Music: a psychophysiological aid to physical exercise and sport

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Summary

The use of music has been identified as a potential ergogenic aid that helps to improve performance in exercise. Music has been classified as a psychological ergogenic aid and has attracted interest mainly for its effects found in studies with a focus on performance during exercise, pre-task and post-task. In this context, the objective of this study was to review the literature about the main effects of music on performance and their possible mechanisms, covering new perspectives about the theme. The method consisted of search, selection and stratification of the original articles of major databases (Medline, Sport Discuss, Scopus, Web of Scienceand Scielo) using the descriptors music, exercise, performance and fatigue. We considered all models and types of exercise and music. These articles suggest that the use of music as an ergogenic aid could be efficient to improve performance; decrease rate perceived of exertion and is capable to bring better feelings to exercise, according to time of application, physical fitness of subjects, type of exercise and musical components,respecting some recommendations and orientations to insertion. The main proposed mechanisms of action for the music ergogenic effects are based on behavioral hypothesis and are still being discussed; also there are not enough evidences to discard any of them, demonstrating the need for future studies in attempt to clarify such effects in central nervous system. To sum it all up, we propose some orientations of use in submaximal and maximal exercise, allowing coaches and athletes apply this technique in their methods of training.

Palabras clave:
Sensory aids.
Sports.
Motor activity.

Música: un recurso psicofisiológico para el ejercicio físico y deporte

Resumen

El uso de la música se ha identificado como un auxiliar ergogénico potencial que ayuda a mejorar el rendimiento en el ejercicio. La música ha sido clasificada como una ayuda ergogénica psicológica y ha despertado el interés principalmente por sus efectos encontrados en estudios con un enfoque en el rendimiento durante, antes y después del ejercicio, En este contexto, el objetivo de este estudio fue revisar la literatura sobre los principales efectos de la música sobre el rendimiento y sus posibles mecanismos, cubriendo nuevas perspectivas sobre el tema. El método consistió en la búsqueda, selección y estratificación de los artículos originales de grandes bases de datos (Medline, Sport Discuss, Scopus, Web of Science and Scielo) que utilizan los descriptores: música, ejercicio, rendimiento y fatiga. Se consideraron todos los modelos y tipos de ejercicio y música. Estos artículos indican que el uso de la música como un auxiliar ergogénico podría ser eficaz para mejorar el rendimiento; disminuir la tasa de percepción de esfuerzo y es capaz de ofrecer mejores sensaciones con el ejercicio, de acuerdo con el tiempo de aplicación, la condición física de los sujetos, el tipo de ejercicio y componentes musicales, respetando algunas recomendaciones y orientaciones para la inserción. Los principales mecanismos de acción propuestos por los efectos ergogénicos de la música se basan en la hipótesis de comportamiento y se siguen discutiendo; tampoco hay evidencias suficientes para descartar cualquiera de ellos, lo que demuestra la necesidad de estudios futurosen un intento por aclarar tales efectos en el sistema nervioso central.Para resumir todo esto, proponemos algunas orientaciones de uso en el ejercicio submáximo y máximo, permitiendo que los entrenadores y atletas aplicar esta técnica en sus métodos de entrenamiento.

Key words:
Ayudas sensoriales.
Deportes.
Actividad motora.

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Introduction

The evolution of science in sports training and the pursuit of the human performance limits, particularly over the last decade, have attracted numerous researchers to investigate the ergogenic potential of different resources that can contribute to the physical performance improvementof athletes in different sports[1,2]. The term "ergogenic" is derived from the Greek words "ergon" and "genes" which means "work" and "production" or "creation", respectively[3]. Ergogenic resources are-traditionally classified into five categories: mechanical, psychological, physiological, pharmacological and nutritional[4,5], ranging from safe and legal procedures (e.g., intake of carbohydrates or caffeine) to illegal and potentially unsafe means, such as the use of anabolic steroids and blood infusion[5,6].

