PSIHOLOGIJA, 2024, Vol. 57(2), 155–175

UDC 159.9.072.532-057.875:159.932(55)
796.012.12-057.875:159.9.075(55)
DOI: https://doi.org/10.2298/PSI220503004R

The Effect of Continuous Artificial Non-musical Auditory Stimulation on Cardiorespiratory Endurance and Perceived Exertion*

Hesam Ramezanzade[1]**, Rasool Abedanzadeh[2], Fabrizio Sors[3], Mauro Murgia[3], Tiziano Agostini[3], & Akbar Forati[4]

[1]Department of Sport Science, School of Humanities, Damghan University, Iran
[2]Department of Motor Behavior and Sport Psychology, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[3]Department of Life Science, University of Trieste, Italy
[4]Master of Sport Physiology, Lecturer in Damghan University, Iran

This study aimed to investigate the effects of auditory stimulation with different frequency variations (increasing, decreasing, and constant) on performance, physiological parameters and perceived exertion in the shuttle run test. Twenty-four healthy sports science students participated in this experimental study and performed the shuttle run test under four different conditions: a) standard (as baseline); b) auditory stimulation with increasing frequency; c) auditory stimulation with decreasing frequency; and d) auditory stimulation with constant frequency. The results showed that maximal oxygen consumption in the decreasing-frequency condition was significantly higher than in any other condition and performance in the increasing-frequency condition was higher than that in the constant and standard conditions. The results also showed that in the initial and intermediate phases of the test, heart rate and perceived exertion were lower in both the increasing– and decreasing– frequency conditions than in the constant frequency and standard conditions. The results of the present study suggest that the use of auditory stimulation with decreasing frequency and increasing frequency can improve performance in endurance tasks. Future studies should better understand the different

Corresponding author: h.ramezanzadeh@du.ac.ir

Ethics Approval. All procedures performed in studies were in accordance with the ethical standards of the institutional research committee.

Conflicts of interest. The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Competing Interests and Funding. The authors report no involvement in the research by the sponsor that could have influenced the outcome of this work.

* Please cite as: Ramezanzade, H., Abedanzadeh, R., Sors, F., Murgia, M., Agostini, T., & Forati, A. (2024). The Effect of Continuous Artificial Non-musical Auditory Stimulation on Cardiorespiratory Endurance and Perceived Exertion. *Psihologija*, *57*(2), 155–175. https://doi.org/10.2298/PSI220503004R

** ORCID ID: 0000-0002-7643-8899

effects of these two types of stimulation and investigate whether they lead to long-term improvements.

Keywords: auditory intervention, sound frequency, perceived exertion, blood pressure, blood oxygen level

Highlights:

- According to the results of this study, artificial sounds (with changing the frequency) can affect performance and perceived exertion (as music does).
- This type of auditory stimulation is only useful at low and medium intensities of performance and has no effect on performance at high intensities.
- Decreasing frequency sounds, more than other sounds (constant and increasing frequency), lead to improved performance and reduced perceived exertion.

Over the past two decades, researchers have focused on sound-based interventions in sport to improve perceptual-motor (Sors., 2015a; Schaffert., 2019) and psychophysiological (Karageorghis & Priest, 2012; Valenti et al., 2012; Gomes et al., 2018) performance. The purpose of sound-based interventions is to understand and modulate the coordination and execution of movements that affect athletic performance (Sors et al., 2015a; Vinken et al., 2013). Indeed, recent research has focused on how auditory information affects the production of complex movements and ultimately leads to the development of motor performance in athletes (Schaffert et al., 2019; Pizzera & Hohmann, 2015). These studies have used natural (Kennel et al., 2014) or artificial (Ramezanzade et al., 2017; Dyer et al., 2015) sounds to produce auditory patterns or feedback.

Studies that focus on the psychophysiological adaptability of athletes are also highly valued. In light of this, researchers have extensively investigated the effect of music on psychological variables such as mood (Tenenbaum, 2001), positive emotional states (Karageorghis et al., 2009; Elliott et al., 2004), and motivation (Hutchinson et al., 2011). In addition, studies have clearly demonstrated the positive effect of auditory stimulation on physical arousal (Karageorghis & Priest, 2012; Hutchinson et al., 2018). In these studies, physiological indicators such as heart rate, blood pressure, blood oxygen level, etc., have been used to measure arousal. Although many studies have also shown that high levels of psychophysiological arousal have an ergogenic effect, i.e., an increase in work capacity (Karageorghis, 2008; Cohen et al., 2007), such an effect has not been observed in some other studies (Yamamoto, 2001; Eliakim et al., 2007). In addition, while some researchers have attributed the positive effect of auditory stimuli (such as music) to a reduction in perceived exertion (Karageorghis & Priest, 2012; Bigliassi et al., 2018; Yamashita et al., 2006), some other studies have not confirmed such an effect (Hutchinson et al., 2011; Dyrlund & Wininger, 2008).

Despite all these discrepancies, most studies consistently indicate that auditory stimuli (such as music) positively affect perceived arousal and exertion (Karageorghis & Priest, 2012), but the intensity of these effects varies widely. To explain the results of different studies, Karageorghis et al. (1999) developed a model where the motivational qualities of music are a determining factor for its effect on arousal, perceived exertion, and different moods. In this model, four index factors were introduced that influence the motivational qualities of music. These factors include two internal factors (rhythm response (effect of music rhythm, especially its pace) and musical components (loudness, frequency, etc.)) and two external factors (cultural and communicative effects) (Karageorghis et al., 1999).

Many researchers agree that rhythm response is the most important determinant of the motivational quality of music (Crust, 2008; Priest & Karageorghis, 2008). The results of various studies indicate that the faster the rhythms, the more motivating the effect and the stronger the effect on arousal and reduction of perceived exertion (Hutchinson et al., 2011; Rendi et al., 2008). Compared with rhythm, other musical components have received less attention. To our knowledge, only one study has compared music with a high and low volume (Edworthy & Waring, 2006) and they tested effects of tempo (slow vs. fast) and intensity (quiet vs. loud) on the self-selected speed of treadmill running during 10-min trials. The results showed no significant difference between high and low volumes for slow rhythm sounds; however, for fast sounds, a loud sound was better than a soft sound. No study was found that examined the effect of changing sound frequency on work performance or perceived exertion. Almost all of the studies used music already familiar to the target audience. This music could have different rhythms and be used depending on the purpose of the study. Other studies have used verbal auditory stimuli (Grande-Alonso et al., 2020).

Given that frequency is a component of sound and that, according to the model proposed by Karageorghis et al. (1999), it is likely to affect the motivational quality of sounds, the question is whether frequency variations in auditory stimulation (from low to high, from high to low, or constant) during a performance can promote changes in work performance and perceived exertion. In particular, the shuttle run test, an endurance task, has been used in the present study. Some previous studies have investigated the effect of music on endurance. The results of these studies confirm the positive effect of stimulating music (with different rhythms) vis-a-vis relaxing music and non-music (in the case of control groups) on cardiorespiratory (Yamashita et al., 2006; Nakamura et al., 2010; Patania et al., 2020) and muscular (Karageorghis, 2008; Crust, 2004a; Crust & Clough, 2006) endurance. In a recent study, Lamoneda et al. (2021) show that the 20m shuttle run with music (20m SRT-music) is a feasible test for measuring cardiorespiratory fitness in adolescents. It should also be noted that the effects of stimulating music on endurance are stronger for slow– to moderate-intensity tasks than for high-intensity tasks, and in many studies, the effect of music on high-intensity endurance tasks (performance to the point of exhaustion) was not apparent (Karageorghis & Priest, 2012; Yamashita, 2006; Harmon & Kravitz, 2007).

