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Effects of Exergame and Music on Acute Exercise Responses to Graded Treadmill Running

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Abstract

Recreational athletes may listen to music or watch videos to prolong their exercise routines. In recent years, use of active videogames has increased. The effects of audiovisual encouragements have not been compared for their potential ergogenic effects on physiological variables during moderate- to high-intensity exercises. Here 60 sedentary healthy male students were divided into four groups—control (CON), audio feedback (A), videogame feedback (V), and a combination of A and V (AV)—based on previous measurement of maximum oxygen uptake using covariate adaptive randomization. Participants completed a bout of running (Balke treadmill test) until exhaustion based on the type of feedback. Exercise responses (time, heart rate, blood sugar level, and creatine kinase level) were compared in all groups before and after participation. Participants in group A ran significantly more than those in the CON group, and those in group AV ran significantly more than those in groups CON and V. In other physiological responses, the differences were not significant among groups. It is proposed that intentional functions from internal (physical feelings) to external perspective (music and video) may have been involved in increasing exercise time but were not strong enough to change levels of other physiological parameters. However, these findings have strong applications for improving fitness exercise programs while using a new generation of videogames.

Introduction

Regular physical activity is essential for keeping our body healthy.[1] But, in today's fast-moving world, although technology intends to improve our quality of life, it seems to be taking over; physical activity has been pushed aside. Although physical activity is not the only solution to weight loss in the excessively obese, exercise has a positive effect on resting glucose levels and glucose tolerance in these individuals.[2]

Participants in physical activities use different ways to keep themselves motivated, from listening to music[3] to watching video.[4,5] In the last two decades, researchers have examined the ergogenic effects of sound and music on exercise performance. Professional and recreational athletes use music to keep motivation, to fight emotional and mental fatigue, to decrease perception of exercise exertion, and to increase the duration of exercise.[6,7]

Alternative active videogames (AVGs) such as "Wii Fit™ Plus" (Nintendo of America, Inc., Redmond, WA) are available for those who do not have access to sport centers or prefer to exercise at home to increase their physical activity.[8] This platform uses a handheld accelerometer to control onscreen actions. AVGs have been shown to have some physiological improvements in terms of increasing heart rate and improving maximum oxygen uptake (VO_2max).[9,10] Disagreement exists because of the variation of the results from one study to another.

Attention plays an important role in the perception of pain. Methods of distraction have been studied widely.[11] Strong evidence that supports the proposal that virtual games can decrease pain and anxiety in children has been reported previously.[12,13] Playing AVGs may have the potential to shift focus from internal stimuli to external cues. Research has been shown the increase in enjoyment while playing with AVGs.[14] Some of these games are so enjoyable that they often meets or exceeds the American College of Sports Medicine's threshold for moderate-intensity physical activity.[15]

Virtual reality may be a potentially effective tool for distraction because of its immersing nature, which demands substantial attentive resources.[16] However, there are some limitations that can reduce ecological realness, and that is because they can affect the way the user moves.[17] One particular example could be virtual running, in which the users are not really running and they move their body in place.

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A great number of studies also examined the ergogenic effects of music, especially prior to and/or during high-intensity exercises.[18,19] That's why synchronizing physiological and motor responses during exercise with music may be one of the reasons why music is influential. Synchronous music is suggested to enact this performance-enhancing effect.[20]

Blood sugar level could be a measurement of fatigue.[21] Biochemical changes in blood glucose level (i.e., <4 mmol, with or without symptoms) can also occur immediately following exercise.[22] When exercise duration lasts more than an hour, the appearance of fatigue symptoms is commonly reported. An increase in metabolic load associated with an increased heat stress, the appearance of central (e.g., reduction neural drive) and peripheral (e.g., decrease in muscle excitability) fatigue phenomena, and several hormonal changes have been reported.

Blood creatine kinase (CK) concentration is a marker of muscle damage that occurs after various forms of physical exercise.[23] In most tissues, increased levels of enzyme have been used as an indirect indicator resulting from tissue damage.[24] Type and intensity of exercise and muscle characteristics are suggested to greatly affect CK activity.[25]

Questions about the potential effects of music and distracting videos and their effects as the intensity of exercise increases are still unanswered. As recreational athletes may use different strategies to meet exercise demand,[26] the potential benefits of merging audio and video during moderate- to high-intensity exercises for maximizing exercise performance shows the importance of investigation. Therefore the aim of this study was to explore and compare two methods of training effects on exercise responses while running on a treadmill. We hypothesize that listening to music and playing with an AVG would significantly affect levels of blood sugar and CK compared with a control group.

