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Psychophysiological responses of music on physical performance: a critical review

Respostas psicofisiológicas da música no desempenho físico: uma revisão crítica

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ABSTRACT: Music can be considered as an ergogenic aid of psychological nature. Currently, athletes of different training status regularly use music as an ergogenic aid to improve performance in different exercise models in their training sessions. In order to understand the effect of music on psychophysiological responses to physical exercise, a music-oriented search was performed on the Pubmed and Web of Science databases to select relevant articles to this theme, thus enabling to present a critical review to explain the three main suggested ergogenic mechanisms of music: 1) Music and perceptive responses during exercise; 2) Influence of music on exercise in different intensities; 3) Action of music on the central nervous system. One of the reasons to listening to music during training sessions is the strong motivational factor during the practice of physical activity. Studies have pointed out benefits such as an improved mood, excitatory control, reduced subjective perception of effort, increased motivation and improved physical performance. In this sense, although the real mechanisms that lead music to be considered as an ergogenic aid to improve performance remain unknown, music seems to have important effects on psychological responses generated in the central nervous system, thus acting as a stimulating agent for the release of excitatory neurotransmitters such as serotonin and endorphin. On the other hand, according to the theory of parallel processing / dissociation, the main mechanism of music to improve physical performance is the increased dissociative thoughts to exercise, thereby reducing perceptual responses processed through the brain that result in increased positive emotional responses to exercise.

Key Words: Physical exercise; Central nervous system; Physical training.

RESUMO: A música pode ser considerada como um recurso ergogênico de natureza psicológica. Atualmente, atletas de diferentes níveis de treinamento utilizam a música como um recurso ergogênico em suas sessões de treinamento em diferentes modelos de exercício para melhorar o desempenho. Para entender o efeito da música nas respostas psicofisiológicas no desempenho físico foi realizada uma busca intencional nas bases de dados 'Pubmed' e 'Web of Science' de artigos relevantes ao tema, desse modo, a presente revisão foi conduzida de maneira crítica para explanar os principais mecanismos sugeridos para a ação ergogênica da música em 3 tópicos: 1) Músicas e respostas perceptivas durante o exercício; 2) Influência da música sobre o exercício em diferentes intensidades; 3) Ação da música sobre o sistema nervoso central. Um dos motivos da utilização da música durante as sessões de treinamento é o forte fator motivacional durante a prática da atividade física. Estudos apontam alguns benefícios como a melhora do humor, controle excitatório, redução da percepção subjetiva de esforço, aumento da motivação e melhora do desempenho físico. Nesse sentido, embora os reais mecanismos que levam a música a ser considerada um recurso ergogênico ainda permanecem desconhecidos, a música parece ter importantes efeitos sobre as respostas psicológicas geradas no sistema nervoso central, atuando como um agente estimulante para a liberação de neurotransmissores excitatórios como a serotonina e endorfina. Por outro lado, de acordo com a teoria do processamento paralelo/dissociação, o principal mecanismo da música sobre o desempenho físico é o aumento da dissociação durante o exercício, reduzindo as respostas perceptivas processadas no cérebro, com a resultante do aumento de respostas emocionais positivas ao longo da tarefa.

Palavras-chave: Exercício físico; Sistema nervoso central; Treinamento físico.

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Introduction

Ergogenic resources are traditionally classified as a mechanical, psychological, nutritional, chemical or pharmacological aid which have the objective to improve sporting exercise performance[1,2]. Among the different types of ergogenic resources, one may highlight that music is an important ergogenic aid of psychological nature[1].

Athletes with different levels of experience use to listen to music to increase motivation during training sessions[3]. Among the beneficial effects of listening to music are the improvement of mood[4], excitatory control[5,6] and improved physical performance[7], as music seems to have important effects on psychological responses generated in the central nervous system (CNS)[8]. A possible mechanism of action of music during exercise is related to increased release of excitatory neurotransmitters (e.g. serotonin and endorphin), that possibly attenuate the feelings of pain and exertion during exercise, thus resulting in better physical performance[9,10].