Based on the available literature, studies on the effect of music with slow to fast rhythms have produced conflicting results, especially in the context of high-intensity endurance activities. To produce a motivational quality, only pre-recorded music known in the community has been used in these studies, and the change in audio frequency has not been intended to produce this motivational quality. This music often has emotional content that reminds participants of specific memories. Therefore, it is not clear whether the effect of the music was due to the rhythm chosen (fast, medium, slow) or due to the distraction caused by the music. Furthermore, most studies have used only very fast or very slow music rhythms. Only one study has examined the effects of music with variable rhythms (rising and falling) on moderate-intensity endurance tasks (Szabo et al., 1999). This study suggests that changing from a slow to a fast rhythm results in higher work performance than when the music is quite fast or slow.

Against this background, the present study aims to answer the following questions by administering auditory stimulation with increasing, decreasing, or constant frequency during the shuttle run test: a) what are the effects of such stimulation on endurance performance and physiological parameters (heart rate, blood pressure, blood oxygen level)? b) Are the effects of such stimulation the same in all phases of the shuttle run test? and c) what are the effects of these auditory patterns on perceived exertion?.

Methods

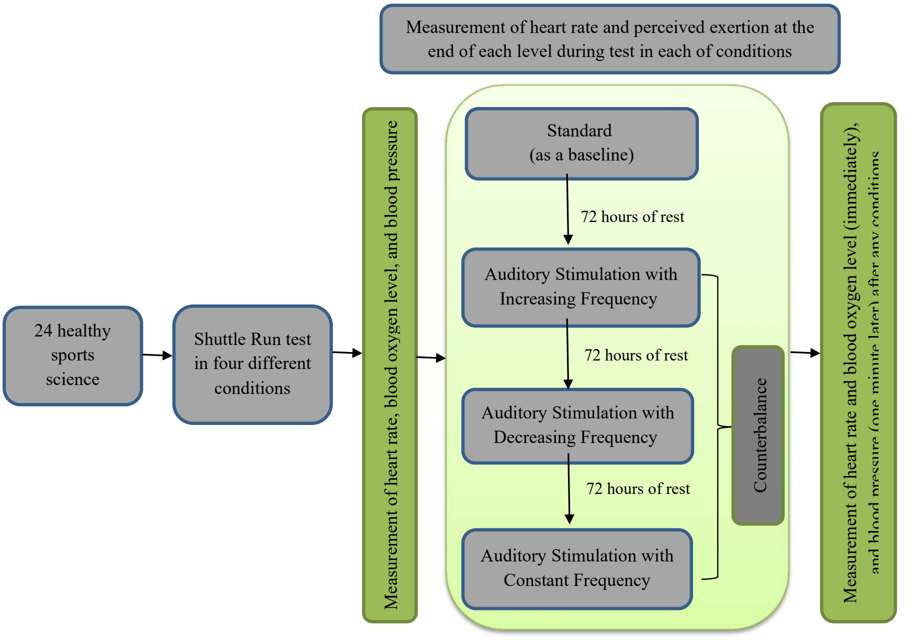
Participants

The participants in this study were 24 undergraduate healthy sports science students, all-male, with a mean age of 19.38 ± 1.14 years. The public health questionnaire developed by Goldberg et al. (1997) was used to assess the participants' general health. All were nonsmokers and did not consume alcohol. Also, all the subjects were in the normal range based on the body mass index. The exclusion criteria in this study included injuries or the appearance of unusual clinical symptoms in the individual, non-adherence to the schedule in the implementation of the research protocol, and the individual's unwillingness to participate in the research. After being informed of the purpose of the study and familiarized with the working method, they signed the informed consent form to participate in the study.

Experimental Design

The design of this study was within-group so that each participant was tested under the following four conditions: a) standard (as baseline); b) auditory stimulation with increasing frequency; c) auditory stimulation with decreasing frequency; and d) auditory stimulation with constant frequency. The standard condition (without auditory stimulation) was the first for all participants, while the order of the other three conditions was counterbalanced between participants. Figure 1 shoes an overview of the research methodology.

Figure 1
Overview of research methodology



Shuttle Run Test

To measure cardiorespiratory endurance, the shuttle run test was used. It was invented by Leger et al as a progressive endurance test that requires the participant to run a distance of 20 meters by running in various levels (Leger et al., 1988). The test consists of 21 levels, with each level comprising a specific number of stages (e.g., level 1 comprises 7 stages, level 2 and 3 comprise 8 stages, level 4 comprises 9 stages, etc.). Each stage corresponds to covering 20 meters once. In this way, after starting the test and playing the audio file simultaneously, the participant has to run 20 meters between two beeps. The interval between the two beeps is fixed for each level and decreases from level to level, which means that the participant must go faster (for example, in the first level, the interval is 9 seconds, in the second level it is 8 seconds, in the third level it is 7.58 seconds, etc.). If the participant does not cover the 20-meter distance before the beep, it will be counted as a failure; if there are three failures, the test is over. Thus, the test is finished when the participant reaches the point of exhaustion and wants to leave the test or makes three mistakes. The level and stage at which the participant exits the test are recorded and used to calculate the VO2 max index. VO2 max is the maximum rate of oxygen consumption attainable during physical exertion.

Leger and Gadori (1989) modified the shuttle run test, originally introduced by Leger and Lambert (1982). Nazem et al. (2002) found a significant correlation between the VO2 max estimate of the shuttle run test and the VO2 max estimate of the Ellestad treadmill test, demonstrating that shuttle run test has high validity for estimating the relative value of VO2 max.

In the present study, participants' scores on the shuttle run test were converted to VO2 max using the following estimation formula (Paradisis, 2014) y = 0.2761 x + 27.504 (where y = VO2 max and x = number of 20-m shuttles).

In this equation, y represents the VO2 max and x represents the number of 20-meter shuttles that the subject has traveled from the beginning of the test to the time of leaving the test. For example, if the subject stops at level 5 and stage 6 of the shuttle run test, he has completed 38 shuttles. Therefore, according to the above formula, the maximum oxygen consumption is:

y = (0.2761 x 38) + 27.504

y = 37.99 ml/kg.min

Auditory Stimulation

In this study, specific auditory stimulation was used that was appropriate for the purpose and type of the endurance test, i.e., shuttle run test. To generate this auditory stimulation, the audio frequency was designed using the Sandbox Sonification program (Davison & Walker, 2007) based on the positive degree-2 function pattern (increasing pitch), the negative degree-2 function pattern (decreasing pitch), and the constant function (constant pitch). In the increasing pattern, the pitch varied from note[1] 32[2] (Ab[3]) (51.91 Hertz) to note 113 (F) (5587.65 Hertz); in the decreasing pattern, the pitch varied from note 113 (F) to note 32 (Ab). For the constant pattern, there was no change in sound frequency. In this study, the resonance of an electric piano was used. The audio patterns were inserted into the intervals between the two beeps of the shuttle run test so that the participants could hear the sound pattern over the loudspeaker as they traveled 20 meters at a time. The duration of the auditory stimulus was proportional to the duration determined to run each length in the shuttle run test. Since in the shuttle run test, the duration of the 20-meter shuttle gradually decreases, the duration of the auditory stimuli decreased accordingly.

Dependent Variables

Cardiorespiratory endurance. Cardiorespiratory endurance is one of the most important factors in physical fitness and refers to the ability of the heart and lungs to supply oxygen to working muscles during continuous physical activity (Ross et al., 2016). In this study, cardiorespiratory endurance was measured using the shuttle run test, calculated as described above.

Heart rate, blood oxygen level, and blood pressure. A heart rate gauge (model Polar S625X – manufactured in Finland) was used to measure heart rate, consisting of two parts: a chest part and a wristwatch. A pulse oximeter from JZIKI (model JZK-303 – manufactured in China) was used to measure blood oxygen levels. Also, a Microlife sphygmomanometer (model BP A2 Basic – manufactured in China) was used to measure blood pressure. The timing of the measurement of physiological parameters is described at length in the following sections.