Subjects and Methods

The purpose of this study was to describe and compare acute exercise responses (dependent variables) during conventional graded treadmill running versus running while receiving two types of feedbacks (auditory and visual). To test the previously stated hypotheses, male college-aged subjects ($n=60$) were divided equally and randomly into control (CON), audio feedback (A), visual feedback (V), and combined audio and visual feedback (AV) groups, with the CON group using a conventional graded running protocol on the treadmill, group A using the same running protocol while listening to a commanded audio file, group V using the same running protocol while playing with "Wii Fit Running" (Nintendo of America Inc.), and group AV using the same running protocol while both listening to commands and playing the exergame. Blood lactate level, CK level, heart rate, and time were recorded and used for subsequent analysis.

Sixty eligible healthy young male adults (age, 20 ± 1 years; height, 1.79 ± 0.04 m; weight, 73.9 ± 14.59 kg) were recruited for this study from a general physical education course through word of mouth. Participants were excluded if they smoked, were on medications that would affect their heart rate and/or blood pressure, had a history of cardiovascular disease or musculoskeletal injuries in the past 3 months, or had familiarity (playing with the device or running game) with the Nintendo Wii. The local institutional review board approved the study, and written informed consent was obtained from all subjects prior to their participation.

Participants completed two study sessions with 2 weeks between each test. On the first session they completed the Balke incremental test on the treadmill until exhaustion to obtain a baseline background on each participant's VO_2max.[27] This test is suitable for active and sedentary individuals. VO_2max was measured using the formula of Pollock et al.[28] At the beginning, the slope was set to 0 percent, and the speed was set at 3.3 mph (5.3 km/h). After 1 minute the slope was set to 2 percent, and then every minute thereafter the slope was increased by 1 percent. The test stopped when the subjects were unable to continue, and their total time was recorded. From the total time, expressed in minutes and seconds, the VO_2max was calculated as follows[1]:

$$VO_2\text{max} = 1.444 \times T + 14.99 \quad (1)$$

in which T is the total time of the test (expressed in minutes and fractions of a minute [e.g., 14 minutes 30 seconds = 14.50 minutes]). VO_2max was normalized with the participant's body weight for distributing normally between training groups.

The treadmill test and the running AVG were chosen to engage both upper and lower extremities. During session 2, participants were divided into four equal groups randomly based on their normalized VO_2max scores using covariate adaptive randomization. Trials were conducted at the same time of the day. The participants were asked to sleep at least 7 hours before the testing. They were told to avoid using nicotine at least 3 hours before testing. They were instructed to eat a set breakfast (10 kilocalories for each kilogram of their body weight plus at least 500 mL of water/liquids) at least 2 hours before the testing session. Urine samples were taken to ensure that the hydration condition was not different between subjects. During each run the participants were encouraged to exert to the maximum.

Warm-up instructions were the same for all participants. They spent 10 minutes for warm-up. In two trials the subjects received video and mixed audiovisual interventions using a 43-inch television (model KP43T75l; Sony, Tokyo, Japan) positioned 2 m in front of the subject and through two headphones (model MDR-V6; Sony) used by each participant. The audio file for verbal and mixed feedback was played by a laptop computer (HP Elitebook 8540w; manufactured in China; Hewlett Packard, Palo Alto, CA).

Resting blood sugar concentration was measured (ACCU-CHEK®; Roche, Mannheim, Germany) via a finger-prick blood sample taken by a qualified phlebotomist. The difference between pre- and post-exercise blood sugar levels was used as an index of fatigue during the maximal effort run. The CK baseline was measured by obtaining 2 mL of blood from the brachial vein. Sera for measurement of CK levels were transferred to the laboratory and after centrifugation of blood at 3,500 rpm (958 g) (Slide Spinner C1303-T; Labnet, Woodbridge, NJ) were kept at -20°C.