Considering the applicability of music during exercise, recent studies have investigated the response of different types of music throughout the exercise[10–12]. The critical knowledge regarding this theme highlights the theory of Rejeski[13] as a possible mechanism of action to improve performance when listening to music during exercise. The theory of parallel processing/dissociation proposed by Rejeski proposes that dissociation (i.e. factors external to exercise) would act as a distraction on perceptual responses to exercise (e.g., pain and effort perceived). Therefore, according to this interpretation, music would increase dissociation during exercise, since feedback from the afferent nerves would take longer to be interpreted by the CNS, thus reducing perceptual responses throughout the exercise.

Another hypothesis has been raised by Yamamoto *et al.*[11], as these authors have demonstrated that the rhythm of the music may alter the release of epinephrine before submaximal intensity exercises. In this regard, it has been reported that listening to slow music in pre-exercise instants reduces plasma epinephrine levels, while listening to music at a faster rate increases blood neurotransmitter concentration. However, in that study, music did not alter either exercise performance or physiological variables measured during exercise.

Assuming that music acts the CNS function, recent studies have used electroencephalography (EEG) to investigate the impact of music on cortical activation[5,14,15]. According to the mentioned studies, listening to music may increase activation of beta waves and reduce activation of theta waves in cerebral regions such as prefrontal cortex (PFC) and anterior cingulate cortex. Accordingly, such a cortical alteration would suggest a "sedative effect" which would decrease the interpretation of afferent signals processed by the PFC areas.

Since performance is integration of different factors (i.e. physical or psychological state) during exercise[16] and recent research showed that PFC activation has been associated with exercise intensity and tolerance[17]. Seen these factors, in this critical review we showed that listen music can provoke a cortical modulation, changes in perceptual responses during exercise and their influence in exercise performance. Therefore, considering the above mentioned mechanisms of action of music on physical performance, the purpose of this review is to critically discuss these different mechanisms as the following: 1) Music and perceptual responses during exercise; 2) Influence of music on exercise at different intensities; 3) Action of music on the central nervous system.

Methodology

To accomplish this proposal, a music-oriented search was carried out on the "Pubmed" and "Web of Science" databases, in order to select relevant articles relevant to the subject. In this regard, seminal and recent studies relating exercise and music were previously selected to analysis. The search was performed by using the following truncated terms: [music AND exercise AND endurance performance], [music AND cortical activation], [music AND perceptual responses OR psychological responses]. In total, 650 studies published from 1995 to 2017 were previously found, and 31 researches were intentionally selected. After initial search, studies were double-checked by the researchers in order

to group them according to proposed mechanisms of action. Therefore, the discussion presented below reflects the critical review of such mechanisms of music during exercise.

Music and perceptual responses during exercise

A recent review[10] suggested different aspects through which music may influence perceptual responses to exercise: rhythm/response and musicality (internal), cultural impact, and associated factors (external). Such factors would be related to changes in motivation during exercise, improving perceptive responses such as excitatory control, exercise sensation and mood. These benefits may increase adherence to exercise and attenuate the monotony of the training routine, as well as potentially increase physical performance[18,19].

The rhythm / response would be related to the speed and the beats per minute of the music being played, so that this factor could dictate the movement and cadence of the task[20]. Hevner's theory[20] is still valid in saying the effect of stimulating music, that is faster and prominent beats are expected to increase excitation. In this regard, cultural traces are a factor related to the influence of a particular type of music on a particular group of individuals, thus explaining the tendency to sympathize more with a particular musical type[21]. The associated factors are translated into feelings that are remembered when listening to a particular type of music, for example, the music of a given move about some motivational aspects can induce beneficial responses to the exercise[22]. These factors alone or in combination may indicate that the type of music can influence exercise. For example, a study by Nakamura *et al.*[23] observed greater distance traveled in a constant-load exercise (in critical power) when the subjects listened to a music of their own preference, when compared to sessions either without music or non-preferred music.