Perceived exertion. The Borg (1980) Perceived Exertion Scale was used to measure the participants' perception of exertion. This scale contains 15 levels (6–20) and 9 verbal descriptors. Grade 6 corresponds to "no exertion," and grade 20 corresponds to "maximal exertion." In this scale, for exertion rate 6, 7, 9, 11, 13, 15, 17, 19 and 20, the following expressions are presented respectively: No exertion, Extremely light, Very light, Light, Somewhat hard, Hard, Very Hard, Extremely hard and Maximal exertion.

---

1 In music, a note is a musical sound. Notes can represent the pitch and duration of a sound in musical notation.

2 Audio pitch in MIDI standard.

3 Audio pitch in Helmholtz system.

Procedure

All participants were asked to avoid any intense and prolonged physical activity at least 24 hours before the start of the experimental protocol and not to drink coffee at least 12 hours before the start of the protocol; they were also asked to eat some light food 2 hours before each session. Except for auditory stimulation, the other factors include performance environment (gym with constant temperature, air humidity and lighting), performance time (Between 4 and 7 in the evening), distance between the four conditions (72 hours), and the variables measured) were the same for all four conditions. The performance protocol consisted of two parts: warm-up and test.

As mentioned earlier, the participants underwent four different experimental conditions in four separate sessions. There was a 72-hour break between sessions to allow for a full recovery. One hour before the start of the first session, all participants received detailed explanations about the warm-up, how to perform the test, the perceived exertion scale, and the physiological parameters to be measured. All participants performed the standard shuttle run test (without auditory stimulation) as baseline in the first session. In subsequent sessions, the experimental conditions were counterbalanced to avoid for the effects of order and sequence. Thus, of 24 participants in the second session, 8 participants were tested under conditions of an increasing auditory pattern, 8 participants were tested under conditions of a decreasing auditory pattern, and 8 participants were tested under conditions of a constant auditory pattern. The same procedure was applied in the third and fourth sessions.

After warming up, the participants' heart rate, blood oxygen level, and blood pressure were measured, and then they were placed behind the starting line of the test. Then, they performed the test (under a certain experimental condition). After the test, their heart rate and blood oxygen level were measured immediately, and blood pressure was measured one minute later. All measurements were performed for all participants in a standing position. Table 1. summarizes the protocol of a single session and the timing of the measurements.

Table 1
Protocol of a single experimental session

Soft Running (2 minutes) Stretching Movements for Upper and Lower Body (3 minutes) Rotational Movements (2 minutes)	Warm-up
Before the start: measurement of heart rate, blood oxygen level, and blood pressure; During performance: measurement of heart rate and perceived exertion at the end of each level; and At the end of the test: measurement of heart rate and blood oxygen level (immediately), and blood pressure (one minute later)	Test

In addition to measuring physiological parameters and perceived exertion, the participants' experience was also examined using an open-ended posttest question in each of the conditions, "How do you perceive performance in the conditions of ... compared to the original test condition?". In addition, at the end of the entire experiment (i.e., after the fourth session), the participants were asked to prioritize the four conditions in terms of feeling better and having a more favorable performance condition.

Statistical Analysis

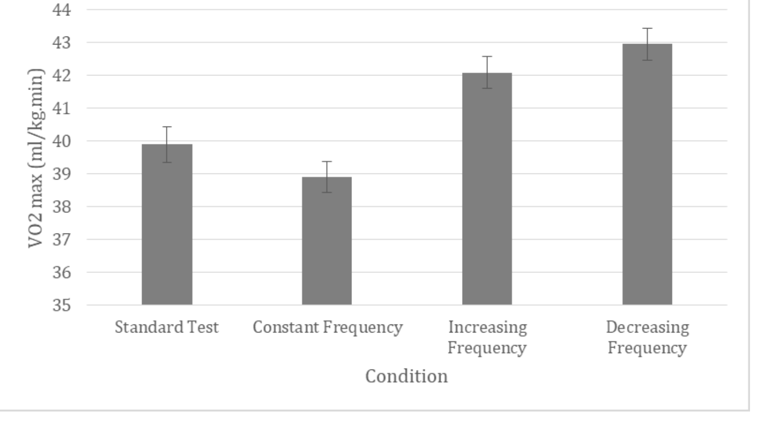
To compare the dependent variables across the four test conditions, a series of repeated measures ANOVAs were conducted; Bonferroni post hoc comparisons were also conducted when appropriate. In this research, there is four conditions and the p value has been corrected for 6 different comparisons. Normality of data distribution and the variance-covariance homogeneity assumption was tested with Mauchly's sphericity and Kolmogorov-Smirnov tests before the repeated measures ANOVAs. When the variance-covariance homogeneity assumption was not confirmed, Greenhouse Geisser was used. The effect size of the statistical tests is expressed in terms of Cohen's d (Cohen, 1992). The graphs were drawn using Excel.

Results

In this study, the standard condition is considered as the baseline and all three other conditions (constant, increasing and decreasing) are compared with these conditions. However, increasing and decreasing frequency conditions have also been compared with constant frequency conditions to find out whether the mere presence of sound can affect subject's performance, or in addition to the presence of sound, changes in the frequency of sound (increasing and decreasing) are also effective.

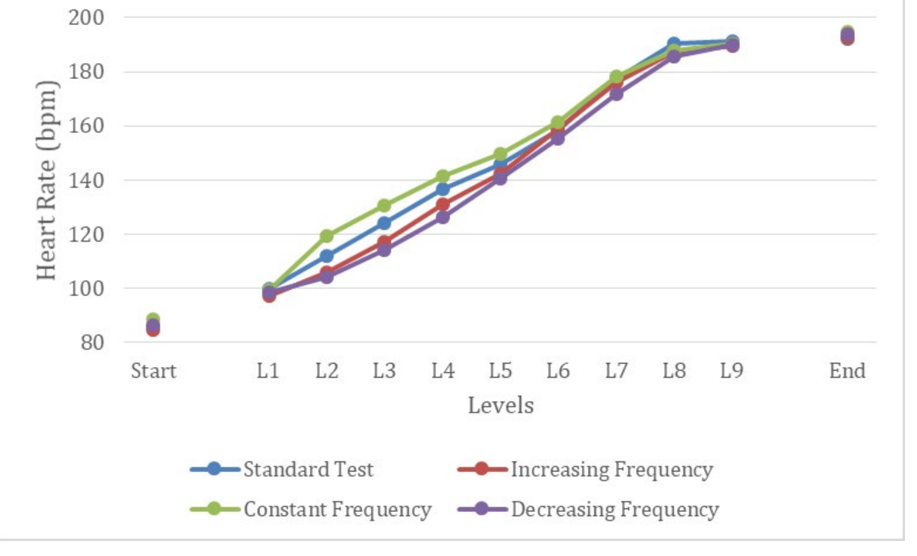
As for cardiorespiratory endurance (VO2 max) (Figure 2), the result of Mauchly's sphericity test showed that the variance-covariance homogeneity assumption was confirmed (*Mauchly's W* = 0.662, *df* = 5, p = .11). Also, the results of Kolmogorov-Smirnov test showed that the normality of data distribution assumption was confirmed (p > .05). Repeated measures ANOVAs showed that the effect of different test conditions was significant ($F(3, 69) = 77.013$, p = 0.001, η = 0.77). Bonferroni post hoc tests revealed that the participants performed significantly better (higher VO2 max) in the increasing (d = 0.865, p = .001) and decreasing (d = 1.22, p = .001) frequency conditions than in the standard condition. In addition, performance in the standard condition was significantly better (higher VO2 max) than in the constant frequency condition (d = 0.399, p = .012). Finally, performance in the decreasing frequency condition was significantly better (higher VO2 max) than in the increasing frequency condition (d = 0.365, p = .003).