Among these resources, the music has been classified as an psychological ergogenic aid[3] and has attracted interest mainly for its effects found in studies with a focus on performance during exercise[7-10], pre-task[11] and post-task[12]. Karageorghis and Terry[13] and more recently Karageorghis and Priest[14] present three possible hypotheses about how music can influence motor behavior. The first hypothesis is that the song "uses" part of the attention, causing the individual to respond less to the signs of fatigue during exercise. This hypothesis is based on a model of parallel information processing[15], according to which information from different afferent pathways are processed simultaneously[16,17]. The second hypothesis advocates a predisposition for synchronizing the movements with the rhythmic component of music[18-19], i.e., the beats per minute (BPM) of the music would influence the pace of the movements of the exercise (e.g. walking or cycling)[20]. The third hypothesis is based on the assumption that music can evoke extra-musical associations, which may be conducive to physical activity (Increasing arousal or accelerating relaxation)[21,22]. The hypothesis is based on the influence of personal experience, often through popular culture (e.g. movies, TV etc..) so that if a song was previously associated with physical activity, it will act as a conditioned stimulus eliciting certain conditioned psychophysical responses[17,23]. Each of these hypotheses will be treated in a practical perspective below.

Along with the study of the mechanisms, a series of experimental approaches are trying to expand the range of expertise in the area, emphasizing the aspects of music that can change the magnitude of the ergogenic effect, such as the type of song and music tempo. The influence of other factors besides the characteristics of music, such as the types of tests used and the level of individual physical fitness have also been studied. All these studies are directed at the consistent test of three possiblehypotheses, previously cited, sustaining the use of music as an ergogenic aid[24-27].

As mentioned above, there is great interest in study music and its potentialergogenic effect. However, the literature lacks a synthesis with the main findings to direct future experiments, reviewing what has been tried and what needs to be addressed. Thus it would be of great importance to organize and identify the main papers that aimed to test the effect of music on physical and emotional performance. Thus, the aim of this literature review was to stratify and organize the evidences on the ergogenic effect of music on exercise performance and address the main hypotheses that explain their effects in a practical perspective to use in physical activities and sports domain.

Methods

The method of this study was the search, selection and stratification of data in the literature of major international (MEDLINE, SPORT DISCUSS, SCOPUS, Web of Science) and national databases (Brazil) (SCIELO). The search was guided by the descriptors music/música, exercise/exercício, performance/desempenho and fatigue/fadiga, in English and Portuguese, respectively, in all different possible combinations. These words were chosen because we believe that are sentences capable to answer our needs to show the effects of music during physical exercise in performance and fatigue parameters.

Inclusion criteria

Only original articles obtained in full, with humans as subjects were considered for analysis. In addition, review articles, non-exercise conditions and pathological populations were excluded, and all exercise protocols found were included in the review. Regardless of the type of music (type, tempo, pace and preference), all studies were included if music was present to the exercise condition.

Mechanisms and prospects of action of music

Hypothesis of parallel processing

The hypothesis of parallel processing states that information processing on internal or external sources, regardless of exercise or lack of it, occurs in parallel[15]. This means that basically a series of stimuli is received, and they are processed by the cerebral cortex in a pre-conscious manner, in order to increase the focus of interpretation to what at any given time is more important[28]. The main afferent information reaches the conscious focus, which can some how be modulated by the subject, since the subject is able to prioritize what he thinks or unconsciously what is the most important at that moment. Many of these responses are observed in the mechanisms responsible for the rate of perceived exertion[15], social affective state, behavior[22] and nonverbal signals[13] . From this perspective, some authors tried to observe the possible responses generated by the interaction between exercise and music as a sign of dissociation[29-31]. A great future perspective to this topic is the volume of sound and a new music capable to distract the listener, mainly in the begin of the exercise, making the rate of perceived exertion smaller than without musicat the moment and postpone the fatigue/time to exhaustion[32].

Synchronization hypothesis

Synchronization mechanisms show the ability of the brain to unconsciously synchronize the movements of specific cyclic exercises, for example, the pace of running in the race and pedaling in cycling, with the beats per minute of music[19]. There is evidence that consolidates

this hypothesis[33]. However, some researchers have shown interest and thereby are investigating the ability to synchronize music with exercise performance or affective responses to exercise[34,35]. This hypothesis has being considered currently the most important in a hierarchical model, proposing the rhythmic response as responsible for making us going further[14]. The new prospect to this hypothesis references on pacing strategy and possibility of keeping the load along the task, that is, when we ran/cycled/swam we adopted a pacing strategy consciously and unconsciously that make us able to finish the task in the minor time, for example. In that way, the synchronous music can act keeping the cadency along the task and possibly decreasing the fall of performance in some moments of the activity[36,37].

