submaximal treadmill exercise (M ± SD).

Respiratory Variables	Treatment 1 Fast Music (A)	Treatment 1 Slow Music (B)	Control No Music (C)	F value	Sig
VCO_2 (L/min)	2.43 ± 0.68	2.33 ± 0.69	2.36 ± 0.68	3.601	.057
V_E (L/breath)	66 ± 18 A-B^ A-C^	63 ± 16	63 ± 16	5.187	.015*
T_v (mL/breath)	1608 ± 426	1590 ± 461	1616 ± 454	.471	.631
F_b (breaths/min)	42 ± 8 A-B^ A-C^	40 ± 8	40 ± 7	4.380	.026*
RER	0.96 ± .06	0.98 ± .07	1.00 ± .05	2.907	.078
RPE	13 ± 1	13 ± 1	13 ± 2	1.207	.302

* ANOVA, $p<0.05$; ^Scheffe $p<0.05$

did not work harder (i.e., as reflected in the unchanged MVO_2) to increase the exercise VO_2. Also, it is likely that the increased Q with the unchanged MVO_2 reflects a favorable physiological result.

The respiratory responses suggest that some of the increase in VO_2 was likely due to increased work of the respiratory system. The lungs worked harder while the subjects listened to fast tempo music. The increase in V_E was caused by an increase in F_b, not T_V. Since it requires more energy to increase respiratory rate than T_V (14), some degree of pulmonary efficiency was lost when the subjects listened to fast tempo music. However, the increase was only 2 breaths per minute, which is not likely a concern to persons with healthy respiratory system.

Listening to fast or slow music did not change substrate utilization (RER, see Table 5). Apparently, people will not burn proportionately more fat while listening to music during exercise. However, according to the results of this study, they will burn more total calories by listening to fast tempo music. Since the RER did not change significantly, more total calories burned should mean more total fat calories burned as well.

Surprisingly, listening to music did not make the submaximal exercise seem any easier. The RPE was the same with and without music. This is a surprising finding because of the common notion that music serves as a distraction from the exercise itself, and other investigators have reported a decrease in RPE when listening to music while exercising (15-17). All three of these studies employed a cycle ergometer rather than a treadmill. Still, other studies that used a cycle ergometer did not find any significant differences in RPE when their subjects listened to music (7,18-20). Brownley et al. (4) used a treadmill and did not observe any differences in RPE. These divergent findings may be at least partly attributed to differences in exercise intensity, duration, trained and untrained states of the subjects, and the music selection process. Given that similarities in exercise intensity and duration occurred across these studies, it seems that the music itself could be the key factor in determining physiological and psychological responses. That is, the subjects' individual tastes in music may be critically important to how they respond to music during exercise.

CONCLUSIONS

The results of this study convey a mixed message. This study showed that listening to fast music during steady-state treadmill exercise resulted in a significant increase in SV and Q, which then resulted in a small increase in VO_2. Neither fast nor slow music influenced HR or BP and, therefore, MVO_2 was not increased. Hence, on one hand, listening to fast music decreased the subjects' cardiovascular efficiency since they were able to perform the same steady-state exercise with either slow music or no music with a lower SV, Q, and VO_2. On the other hand, it may allow individuals to burn slightly more calories during steady-state exercise when they listen to fast tempo music while still avoiding an increase in the work of the heart (MVO_2). By acting as a positive influence on caloric expenditure, fast music may motivate the individual to increase adherence to exercise, allowing a greater caloric expenditure over time.

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