Nintendo "Wii Fit Running" (Fig. 1) was used as the video intervention protocol. It has a handheld remote control that measures users' movements, which are translated onscreen; the remote detects changes in acceleration and orientation, and the system adjusts feedback accordingly.[29] "Wii Fit

FIG. 1. TV screen image in the video and mixed (audio + video) intervention groups. Color images available online at www.liebertonline.com/g4h

Running" involves movement and uses the remote control in ways that are similar to completing the actions in real life. In order to simulate running better, the subjects were asked to put the remote controllers in their pockets. Because of the time limitations, the game was restarted several times, but they were encouraged to continue their running. In the mixed audio and video group intervention, the above conditions were mixed together. During the test, we covered the treadmill's display (heart rate, time, and distance) with a piece of cardboard. Heart rate was measured every 30 seconds using a Polar heart rate monitor (Polar Electra Oy, Kempele, Finland).

Participants in the audio group listened to a motivational mp3 file (Fig. 2) consisting of music chosen based on the basis of tempo and inspirational lyrics,[18] motivational commands, hand applause, whistles, and screams. We also synchronized the tempo of the music with the pace (VirtualDJ Home; Atomix Productions, Los Angeles, CA). The level of music was standardized for all subjects to 75 dB as this was a secure level and loud enough not to be drowned out by the treadmill's noise.[30] Positive comments were provided every 30 seconds in the mp3 file. Two seconds before and after commands, the total volume of the music file decreased to 66 percent, and the level of volume for commands would increase to 100 percent. This was done to highlight the positive command and make it clear and important to the subject. All of these parts were considered in a master mp3 file using a professional sound editor (Sound Forge™ Pro 10; Sony Corporation of America, New York, NY). Participants in the CON group completed their warm-up and Balke test but did not receive any feedback while running. After they finished the running protocol, a post-exercise sample of blood was taken.

The changes in blood sugar and CK levels for each maximal effort run, time, and heart rate were analyzed. Data were

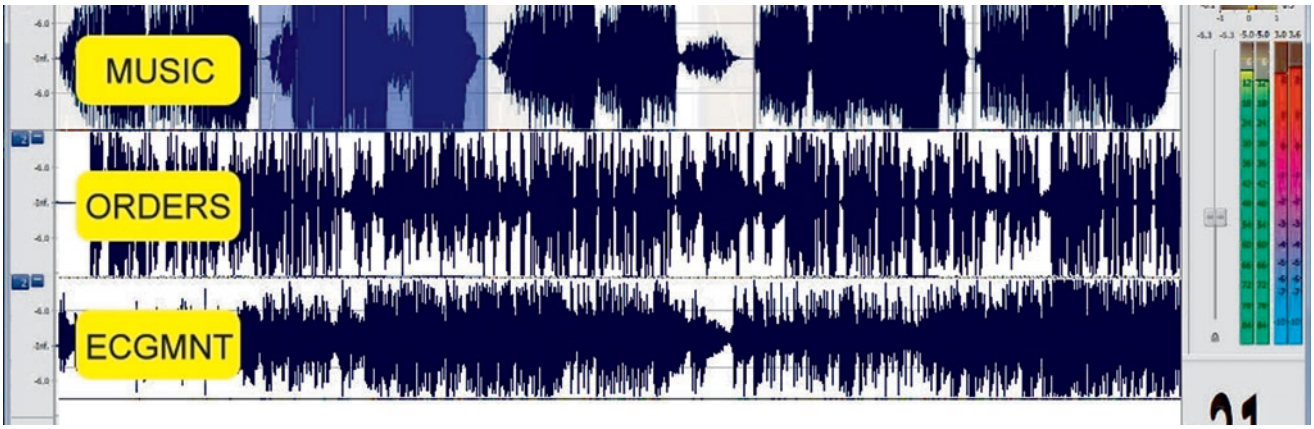

FIG. 2. Simulated image of the mp3 file consisting three parts: music, orders, and positive encouragements (ECGMNT). Color images available online at www.liebertonline.com/g4h

analyzed using analysis of covariance for comparing the groups based on blood sugar and CK with the controlling covariate (VO_2max). The homogeneity of regression assumption was tested between type of training and covariate before conducting analysis of covariance, which did not have a significant interaction ($P = 0.587$). A dependent t test was conducted for comparing each group in blood sugar from pre- to post-test, and finally Tukey's Highly Significant Difference *post hoc* test was used if any significant effects were detected. One-way analysis of variance was used to compare heart rate and time of running between different groups. Significance level was accepted at $P < 0.05$.