To synchronize the beat of music with cadency of cyclic movements, some devices were purposed, the moBeat was designed to make heart rate match music tempo (heart rate is a physiologic indicator of physical performance)[38], also to use this component on ecological validity, the BODiBEAT(Yamaha®) was purposed too, to make this match with movement pattern and tempo.

Motivational/Mood hypothesis

This hypothesisis based on behavioral aspects, primarily in the affective and socio-cultural mechanisms. The mood hypothesis indicates a change in the central nervous system arousal occurred during a particular song, since the memory can associate that particular song or rhythm with a specific situation[22]. This can often promote feelings of relaxation, anger, longing, happiness, among others,which in the case of exercise can lead to changes in performance[16,17,25]. Regarding athletes, the songs are used to decrease pre-competitive anxiety, or to increase the motivation and desire to win[39]. From this perspective, studies that have focused on this theory test the use of music as an ergogenic specifically in different conditions of changes in affective state and mood during exercise[20,40,41]. This hypothesis has two different aspects that must be contemplated, a direct and indirect way. The direct way makes reference to act of components of music in the subject (melody, harmony, tune and timbre), but the indirect way shows a great perspective to future studies, a time that self select music can bring memories and remembers capable to increase our vigor and desire to task, then indentify inspirational songs with intrinsic properties to everyone is a good way to recommend the choice.

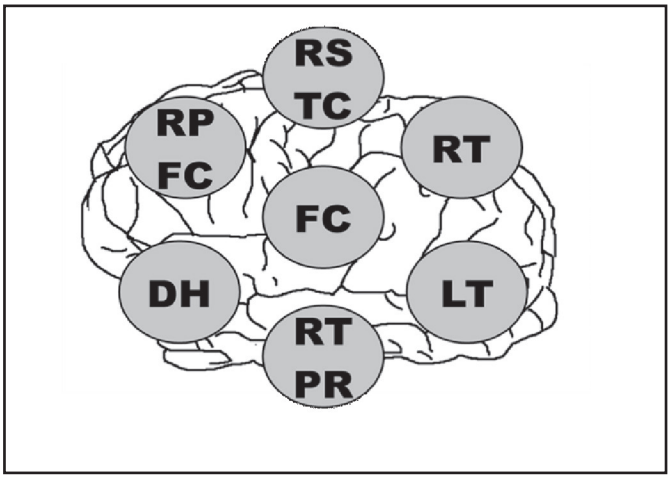
Music, its components and activation

The music has been largely studied in many contexts, since its use as a therapy for diseases (hypertension, autism and neurological rehabilitation)[42-44], to the intervention in stress cases, improvement of mood and memory[45] and in physical exercises and sports as a way to enhance the performance or just turning it into a nicer activity to do[7,8]. The music is characterized as a harmonious form of sound's that works in with constant time spaces or sometimes inconstant, translated in a melodic form. It is sometimes called art, containing specific components that make the music able to cross the barriers of thought and subconscious, acting in our emotion and memory. Their components are individual parts of a whole, able to be analyzed and modulated by the ones who composes or experiment it. They are: melody, translated as a complex successive organization of sounds and silence, normally transcribed in a linear form with its own characteristics; The harmony, been a set of simultaneous emissions of related sounds, with different sound frequency, known as the result of different notes overlaid; rhythm, called as the elapsed art in time domain, between regular intervals in a musical verse; tone, known as the sound height inside a reference scale and the timbre, bring sense to the sound quality, been the point that allows to distinguish sounds from different sources.

Each musical component tends to be interpreted in different brain places as shown in Figure 1. A specialized neural system located in the right superior temporal cortex (RSTC) is responsible for the melody analyzes, such as a neural net in the right pre-frontal cortex (RPFC) interprets the tone comparisons, furthermore, this component seems to beanalyzed in the right temple too (RT) and in the frontal cortex (FC). The dominant hemisphere (DH) that in most people is the left side is related with the rhythm analyzes, brakes and also the tone, and everything indicates that the left temple (LT) performs only the perception of the brakes, while the right temporoparietal region (RTPR) interprets the emotions and hedonistic answers to the music and also percept the music timbre[46] (Figure 1).