Music seems to exert physiological changes during exercise that can modulate perceptual responses such as the sensation of exertion[8,10,11,24]. Arazi *et al.*[25] evaluated well-trained subjects during warm-up and resistance circuit sessions in conditions with and without music and the results indicated a lower rating of perceived exertion (RPE) and heart rate (HR) in the music condition. Szmedra and Bacharach[24] tested the effects of the music during 15 minutes of treadmill at 70% $VO2_{MAX}$, the results showed a lower level of HR, RPE, lactate, epinephrine and blood pressure in the music condition. Both studies supported the notion that listening to music during exercise may reduce the levels of circulating epinephrine, thus consequently modulating the sympathetic nervous system tonus and influencing the cardiac output and blood delivery through peripheral tissues. As a result, there was a greater muscle efficiency and lowered RPE[10,24,25].

Considering the action of the music on motivation, some studies were designed to test its applicability in exercise practice. Hutchinson *et al.*[26] submitted active subjects to a Wingate test with and without music. The results indicated a higher peak power, mean power, positive affect and motivation in the music condition, although the perception of the effort was the same for both situations. Edworthy and Waring[27] tested the performance in 10 minutes of treadmill with self-selected load, listening to music of different speeds and volume. The results showed that for conditions with high-velocity music and high volume the subjects run in a greater intensity while reporting higher affect and motivation response than conditions with other musics or without music. In addition, Stork *et al.*[28] submitted subjects to sprint interval exercises and found that individuals reported more enjoyment sensation when exercising listening to music. Both studies supported the hypothesis that music is a motivational factor that increases exercise adherence, based on Rejeski's dissociative theory[13]. Therefore, preferred, faster, high-volume music tends to reduce afferent signals from muscles during exercise, thus increasing pleasure/adherence sensations to exercise. In fact, listen to music can activate pleasant memories, thereby inducing increased motivation and sensation of pleasure during exercise.

Influence of music on exercise at different intensities

Recently, studies have demonstrated the influence of music on different intensities of exercise, based on the rhythm, musical preference and beats per minute of each musical track[5,7,15,29]. However, the mechanisms of action of music in different intensities are not the same[8,10]. Studies associating music and performance improvement are based on Rajeski's theory of parallel processing/disassociation[13], in which physiological and psychological afferent inputs are processed preconsciously and in parallel, so that overall emotional perception would be the sum of physiological and psychological inputs from the body during exercise.

High-intensity exercises (HIT) may be preferred for short-term sessions, however, this type of high-intensity exercise induce high levels of effort and metabolic accumulation[30], and these features decrease the exercise adherence to the HIT practice. Stork *et al.*[28] suggested that the use of music during high-intensity exercise sessions may alleviate unpleasant sensations to this model. These authors verified this hypothesis by subjecting untrained subjects to four sprints of 30 seconds in the cycle ergometer, and the results indicated a higher mean power, compliance and motivation when participants listened to music rather than when they listened no music. Barwood *et al.*[31] tested the hypothesis of music as a high-intensity exercise motivator, so that participants had 15 minutes to run as far as possible in conditions with music and without music. The results showed the same perception of effort between conditions, despite the increased distance covered and higher blood lactate concentration in music condition. Based on Rejeski's theory[13], the interpretation of the effect of music on high-intensity exercises is associated with pronounced physiological responses, as music would compete with the interpretation of afferent signals from peripheral organs and muscles, thus dissociating the subject's sensation from body signals and reducing the perception of effort and pain.

The action of music for lower intensity efforts also seems to be related to the RPE responses, although this does not seem to induce to an improved exercise performance[32]. For example, in a seminal study by Potteiger[33], it was shown that the music reduced the perception of effort during a 20-minute treadmill exercise at 70% $VO2_{peak}$. Accordingly, a recent study by Lopes-Silva *et al.*[34] found similar results. In this study, when 14 participants performed an exercise at 60% W_{MAX} to exhaustion while listening to music, there was a reduction in the perception of effort from the very beginning of the exercise when compared to the control condition, despite the distance covered has been the same. Both studies supported the Rejeski's theory[13], as music at lower intensities would act as a distraction, thus reducing the perception of effort.