Results

Table 1 gives descriptive statistics between groups. Mean total time of running is presented in Table 2. Because the speed of the treadmill did not change, we also had total distance covered. It is notable that in group AV, participants endured for more than 1 minute (Fig. 3), and one-way analysis of variance showed that there was a significant difference among the CON, A, V, and AV groups ($F_{3,56} = 8.633$, $P = 0.001$) for total running time. The *post hoc* analysis revealed that the running time of group A was longer than that of the CON group (735.00 ± 251.08 versus 963.67 ± 337.35 seconds, $P = 0.03$), that of group AV was longer than that of the CON group (735.00 ± 251.08 versus 1,101.20 ± 199.98 seconds, $P = 0.001$), and that of group AV was more than that of group V (767.53 ± 78.81 versus 1,101.20 ± 199.98, $P = 0.001$). The one-way analysis of variance for the heart rate (Fig. 4) showed that there was no significant change among the four groups ($F_{3,56} = 2.274$, $P = 0.90$).

Analysis of covariance indicated no difference in blood sugar and CK levels between groups ($F_{3,55} = 1.32$, $P = 0.28$ and $F_{3,55} = 0.21$, $P = 0.89$, respectively). Therefore different types of training do not have a statistically significant effect on change in blood sugar levels even when we controlled VO_2max.

Discussion

The purpose of this study was to characterize the acute muscle contusion and changes in levels of blood glucose right after running on a treadmill while receiving four types of feedbacks. It was hypothesized that playing an exergame and listening to music would significantly affect levels of CK and blood glucose after running on the treadmill. These hypotheses were not supported because there were no significant changes among the group. However, there was a significant change in total time of running among the groups. It seems that the distraction caused by audio and visual feedbacks resulted in spending more time on the treadmill and therefore increasing the distance covered. In our study, the role of auditory feedback was more important than visual feedback, as we saw there were significant differences in total time of running only when audio was involved. This may be due to the design and visual elements of the game. It seems that audio could play a greater role when it comes to motivation. Most of the subjects said that they were waiting to hear the positive commands because they found them funny, and meanwhile they were syncing themselves with the pace of the music. On the other hand, changes in distance covered among the groups may be due to the design of the game, specifications, and the individual response of each participant to the type of feedback. This finding has important practical implications because recreational runners can significantly prolong their practice by using music and virtual games. Music increased time to exhaustion by well over a minute in the verbal and mixed feedback group compared with the CON group.

Previous studies evaluated the effect of music on running performance outcome. As mentioned by Barney et al.,[6] college students who are just beginning an exercise program may benefit more from listening to music. The present data did support these findings. Both groups A and AV showed a significant difference compared with the CON group. Lane et al.[3] found that regardless of the type of music, subjects showed increased pleasant emotions. Terry et al.[31] found that even elite runners can benefit from music in their schedule. In our study, these effects were even higher for non-athlete runners. It may

Table 1. Physical Characterization of Participants

Type of training	n	*Age (years)*	*Height (m)*	*Mass (kg)*
Control	15	20.46 ± 1.55	179.93 ± 4.36	73.90 ± 14.59
Audio	15	20.20 ± 1.77	175.53 ± 7.83	69.50 ± 17.22
Video	15	20.26 ± 1.83	173.86 ± 5.96	63.98 ± 8.00
Audio + video	15	20.26 ± 1.83	173.86 ± 5.96	63.98 ± 8.00

Data are mean ± standard deviation values.

Table 2. Descriptive Statistics for Total Running Time and Heart Rate

Type of training	n	*Total time (seconds)*	*Total distance (m)*
Control	15	735.00 ± 251.08	1,048.29 ± 370.40
Audio	15	963.67 ± 337.35[a]	1,421.63 ± 497.66
Video	15	767.53 ± 78.81	1,132 ± 116.26
Audio + video	15	1,101.20 ± 199.98[bc]	1,624.52 ± 295.01
Total	60	891.85 ± 267.55	1,315.68 ± 394.69

[ab]Significantly different from control group value.
[c]Significantly different from video group value.