However, when cerebral specific regions from movement control are analyzed, we can see that few of them maintain relationship or similarity, been especially evidenced, the pre-motor cortex, the pre-supplementary motor area, the primary motor cortex and the inferior part of the posterior parietal cortex, apparently. What must be clear is that despite different areas of comprehension, analyze, interpretation and command, the procedures resources are the same capable to act in a parallel form, been dependent of the activation level[28], that induct the necessity of prioritize different intensities of intervention with psychological patterns[47]. In this way, the music perception happens in three stages, since the initial moment as the pure perception of the hearing stimulus alone, for the analysis of the music structure subdivi-

Figure 1. Cerebral regions specialized in perceptual analysis of the music components.

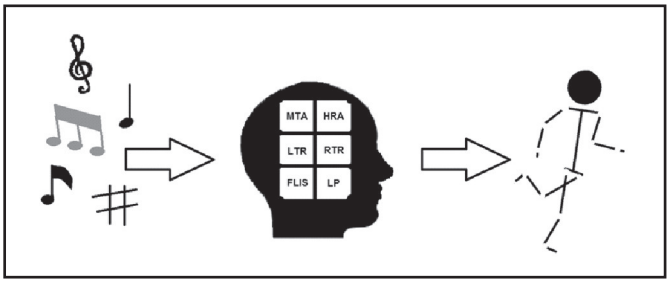


RSTC: right superior temple cortex; RPFC: right pre-frontal cortex; RT: right temple; FC: frontal cortex; DH: dominant hemisphere; LT: left temple; RTPR: right temporoparietal region.

ded in its basics components or complex, until the moment of sound identification that is been played, occurring the knowledge of its source and comparison[48].

Mainly the medium temporal area (MTA) is responsible for the emotions caused by the music and also, the hippocampus right area (HRA), left temporal region (LTR), right temporal region (RTR), frontal left inferior spin (FLIS), left precuneus (LP), that are regions indentified by the memory[46].

Figure 2. Illustrative representation about how music can act on cerebral regions related to memory and emotions, allowing an increase in the performance.



MTA: medium temporal area; HRA: hippocampus right area; LTR: left temporal region; RTR: right temporal region; FLIS: frontal left inferior spin; LP: left precuneus.

Effects of music on physical performance

The main research models of the interplay between music and exercise use primarily submaximal[26,29,49] and maximal intensities[25,33,50]. During the searching process, few studies have targeted closed-loop exercise, such as Time Trial[34,35] and one study has used isometric exercise17. The populations studied are predominantly active, healthy individuals, with some degree of training, but non-athletes. Among the articles reviewed, mosthave found some kind of positive effect associated with the use of music in parallel to exercise, regardless of the type of exercise.The significant differences found regarding the ergogenic effect of music compared to the control condition are related to increased time to exhaustion[50,51], decreased rate of perceived exertion or decrease of the total test time[29,34].

Submaximal exercise

The ergogenic effect of music has been reported in submaximal exercise, with a positive effect being observed in about 90% of the studies reviewed (Table 1), indicating that at intensities below the anaerobic threshold the dissociation theory seems to have more influence. In the study by Waterhouse *et al*.[29], the authors investigated different types of music selectedaccording to the musical preferences of the volunteer. The presence of fast music during submaximal exercise of 25 minutes provided a significant positive effect of interaction between the music track and time of the program, allowing changes of 2.1%, 3.5% and 0.7% in the variables distance, power and cadence, respectively. In contrast, in the same study, there was a decrease in the slow music condition of 3.8%, 9.8% and 5.9% in the same variables, indicating the importance of musical components such as tempo and duration.

In the study by Edworthy and Warind[31], various types of musical rhythm and volume were tested during several sessions of ten minutes of walking and running, configured so that the volunteers feelcomfortable. Measures of perceived exertion, heart rate, speed, and affective state were obtained. The data demonstrated that both the musical rhythm and volume influence the performance parameters, heart rate and subjective variables, with heart rate being primarily influenced by the rhythm rather than the volume, with the presence of increased systole with the use of faster pace music. Additionally, it was found that increasing the volume only provides an effect if associated with fast pace.