Figure 2
Vo2 max of the participants in different conditions



As for heart rate, the ANOVA showed no significant difference between conditions in the first stage of the test. The results of the Bonferroni post-hoc test showed that in the second (F(2.175, 50.021) = 131.771, p = .001, η = 0.851), third (F(3, 69) = 154.057, p = .001, η = 0.8700, fourth (F(2.116, 48.671) = 94.776, p = .001, η = 0.805), and fifth (F(3, 69) = 26.1, p = .001, η = 0.532) levels, there was a significant difference in favor of the increasing and decreasing frequency conditions compared to the standard (base line) and constant frequency conditions. Heart rate was significantly lower in the standard condition than in the constant frequency conditions at the same levels. At the sixth (F(3, 69) = 8.412, p = .001, η = 0.268) and seventh (F(3, 60) = 15.694, p = .001, η = 0.44) levels, a significant difference was observed in favor of the decreasing frequency condition compared to the other three conditions. There was no significant difference between the four conditions at the remaining stages (eighth and ninth stages) and at the end of the test. Figure 3 illustrates the mean heart rates of the participants at different levels in the four different test conditions.

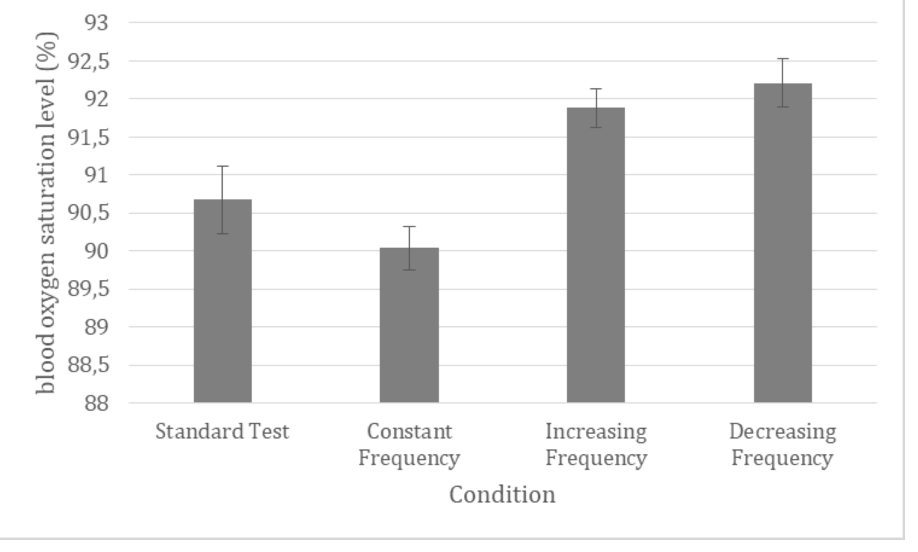
Figure 3
The mean heart rates of the participants at different levels of the shuttle run test in the four conditions



Regarding the blood oxygen level (Figure 4), there was a significant difference between the different test conditions (F(1.946, 44.769) = 16.307, p = .001, η = 0.415). Bonferroni post hoc tests showed a significant difference (higher oxygen level) between the increasing frequency and decreasing frequency conditions with the standard test conditions (respectively p = .025, d = 0.68 and p = .024, d = 0.812) and the constant frequency (respectively p = .001, d = 1.38

and p = .001, d = 1.45) in favor of the increasing frequency and decreasing frequency conditions. In addition, there was no statistical significant difference between the increasing and decreasing frequency conditions (p = 0.98, d = 0.23), nor between the constant frequency conditions and the standard test (p = 0.316, d = 0.34).

Figure 4
Blood oxygen saturation levels of the participants under different conditions

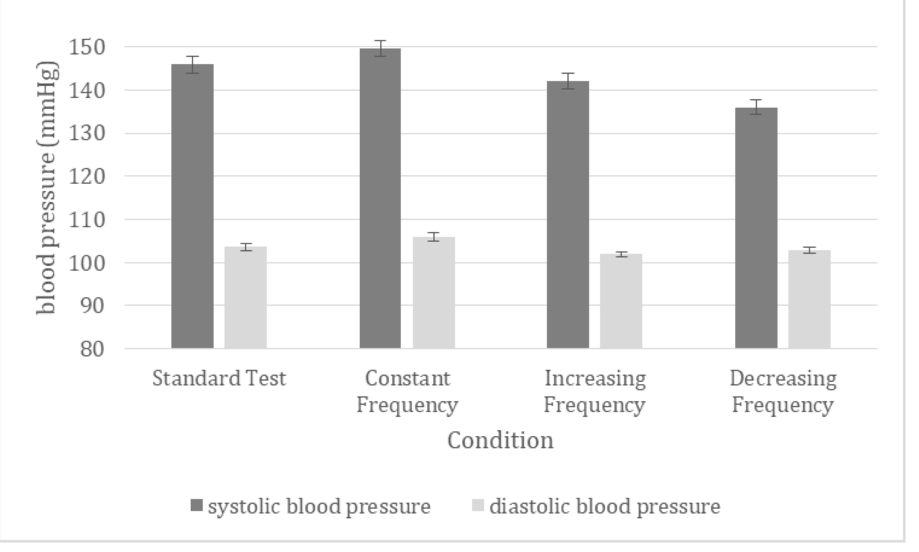


There was also a significant difference for systolic blood pressure (Figure 5) between the different test conditions (F(1.797, 41.322) = 14.273, p = .001, η = 0.383). Bonferroni post hoc tests showed a significant difference (lower systolic blood pressure) between the increasing frequency condition and both the standard (base line) condition (p = .009, d = 0.42) and the constant condition (p = .001, d = 0.87) in favor of the increasing frequency condition. In addition, the differences between the decreasing frequency condition and the increasing frequency condition (p = .048, d = 0.7), constant frequency (p = .001, d = 1.62), and standard conditions (p = .001, d = 1.12) were significant and in favor of the decreasing frequency condition. In addition, the difference between the standard condition and constant frequency (p = .001, d = 1.62) was significant and in favor of the standard frequency condition.

There was also a statistical significant difference for diastolic blood pressure between the different test conditions (F(3.69) = 8.888, p = .001, η = 0.279). Bonferroni post hoc tests revealed no significant difference between increasing frequency, decreasing frequency, and standard conditions. However, diastolic blood pressure was significantly lower in these three conditions than in the constant frequency condition.

Figure 5

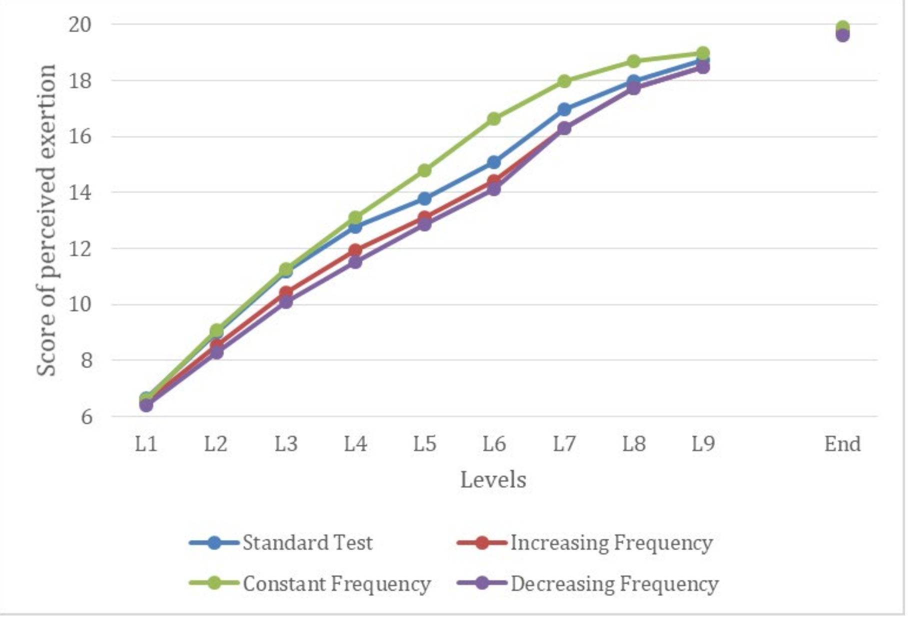
Systolic and diastolic blood pressure under different conditions