Some studies have tested the applicability of music in laboratory tasks that simulate competitions such as time-trial (TT) tests. In a seminal study by Atkinson[6] it was shown that the music improved the performance in a TT10km, the results of this study found a greater power output in the first 3km when participants listened to music, although the lack of difference in RPE between experimental conditions. Lima-Silva and colleagues[7] observed a higher velocity in the first 1.5km of a TT5km, although the performance has been the same and RPE has increased linearly in both conditions. Both studies were performed with recreational athletes, who are apparently more susceptible to motivational influence of music. Hagen *et al.*[35] tested the effect of music on well-trained athletes (± 54.8 $VO2_{MAX}$) in a TT10km and did not find physiological and psychological differences in both conditions. The current literature supports the notion that there is a relationship between level of training and sustained attention throughout the task, so that subjects with more training experience would show no influence of music during exercise, since they remain more focused on the physical task[8,10].

Action of music on the central nervous system

Considering the influence that music exerts on perceptual and physical performance responses during exercise, one may argue that the music action is directly linked to the central nervous system[10,18]. In addition to the modulation of

neurotransmitters[24,25] and dissociative effect[13], music is capable of modulating pre, post and exercise cortical activity[36] that is processed in cerebral regions such as anterior cingulate cortex and amygdala[4], as well as PFC[14].

The motivational effect of music may attenuate afferent responses to physical exertion, despite occurring for a short period of time as the symptoms related to fatigue (ie, feeling of exertion and pain) overcome this "sedative effect" during exercise[5,13]. Assuming these afferent responses are interpreted by the PFC[37], a possible intervention could be beneficial. It has been demonstrated by Bigliassi and colleagues[5], who submitted 19 subjects to two sessions of maximum voluntary contraction in music and control condition with EEG measures during exercise. The results suggested a greater activation of beta waves and lower activation of theta waves in frontal, central and parental cortical regions, in addition to the improvement in performance and affective responses. The authors suggested that the best performance was due to a lower attention paid to the exercise sensations in the presence of music, due to the altered brain activation in these conditions. Still Bagliassi *et al.*[15] in another study tested the efficiency of different types of music in 5km run. The experimental situations were: 1) pre-test motivational music, 2) fast music during the test, 3) slow music during the test, 4) quiet music post-test and control (silence). The results showed a greater activation in the three regions of PFC (median, right and left dorsolateral), generating positive emotional consequences such as reduction of RPE and increase of positive affect, in addition to the increased performance in the initial 800m (conditions 2 and 3). In addition to these findings, the authors pointed out that the HR variability was improved in post-exercise recovery for condition 4. Somehow, this may evidence that changes in PFC cortical activation when listening to music may be associated to an improved performance, being related to the lower attention to afferent responses signaled to the brain.

Recently, studies indicated that mental fatigue, which is reached or induced after a great mental demand for sustained attention[38], can generate a loss of performance without alteration in physiological responses. In this sense, mental fatigue would alter PFC activation, increasing the perception of effort during exercise for a same exercise intensity[39]. Guo and colleagues[40] submitted 36 young participants to a mental fatigue protocol, thereafter they performed the Go/No Go test to verify the number of hits and inhibitory control, under conditions with and without music. Through the EEG analysis, the results indicated a greater cortical activation in cortical regions involved in cognitive processing, less sensation of mental fatigue and less time of reaction when mentally fatigued participants listened to music, rather than when they listened to no music.

Conclusions

Due to their characteristics of rhythm, musicality, cultural impact, and associated factors, music can influence psychological aspects such as affect and motivation so that this may alter perceptual responses during exercise, decrease RPE and increase exercise adherence. Regarding the exercise intensity, music may improve performance in high-intensity exercise modes. In contrast, music may increase pleasure sensation during lower intensity exercises. The increased dissociation thoughts to exercise when listening to music reduces the impact of afferent responses from organs and muscles to cerebral regions apparently related to exercise modulation.

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