Szmedra and Bacharach[52] have identified positive outcomes from the use of music as an ergogenic aid for submaximal exercise on physiological and psychological variables. The protocol consisted of 15 minutes of running at 70% VO_{2max} in the control and classical music conditions. Among the study's findings, we highlight a lower heart rate, lower systolic blood pressure, lower blood lactate concentration, lower rate of pressure product ([heart rate] * [systolic blood pressure]/100) and lower perceived exertionin the music condition compared to the control condition ($P < 0.05$), and smaller, but not significant, amount of circulating norepinephrine ($P = 0.07$). Karageorghis *et al*.[16], investigated the influence of music tempo during submaximal exercise, with the purpose of verifying the ergogenic effect on motivation.They used a protocol of 26 minutes at 70% of the reserve heart rate. The results showed that an average tempo (115 - 120 beats per minute) with 75 decibels was considered by the students more interesting for performing exercise and able to improve their current motivational state.

In summary, the ergogenic effect of music during submaximal exercise is consistent in the available literature. As exemplified in the above-mentioned articles, the main influences are rhythm and familiarity and musical taste, demonstrating an effect on physiological and subjective variables. The volume provides an effect only if associated with a high pace. To be considered ergogenic effect on the Tables 1, 2 and 3, anystatistic significant change in any variable studied was used.

Maximal exercise

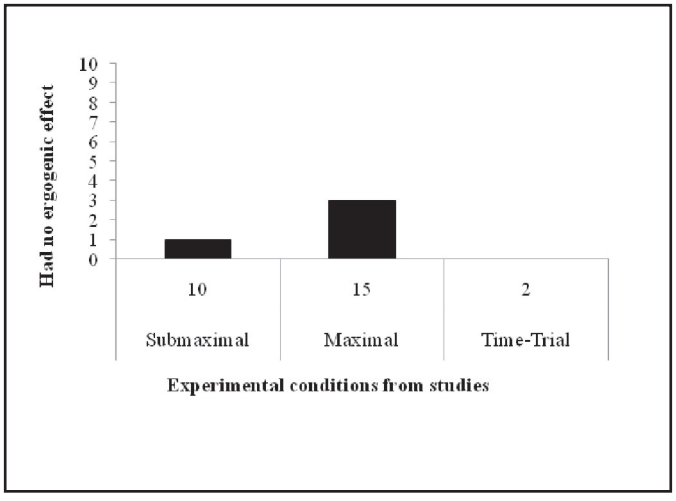
There is a medium rate of positive effects in the context of maximal exercise, around 80% of the studies showed such an effect. However, this index can be viewed asa considerable achievement. Within this perspective, the main findings within this context were on some performance variables (Table 2), for example, time to exhaustion. Karageorghis, *et al*.[50], evaluating active individuals in a race at 75% heart rate reserve until exhaustion in the conditions motivational music, non-motivational music and control, noted that the results showed that the motivational music condition was able to increase the total test time compared to the other conditions ($P < 0.05$), besides having lower perceived exertion and better affective state in the two minutes before starting the test.

In the study by Elliott *et al*.[23], following a rigorous methodological process of music selection, going through assessments of language, socio-cultural and motivational qualities of music, the subjects performed a 12-minute test on a cycle ergometer at three different condi-

tions (motivational condition, non-motivational condition and control condition). The distance covered was of 7.11 km for the motivational music condition, 6.87 km for the non-motivational music condition and 6.41 km for the control condition. There was a statistically significant difference between the motivational music condition and the control condition (P<0.05). Mohammadzadeh, *et al.*[25], in performing the Bruce test in subjects with different levels of fitness, always subjected to the same music, found significant differences (P<0.05) in perceived exertion in untrained volunteers between the music (3.82) and no music (4.79) conditions. No significant difference was found when trained subjects were compared in the music (3.98) and no music conditions (3.64) (P> 0.05). In addition, time to exhaustion was higher in the condition with music for both groups but without statistical significance.

By comparing five conditions related to musical tempo during maximal incremental cycle ergometer (fast rhythm (FR), slow rhythm (SR), fast to slow rhythm (FSR), slow to fast rhythm (SFR) and control (C)), Szabo, *et al.*[27] observed that in the SFR condition the workload was statistically higher than in all other conditions (P> 0.05). However, there were no differences in heart rate and maximum heart rate reserve. Additionally, the efficiency (power/heart rate reserve) was higher than for the same condition (SFR) in comparison to others. The results imply that when faced with the rising difficulty of the test, fast music can act in a positive way to exercise performance, allowing the participant to achieve a greater workload. According to the aforementioned studies and data from Table 2, there is an indication that the ergogenic effect of music during maximal exercise is related to the longer duration models, and this effect seems to have the motivational factors as its primary mechanism. Studies with the presence of music during short-term models (e.g.,Wingatetest) are scarce and have not shown significant differences. The Figure 3 shows an Illustrative description of different experimental conditions from studies and the score of neutral outcomes, but time-trial conditions can be called as maximal exercise, then the results obtained can be changed.