Finally, ANOVA results indicated no statistical significant differences in the first stage among the four conditions regarding perceived exertion. The results of the Bonferroni post hoc test showed that in the second ($F(3, 69) = 15.045$, $p = .001$, $\eta = 0.395$), third ($F(2.227, 51.232) = 21.124$, $p = .001$, $\eta = 0.479$), fourth ($F(3, 69) = 36.949$, $p = .001$, $\eta = 0.616$), fifth ($F(2.041, 46.953) = 47.23$, $p = .001$, $\eta = 0.673$), sixth ($F(2.245, 51.638) = 77.012$, $p = .001$, $\eta = 0.77$), seventh ($F(2.163, 49.743) = 34.344$, $p = .001$, $\eta = 0.599$), and eighth ($F(1.914, 24.881) = 16.981$, $p = .001$, $\eta = 0.566$) levels, scores were significantly lower in the increasing and decreasing frequency conditions than in the standard and constant frequency conditions. However, in the other levels, except for the third and fourth levels, the difference between the increasing and decreasing frequency conditions was insignificant. It was also found that the difference between the standard condition and the constant condition was significant and in favor of the standard at the fourth to eighth stages. No significant difference was found between the four conditions at the ninth stage and the end of the test. Figure 6 shows the mean perceived exertion of the participants at the different stages of the shuttle run test.

Figure 6

The mean perceived exertion of the participants at different levels of the shuttle run test under the four conditions



Prioritization and Self-assessment Results

To prioritize the test conditions, the Friedman test was used. The results in terms of mean ranking showed that the conditions with decreasing frequency ranked first with an average score of 1.83, and the conditions with increasing frequency, standard test, and constant frequency ranked second to fourth with an average score of 2.25, 2.67, and 3.25, respectively. Furthermore, the results of the Friedman test showed that the difference between the ranks of the different test conditions was statistical significant ($\chi^2 = 15.8$, $df = 3$, $p = .001$) and that the conditions with decreasing frequency had a higher priority for the participants than the other conditions.

Finally, the following passages were taken from the participants' responses to the question "How do you perceive performance under the condition ... Compared to the original test condition?

- Decreasing frequency condition: provides relaxation; creates more accurate timing for performance; is very useful in stress management, especially in the first stages of the test; causes less exertion and keeps the test on the last stages;
- Increasing frequency condition: encourages the person to work at higher intensity; motivates at the end of each stage to start the next stage;

– Constant frequency condition: causes confusion in setting the time for each stage; causes mental exertion, makes it difficult to continue the test; makes the test more mentally demanding for the person.

Discussion

This study aimed to investigate the effect of auditory stimulation at different frequencies (increasing, decreasing, or constant) on subjects' performance in the shuttle run test and on perceived exertion. For this purpose, 24 participants performed the shuttle run test under four different conditions: a) standard (as baseline); b) increasing frequency; c) decreasing frequency; and d) constant frequency.

The results showed that, on the one hand, the participants performed better (higher VO2max) in the increasing and decreasing frequency conditions than in the other two conditions, and, on the other hand, the performance in the decreasing frequency condition was better (higher VO2max) than that in the increasing frequency condition. The participants' superior performance in the increasing frequency condition over the standard test was predictable and is consistent with studies that have shown the positive effect of music with high rhythm on endurance performance (Yamashita, 2006; Nakamura et al., 2010; Patania et al., 2020; Crust & Clough, 2006). High-rhythm music has also been shown to increase motivation for activity (Hutchinson et al., 2011; Karageorghis et al., 2013) and physiological arousal (Birnbaum et al., 2009; Priest et al., 2004), which appears to help maintain endurance activity. Priest et al (2004) have shown that the rhythmical elements of music elicit an arousal response in addition to a synchronization effect. A recent study has also shown the association of cardiorespiratory fitness with achievement motivation and a higher level of cardiorespiratory fitness (based on shuttle run test) and VO2max is related with a higher level of motivation (Cadenas-Sanchez et al., 2021). Thus, music may activate certain neural structures to promote rhythmic movements and be responsible for stimulating certain parts of the brain that control arousal. Bernardi et al. (2009) found a relationship between arousal and sound rhythm with rapid breathing. Therefore, the relationship between sound rhythm and exercise intensity may be explained by psychomotor arousal. Although the type of sound modulation used in this study (frequency change) was different from the sound modulation used in other studies (rhythm change), it seems that increasing the sound frequency during the task plays a stimulating and motivating role (the same result was observed in self-reports).

Although music with high rhythm (motivational music) increases work performance by developing motivation for activity and triggering physiological responses, it seems that its positive effects are greater in short-term activities with intensity above the average level. In this type of activity, the increase in heart rate (an indicator of physiological arousal), together with the high rhythm of the music (Karageorghis et al., 2006), favors task performance (Crust, 2004a; Crust & Clough, 2006). Stimulating music, however, does not appear to be as effective in endurance activities as in short-term activities. Birnbaum et al. (2009) showed that fast music decreases cardiovascular efficiency (which is a key factor for success in endurance tasks), consistent with the present study results. Indeed, we observed that participants' performance was better in the decreasing frequency condition than in the other conditions. Several studies have confirmed that the use of relaxing music does not produce good results in short and intense tasks (hand holding power) (Pearce, 1981; Karageorghis et al., 1996). Some studies have found that slow and relaxing music lowers blood pressure (Merakou et al., 2015) and heart rate (Knight & Richard, 2001), reduces cerebral arterial flow (Karageorghis et al., 1996), and generally reduces physiological arousal (Priest & Karageorghis, 2008). Reducing arousal during an endurance exercise appears to require less energy because it results in energy savings. In this study, systolic (rather than diastolic) blood pressure at the end of the test was lower in the decreasing frequency condition than in the other conditions, although there was no difference in blood oxygen levels between the decreasing and increasing frequency conditions. However, blood oxygen levels were higher in both conditions than in the constant frequency conditions and the standard test. Heart rate was also significantly better (lower) under the increasing and decreasing frequency conditions from the second to the seventh stage than under the constant frequency conditions and the standard test. The present study results are consistent with previous studies highlighting that the use of relaxing music during endurance tasks leads to performance enhancement (Hepler & Kapke, 1996; Ghaderi et al., 2009).

Although the participants in this study performed better (higher VO2 max) in both increasing– and decreasing-frequency conditions than in the standard test, they performed better in the decreasing-frequency condition than in the increasing-frequency condition. In addition to lower systolic blood pressure in the decreasing-frequency condition compared with the increasing-frequency condition, heart rate was significantly lower in the decreasing-frequency condition than in the increasing-frequency condition at the sixth and seventh stages of the test. These results suggest that performing with a decreasing frequency sound leads to lower blood pressure and heart rate values, and thus increased performance (higher VO2 max). Some researchers have also found a clear link between heart rate during exercise and music rhythm (Karageorghis et al., 2006; Iwanaga, 1995a). In addition, the results of the perceived exertion variable indicate that in the third and fourth stages of the test, participants' perceived exertion is significantly lower in the decreasing-frequency condition than in the increasing-frequency condition (no difference was found in the other stages). The lower perceived exertion in the decreasing frequency condition may be another reason for the increased performance in this condition compared to the other conditions.

The results of perceived exertion were nearly identical to the performance results. Participants in the increasing and decreasing frequency conditions perceived lower exertion than those in the constant frequency and standard test conditions. This suggests that auditory stimulation positively affects people's performance by reducing perceived exertion. From this point of view, the results of this study are consistent with the studies of Bigliassi et al. (2015) and Yamashita et al. (2006). However, the participants' perceived exertion was lower in the decreasing-frequency condition than in the other conditions. Based on these results, it appears that decreasing-frequency auditory stimulation (which the participants self-assessed as somewhat relaxing) is more beneficial than increasing-frequency auditory stimulation (motivational stimulation) in reducing perceived exertion. Ghaderi et al. (2009) also showed that relaxing music reduced perceived exertion during their experiment and subsequently reduced cortisol (a biochemical stress index) 5 minutes after the test. They concluded that while motivational music can improve performance, soothing music reduces motivation.