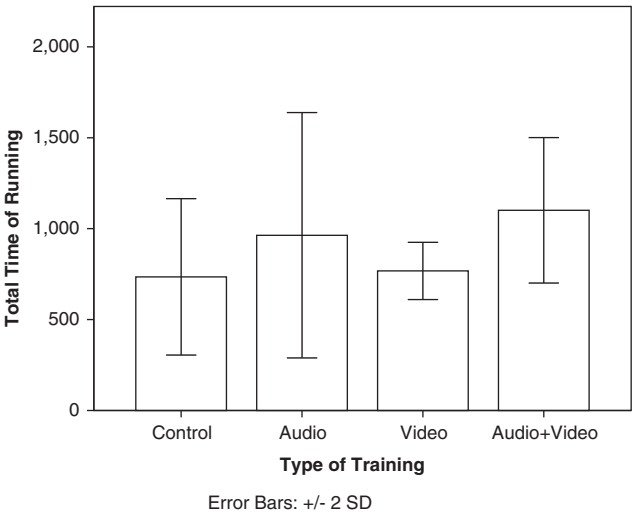

FIG. 3. Total time of running in different types of training.

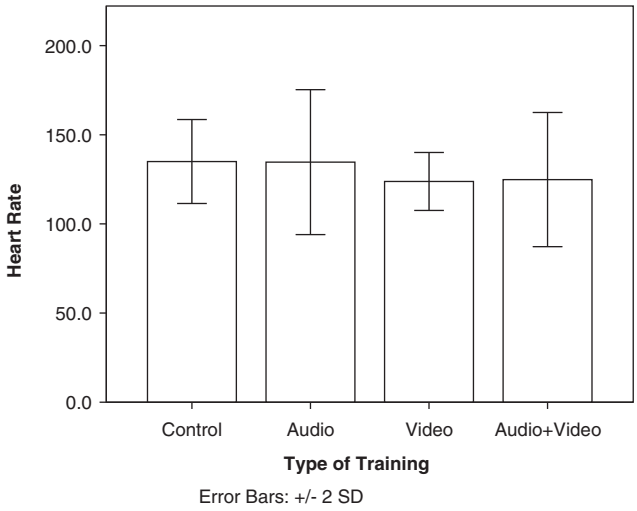

FIG. 4. Mean heart rate during different types of training.

be due to the mixture of several commands and positive encouragements offered during running. Although Potteiger et al.[32] discovered that music can decrease perceived exertion when exercising at the same level, they eventually showed that it does not affect heart rate significantly. Our findings were similar to theirs in that the changes in heart rate among exercise groups were not significantly different.

Music and positive verbal commands have showed to be most effective during low to moderate work intensities or in untrained participants.[18,33] Wollersheim et al.[34] showed that visual feedback offering by gaming consoles like Wii don't provide substantial physical effects. Music may provide benefits in other submaximal activities, including swimming, cycling, and rowing. As we previously synchronized the movement with tempo, this potential effect may be more important than perceived motivational qualities of music.[35]

AVGs significantly elevate heart rate, but the increase is dependent on the type of game.[36] On one hand, the results of Stroud et al.[36] confirm what we measured during our study, but in our study the elevation of heart rate was not exactly because of the AVG. Therefore, it seems that running by itself on the treadmill had the greatest impact on increasing heart rate.

It seems that motivational mechanisms of Nintendo "Wii Fit Running" auditory commands created a positive atmosphere and therefore resulted in increased time spent running. Most of the subjects confirmed that Nintendo was fun for them, and although the game was not competitive, they wanted to run as far as they could. The effects of music and audio commands were stronger than the visual feedback presented by the game. It seems that they wanted to synch themselves with the beat, and therefore they ran more compared with the visual group.

Moreover, there is a proportional relationship between length of run, distance, and/or duration of run and the resulting elevation of CK level.[37,38] However, insignificant changes of CK level may be due to immediate sampling of blood, for which the occurrence of fatigue may differ from subject to subject. To our knowledge, this was the first study testing CK level as a symbol of acute muscle contusion with exergames and music while running on a treadmill.

This study showed that the combination of music and an AVG as a video intervention did not have any significant effect on changing levels of heart rate, blood sugar, and CK compared with the CON or other training groups, but there was a significant change in values with time among groups. As we saw, AVG and music may be of use by recreational users who are more likely to choose strategies to increase the time of their exercise or to tolerate higher-intensity workload. In order to establish suitably motivating video components for these interventions, research tools should be developed to help participants and researchers in future studies.

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Author Disclosure Statement

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