Based on the results of the present study, the participants' performance was higher in the increasing– and decreasing-frequency conditions and in the standard test than in the constant-frequency condition. This result indicates that no type of auditory stimulation per se has positive effects on performance, but it is important to consider its characteristics (such as frequency variations). In some studies, the effect of music on performance has been attributed to its ability to create distraction (Grande-Alonso et al., 2020; Elliott et al., 2005). In their study, Grand-Alonso et al. (2020) examined the effect of distraction stimuli on endurance and strength and found that the visual and auditory distraction groups performed significantly higher than the control group. However, in the present study, performance in the constant frequency condition was worse than in the standard test. Therefore, distraction alone cannot explain superior performance in auditory stimulation situations. Another possible explanation for the increased performance in the decreasing-frequency condition vis-a-vis the other conditions is increased activity in certain brain areas. For example, Kornysheva et al. (2010) showed the involvement of premotor areas and the cerebellum when listening to preferred rhythms versus non-preferred rhythms. They found that activity in the premotor ventral cortex increases as a result of the preferred rhythm of the music and that this increase facilitates the process of "tuning in" to an attractive musical rhythm. Another possibility is an increase in neuromuscular efficiency (muscle activation patterns), resulting in decreased metabolic energy (Roerdink, 2008).

One of the notable findings of this study is that while there was a significant difference in heart rate between conditions in the initial and intermediate stages of performance, no such difference was observed in the final stages. This pattern was also observed for the variable of perceived exertion. This result suggests that auditory stimulation is ineffective in the more strenuous stages of the shuttle run test. The results of this study are consistent with those of Razon et al. (2009), who also showed that music reduces perceived exertion in the early stages, whereas the effects are reversed in the latter stages. Hutchinson & Tenenbaum (2007) also showed that people's perceived exertion was not affected by music. They attributed this to the very high intensity of the exercise. Most studies have confirmed a reduced perceived music-induced exertion at slow to moderate intensity (Yamashita et al., 2006). These results are consistent with the parallel processing hypothesis of Rejeski (1985), according to which physiological symptoms (such as heart rate, respiratory rate) predominate over psychological symptoms with increasing training intensity. It appears that at high training intensity, physiological features predominate over processing capacity because of their relative strength, whereas at moderate training intensity, both internal (kinesthetic) and external (music) cues can be processed simultaneously and in parallel (Karageorghis, 2009). Atkinson et al. (2004) examined the effect of music on a 10-km endurance run and concluded that the ergogenic effect was significant during the first 3 km, where perceived exertion was relatively low compared with later stages. Tenenbaum et al. (2004) also suggested in their studie that the high intensity of the running task reduced the effect of the accompanying music. This explanation is consistent with the theoretical predictions of Rejeski (1985), according to which physiological feedback during very high-intensity exercise exceeds the capacity of the nervous system. Despite the consistency of the results of this study with previous findings, the increased performance of the participants (lower heart rate) in the decreasing-frequency condition compared with the increasing-frequency condition at higher stages of the test (levels six and seven) indicates that decreasing frequency may, to some extent, delay the dominance of physiological responses over external stimuli. At these levels (the sixth and seventh levels), there was no difference between the decreasing-frequency and increasing-frequency conditions in terms of perceived exertion, which calls for further investigation.

This study clearly demonstrated that the use of auditory stimulation with varying frequency (increasing and decreasing) resulted in increased performance of the participants (VO2 max) in the shuttle run test compared to the standard test (base line) and the constant-frequency condition. Participants in the increasing– and decreasing-frequency conditions also experienced lower heart rate, lower perceived exertion during the test (in some stages, only in the decreasing frequency), higher blood oxygen levels, and lower systolic blood pressure at the end of the test. It appears that both increasing– and decreasing-frequency play an important role in continuing activity and achieving a higher record, with the former increasing motivation and the latter promoting composure. The difference between increasing and decreasing frequency needs to be investigated in future studies regarding motivation for activity and more accurate indices (e.g., skin electrical conductivity, body temperature, pupil changes, etc.). Future studies should also examine whether similar auditory stimuli can help produce long-term improvements. Participants of this research were an average level in terms of cardiorespiratory endurance (average VO2max). It is not clear whether the results of this study can be replicated for people with good or poor cardiorespiratory endurance levels. Therefore, it is suggested that the intervention of current study be re-implemented for groups with good and poor cardiorespiratory endurance.

References

Atkinson, G., Wilson, D., & Eubank, M. (2004). Effects of music on work-rate distribution during a cycling time trial. *International Journal of Sports Medicine*, *25*, 611−615. http://doi.org/10.1055/s-2004-815715

Bernardi, L., Porta, C., Casucci, G., Balsamo, R., Bernardi, N. F., Fogari, R., & Sleight, P. (2009). Dynamic interactions between musical, cardiovascular, and cerebral rhythms in humans. *Circulation*, *119*, 3171−3180. http://doi.org/10.1161/circulationaha.108.806174

Bigliassi, M., Karageorghis, C. I., Bishop, D. T., Nowicky, A. V., and Wright, M. J. (2018). Cerebral effects of music during isometric exercise: An fMRI study. *International Journal of Psychophysiology*, *133*, 131−139. http://doi.org/10.1016/j.ijpsycho.2018.07.475

Bigliassi, M., León-Domínguez, U., Buzzachera, C. F., Barreto-Silva, V., Altimari, L. R. (2015). How does music aid 5 km of running?. *The Journal of Strength & Conditioning Research*, *29(2)*, 305−314. http://doi.org/10.1519/JSC.0000000000000627

Birnbaum, L., Boone, T., & Huschle, B. (2009). Cardiovascular responses to music tempo during steady-state exercise. *Journal of Exercise Physiology Online*, *12*, 50−57.

Cadenas-Sanchez, C., Lamoneda, J., & Huertas-Delgado, F. J. (2021). Association of Cardiorespiratory Fitness with Achievement Motivation in Physical Education in Adolescents. *International Journal of Environmental Research and Public Health*, *18*(5), 2317. http://doi.org/10.3390/ijerph18052317

Cohen, J. (1992). A power primer. *Psychological bulletin*, *112*(1), 155. http://doi.org/10.1037//0033-2909.112.1.155

Cohen, S. L., Paradis, C., & LeMura, L. M. (2007). The effects of contingent-monetary reinforcement and music on exercise in college students. *Journal of Sport Behavior*, *30*, 146−160.

Crust, L. (2004a). Carry-over effects of music in an isometric muscular endurance task. *Perceptual and Motor Skills*, *98*, 985−991. http://doi.org/10.2466/pms.98.3.985-991

Crust, L. (2008). The perceived importance of components of asynchronous music in circuit training exercise. *Journal of Sports Sciences*, 23, 1−9. http://doi.org/10.1080/02640410802315427

Crust, L., & Clough, P. J. (2006). The influence of rhythm and personality in the endurance response to motivational asynchronous music. *Journal of Sports Sciences*, 24, 187−195. http://doi.org/10.1080/02640410500131514

Davison, B. K., & Walker B. N. (2007). *Sonification sandbox reconstruction: Software standard for auditory graphs* [Paper presentation]. Proceedings of the International Conference on Auditory Display, Montreal, Canada.

Dyer, J. F., Stapleton, P., and Rodger, M. (2015). Sonification as concurrent augmented feedback for motor skill learning and the importance of mapping design. *The Open Psychology Journal*. *8,* 192−202. https://doi.org/10.2174/1874350101508010192

Dyrlund, A. K., & Wininger, S. R. (2008). The effects of music preference and exercise intensity on psychological variables. *Journal of Music Therapy*, *45*, 114−134. http://doi.org/10.1093/jmt/45.2.114

Edworthy, J., & Waring, H. (2006). The effects of music tempo and loudness level on treadmill exercise. *Ergonomics*, *49*, 1597−1610. http://doi.org/10.1080/00140130600899104

Eliakim, M., Meckel, Y., Nemet, D., & Eliakim, A. (2007). The effect of music during warm-up on consecutive anaerobic performance in elite adolescent volleyball players. *International Journal of Sports Medicine, 28*, 321−325. http://doi.org/10.1055/s-2006-924360

Elliott, D., Carr, S., & Orme, D. (2005). The effect of motivational music on sub-maximal exercise. *European Journal of Sport Science*, *5*, 97−106. https://doi.org/10.1080/17461390500171310

Elliott, D., Carr, S., & Savage, D. (2004). Effects of motivational music on work output and affective responses during sub-maximal cycling of a standardized perceived intensity. *Journal of Sport Behavior*, *27*, 134−147.

Ghaderi, M., Rahimi, R., & Ali Azarbayjani, M. (2009). The effect of motivational and relaxation music on aerobic performance, rating perceived exertion and salivary cortisol in athlete meals. *South African Journal for Research in Sport, Physical Education & Recreation*, *31*, 29−38. http://doi.org/10.4314/sajrs.v31i2.47589

Goldberg, D.P., Gater, R., Sartorius, N., Ustun, T.B., Piccinelli, M., Gureje, O., & Rutter, C. (1997). The validity of two versions of the GHQ in the WHO study of mental illness in general health care. *Psychological Medicine*, *27(1)*, 191−7. http://doi.org/10.1017/s0033291796004242

Gomes, R. L., Vanderlei, L. C. M., Garner, D. M., de Marco, R. L., Gonzaga, L. A., & Valenti, V. E. (2018). The effect of musical auditory stimulation on cardiorespiratory variables after aerobic exercise. *Science and Sport*, *33(4)*, 221−227. https://doi.org/10.1016/j.scispo.2018.01.002

Grande-Alonso, M., Ortega-Lopez, F., Vittecoq, R., Mayo-Fernandez, E., Navarro-Fernandez, G., Cuenca-Martinez, F., Touche, R. L., & Paris-Alemany, A. (2020). Auditory and visual distraction improve muscle endurance: a randomized controlled trial. *Somatosensory & Motor Research*, *37(4)*, 334−342. http://doi.org/10.1080/08990220.2020.1834378

Harmon, N.M., & Kravitz, L. (2007). The beat goes on: The effects of music on exercise: A review of the research on the ergogenic and psychophysical impact of music in an exercise program. *IDEA Fitness Journal. 4*, 72−77.

Hepler, C., & Kapke, R. (1996). Effect of music on cardiovascular performance during treadmill walking. *Indian Journal of Physiology and Pharmacology*, *57(4)*, 448−451.

Hutchinson, J. C., Jones, L., Vitti, S. N., Moore, A., Dalton, P. C., & O'Neil, B. J. (2018). The influence of self-selected music on affect-regulated exercise intensity and re– membered pleasure during treadmill running. *Sport, Exercise and Performance Psycho*logy, *7*, 80−92. http://doi.org/10.1037/spy0000115

Hutchinson, J. C., Sherman, T., Davis, L. K., Cawthon, D., Reeder, N. B., & Tenenbaum, G. (2011). The influence of asynchronous motivational music on a supramaximal exercise bout. *International Journal of Sport Psychology*, *42*, 135−148.

Hutchinson, J. C., & Tenenbaum, G. (2007). Attention focus during physical effort: The mediating role of task intensity. *Psycholoy of Sport and Exercise*, *8*, 233−245. http://doi.org/10.1016/j.psychsport.2006.03.006

Iwanaga, I. (1995a). Relationship between heart rate and preference for tempo of music. *Perceptual and Motor Skills*, *81*, 435−440. http://doi.org/10.1177/003151259508100215

Karageorghis, C. I. (2008). The scientific application of music in sport and exercise. In A.M. Lane (Ed.), *Sport and exercise psychology* (pp. 109−137). Hodder Education.

Karageorghis, C. I., Drew, K. M., & Terry, P. C. (1996). Effects of pretest simulative and sedative music on grip strength. *Perceptual and Motor Skills*, *83*, 1347−1352. http://doi.org/10.2466/pms.1996.83.3f.1347

Karageorghis, C. I., Hutchinson, J.C., Jones. L., Farmer, H. L., Ayhan, M. S., Wilson, R. C., Rance, J., Hepworth, C. J., & Bailey, S. G. (2013). Psychological, psychophysical, andergogenic effects of music in swimming. *Psychology of Sport and Exercise*, *14(4)*, 560−568. https://doi.org/10.1016/j.psychsport.2013.01.009

Karageorghis, C. I., Jones, L., & Low, D. C. (2006). Relationship between exercise heart rate and music tempo preference. *Research Quarterly for Exercise and Sport*, *26*, 240−250. http://doi.org/10.1080/02701367.2006.10599357

Karageorghis, C. I., Mouzourides, D., Priest, D. L., Sasso, T., Morrish, D., & Whalley, C. (2009). Psychophysical and ergogenic effects of synchronous music during treadmill walking. *Journal of Sport & Exercise Psychology*, *31*, 18−36. http://doi.org/10.1123/jsep.31.1.18

Karageorghis, C. I., & Priest, D. L. (2012a). Music in the exercise domain: a review and synthesis (Part 1). *International Review of Sport and Exercise Psychology*, *5(1)*, 44−66. http://doi.org/10.1080/1750984X.2011.631026

Karageorghis, C.I., Terry, P.C., & Lane, A.M. (1999). Development and initial validation of an instrument to assess the motivational qualities of music in exercise and sport: The Brunel Music Rating Inventory. *Journal of Sports Sciences*, *17*, 713−724. http://doi.org/10.1080/026404199365579

Kennel, C., Hohmann, T., & Raab, M. (2014). Action perception *via* auditory information: Agent identification and discrimination with complex movement sounds. *Journal of Cognitive Psychology*, *26*, 157−65. https://doi.org/10.1080/20445911.2013.869226

Knight, W. E. J., Richard, N. S. (2001). Relaxing music prevents stress-induced increases in subjective anxiety, systolic bloodpressure, and heart rate in healthy males and females. *Journal of Music Therapy*, *4*, 254−272. http://doi.org/10.1093/jmt/38.4.254

Kornysheva, K., von Cramon, D.Y., Jacobsen, T., & Schubotz, R. I. (2010). Tuning-in to the beat: Aesthetic appreciation of musical rhythms correlates with a premotor activity boost. *Human Brain Mapping*, *31*, 48−64. http://doi.org/10.1002/hbm.20844

Lamoneda, J., Huertas-Delgado, F. J., & Cadenas-Sanchez, C. (2021). Feasibility and concurrent validity of a cardiorespiratory fitness test based on the adaptation of the original 20 m shuttle run: The 20 m shuttle run with music. *Journal of Sports Sciences*, *39*(1), 57−63. https://doi.org/10.1080/02640414.2020.1804785

Leger, L. A., & Lambert, J. (1982). A maximal multistage 20-m Shuttle Run test to predict VO2 max. *European Journal of Applied Physiology and Occupational Physiology*, *49*, 1−12. http://doi.org/10.1007/BF00428958

Leger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 meter shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6(2)*, 93−101. http://doi.org/10.1080/02640418808729800

Merakou, K., Varouxi, G., Barbouni, A., Antoniadou, E., Karageorgos, G., Theodoridis, D., Koutsouri, A., & Kourea-Kremastinou, J. (2015). Blood pressure and heart rate alterations through music in patients undergoing cataract surgeryin Greece. *Ophthalmology and Eye Diseases*, *7*, 7−12. http://doi.org/10.4137/OED.S20960

Nakamura, P. M., Pereira, G., Papini, C. B., Nakamura, F. Y., & Kokubun, E. (2010). Effects of preferred and nonpreferred music on continuous cycling exercise performance. *Perceptual and Motor Skills*, *110*, 257−264. http://doi.org/10.2466/PMS.110.1.257-264

Nazem, F., Sazvar, A., & Frahpour, N. (2002). Validity of Shuttle Run test to estimate VO2 max. *Research in Sport Science*, *1(2)*, 59−76.

Paradisis, G. P., Zacharogiannis, E., Mandila, D., Smirtiotou, A., Argeitaki, P., & Cooke, C. B. (2014). Multi-Stage 20-m shuttle run fitness test, maximal oxygen uptake and velocity at maximal oxygen uptake. *Journal of Human Kinetics*, *41*, 81−87. http://doi.org/10.2478/hukin-2014-0035

Patania, M. V., Padulo, J., Luliano, E., Ardigo, L. P., Cular, D., Miletic, A., & De Giorgio, A. (2020). The psychophysiological effects of different tempo music on endurance versus high-intensity performance. *Frontiers in Psychology*, *11*, 74. https://doi.org/10.3389/fpsyg.2020.00074

Pearce, K. A. (1981). Effects of different types of music on physical strength. *Perceptual and Motor Skills*, *53*, 351−352. https://doi.org/10.2466/pms.1981.53.2.351

Pizzare, A., & Hohmann, T. (2015). Acoustic information during motor control and action perception: A review. *The Open Psychology Journal*, *8*, 183−191. http://doi.org/10.2174/1874350101508010183

Priest, D. L., & Karageorghis, C. I. (2008). A qualitative investigation into the characteristics and effects of music accompanying exercise. *European Physical Education Review*, *14*, 347-366. https://doi.org/10.1177/1356336X08095670

Priest, D. L., Karageorghis, C. I., & Sharp, N. C. C. (2004). The characteristics and effects of motivational music in exercise settings: The possible influence of gender, age, frequency of attendance, and time of attendance. *Journal of Sports Medicine and Physical Fitness*, *44*, 77−86.

Ramezanzade, H., Abdoli, B., Farsi, A. R., & Sanjari, M. A. (2017).The effect of sonification of visual modeling on relative timing: The role in motor learning. *Acta Kinesiologica*, *11*, 17−27.

Razon, S., Basevitch, I., Land, W., Thompson, B., & Tenenbaum, G. (2009). Perception of exertion and attention allocation as a function of visual and auditory conditions. *Psychology of Sport and Exercise*, *10*, 636−643. http://doi.org/10.1016/j.psychsport.2009.03.007

Rejeski, W.J. (1985). Perceived exertion: An active or passive process?. *Journal of Sport Psychology*, *75*, 371−378. https://doi.org/10.1123/jsp.7.4.371

Rendi, M., Szabo, A., & Szabo´, T. (2008). Performance enhancement with music in rowing sprint. *The Sport Psychologist*, *22*, 175−182. https://doi.org/10.1123/tsp.22.2.175

Roerdink, M. (2008). Anchoring: Moving from theory to therapy. IFKB.

Ross, R., Blair, S. N., Arena, R., Church, T. S., Després, J. P., Franklin, B. A., Haskell, W. L., Kaminsky, L. A., Levine, B. D. (2016). Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation*, *134(24)*, e653−e699

Schaffert, N., Janzen, T. B., Mattes, K., & Thaut, M. H. (2019). A review on the relationship between sound and movement in sports and rehabilitation. *Frontiers in Psychology*, *10*, 244. https://doi.org/10.3389/fpsyg.2019.00244

Sors, F., Murgia, M., Santoro, H., & Agostini, T. (2015). Audio-based interventions in sport. *The Open Psychology Journal*, *8*, 212−219. http://doi.org/1874-3501/15

Szabo, A., Small, A., & Leigh, M. (1999). The effects of slow– and fast-rhythm classical music on progressive cycling to voluntary physical volitional exhaustion. *Journal of Sports Medicine and Physical Fitness*, *39*, 220−225.

Tenenbaum, G. (2001). A social-cognitive perspective of perceived exertion and exertion tolerance. In R.N. Singer, H.A. Hausenblas, & C. Janelle (Eds.), *Handbook of sport psychology* (pp. 810−22). Wiley. http://doi.org/10.1002/9781118270011.ch25

Tenenbaum, G., Lidor, R., Lavyan, N., Morrow, K., Tonnel, S., Gershgoren, A., Meis, J., & Johnson, M. (2004). The effect of music type on running perseverance and coping with effort sensations. *Psychology of Sport and Exercise*, *5*, 89−109. https://doi.org/10.1016/S1469-0292(02)00041-9

Valenti, V. E., Guida, H. L., Frizzo, A. C. F., Cardoso, A. C. V., Vanderlei, L. C. M., & de Abreu, L. C. (2012). Auditory stimulation and cardiac autonomic regulation. *Clinics*, *67(8)*, 955−958. http://doi.org/10.6061/clinics/2012(08)16

Vinken, P. M., Kroger, D., Fehse, U., Schmitz, G., Brock, H., & Effenberg, A. O. (2013). Auditory Coding of Human Movement Kinematics. *Multisensory Research*, *26*, 533−552. http://doi.org/10.1163/22134808-00002435

Yamamoto, T., Ohkuwa, T., Itoh, H., Kitoh, M., Terasawa, J., Tsuda, T., & Kitagawa, S., & Sato, Y. (2003). Effects of pre-exercise listening to slow and fast rhythm music on supramaximal cycle performance and selected metabolic variables. *Archives of Physiology and Biochemistry*, *111*, 211−214. http://doi.org/10.1076/apab.111.3.211.23464

Yamashita, S., Iwai, K., Akimoto, T., Sugawara, J., & Kono, I. (2006). Effects of music during exercise on RPE, heart rate and the autonomic nervous system. *Journal of Sports Medicine and Physical Fitness*, *46*, 425−430.

Efekat kontinuirane veštačke nemuzičke slušne stimulacije na kardiorespiratornu izdržljivost i percipirani napor

Hesam Ramezanzade[1], Rasool Abedanzadeh[2], Fabrizio Sors[3],
Mauro Murgia[3], Tiziano Agostini[3], & Akbar Forati[4]

[1]Department of Sport Science, School of Humanities, Damghan University, Iran
[2]Department of Motor Behaviour, Faculty of Sport Science,
Shahid Chamran University of Ahvaz, Iran
[3]Department of Life Science, University of Trieste, Italy
[4]Master of Sport Physiology, Lecturer in Damghan University, Iran

Ova studija je imala za cilj da istraži efekte slušne stimulacije sa različitim varijacijama frekvencije (rastućim, opadajućim i konstantnim) na postignuće, fiziološke parametre i percipirani napor na šatl ran testu (eng. shuttle run test). Dvadeset četiri zdrava studenta sporta učestvovala su u ovoj eksperimentalnoj studiji i izvela šatl ran test pod četiri različita uslova: a) standardni (kao osnovni); b) slušna stimulacija sa rastućom frekvencijom; c) slušna stimulacija sa opadajućom frekvencijom; i d) slušna stimulacija sa stalnom frekvencijom. Rezultati su pokazali da je maksimalna potrošnja kiseonika u uslovima opadajuće frekvencije bila značajno veća nego u bilo kom drugom stanju, a postignuće u uslovima rastuće frekvencije bilo je veće od postignuća u uslovima konstantne frekvencije i standardnim uslovima. Rezultati su takođe pokazali da su u početnoj i srednjoj fazi testa, otkucaji srca i uočeni napor bili niži u uslovima rastuće i opadajuće frekvencije nego u uslovima konstantne frekvencije i standardne situacije. Rezultati ove studije sugerišu da upotreba slušne stimulacije sa smanjenjem i povećanjem frekvencije može poboljšati performanse u zadacima izdržljivosti. Buduće studije bi trebalo da bolje ispitaju različite efekte ove dve vrste stimulacije i istraže da li one dovode do dugoročnih poboljšanja.

Ključne reči: slušna intervencija, zvučna frekvencija, percipirani napor, krvni pritisak, nivo kiseonika u krvi

RECEIVED: 03.05.2022.
REVISION RECEIVED: 13.10.2022.
ACCEPTED: 09.05.2023.