Figure 3. Illustrative description of different experimental conditions from studies and the score of neutral outcomes using music in exercise to each classification.



Time Trial

A couple of studies that investigated the music and Time Trial interaction were found[34,35]. By analyzing the results, both studies showed some type of benefit arising from the use of music (Table 3). In the study by Lim *et al.*[35], during a10-km time trial, the musical intervention occurred at different times, being in one condition between the start of the test and the fifth kilometer (M1) and in another condition from the fifth to the tenth kilometer (M2). The main difference found was in the speedduring thetime trial. When the subjects knew that music would be introduced in the final five kilometers, they started the trial with a higher speed (+ 1 to 1.25 $km.h^{-1}$), and the interaction between condition and distance showed statistically significant differences in relation to other conditions (P<0.05). The study by Atkinson *et al.*[34] also observed effects on speed, which was statistically superior in the music condition compared to the condition without music (P<0.05), consequently resulting in a decrease in the total time required to finish the test. However, heart rate, perceived exertion and the power generated during the time trial did not differ significantly.

Both studies showed a higher average speed, with no differences in perceived exertion and other physiological variables, demonstrating a positive effect on the volunteers'pacingstrategy.

Other important factors

Population studied

Overall, we found in this review that the population was composed of individuals who, even in different classifications, were considered as physically active, trained and healthy individuals. We observed a trend in the claims of researchers who showed the greatest expression in terms of positive effects in populations with low or non-trained physical fitness[25,49], since in situations of exercise in the moderate to severe intensity domain, mainly done by volunteers with greater physical fitness, the theory of parallel processing does not seem to account for large effects[17,53]. The stimuli generated by the music at this intensities does not seem to be interpreted with the same importance, and thus have less importance than, for example, their perception of effort, their sense of pain or the will to finish the race as best as possible[49]. So, a fewer physical fitness appear as positive aspect capable to increase the ergogenic effect of music while a psychological intervention in exercise[54,55].

Type of music

The type of music chosen and used for testing, physical exercise, and relaxation and to situations of increased aggression seems extremely crucial to the goal in question[30,41]. Although there are three possible hypotheses for the application of music as an ergogenic aid, the individual may be motivated by music, be able to synchronize the rhythm of his stride with it and still process the afferent information in parallel.

Given the importance of musical components, the studies comprising this review appear to test one of three theories in particular: the decoupling hypothesis[52], rhythm hypothesis[56] or psychomotor hypothesis[57]. However, according to Karageorghis *et al.*[58], all components (beats

Table 1. Effect of music on submaximal exercise.

Investigators	N	Gender	Population	Type of music	Test type	EE?	Comments
Waterhouse, *et al.* (2009)	12	M	Healthy	Own Choice	25 min - in sub-maximal cycling	Yes	Interaction between the music track and time (P <0.05), giving differences of 2.1%, 3.5% and 0.7% in the variables: distance, power and cadence, respectively for fast music and 3.8%, 9.8% and 5.9% in the same variables for the slow music condition.
Shaulov, *et al.* (2009)	28	14M and 14F	Healthy	Different Songs	Indoor Cycling Class	Yes	Reported more pleasure and less tiredness, but the heart rate and calories found no difference.
Karageorghis, *et al.* (2008)	29	15M and 14F	Healthy	Own Choice	26 min walk - 70% HR reserve	Yes	Positive effects were generated in the evaluation of some aspects of motivational music with average time (P <0.05).
Dyrlund, *et al.* (2008)	200	74M and 126f	Considered low risk (ACSM)	Favorite and Least Favorite Music	20 min walk	No	The subjective perception of effort and focus of attention showed no difference, besides the use of preferred music to present a greater dissociation in relation to exercise (P <0.01).
Nakamura, *et al*. (2008)	10	6M and 4F	Active	Favorite and Least Favorite Music	27 Km/hr in the cycle ergometer at 75rpm	Yes	The mood was influenced by the choice of music (P <0.05), but the performance has not changed.
Edworthy, *et al.* (2006)	30	15M 15F	Not specified	'The Beiderbecke Connection' played by Frank Ricotti Allstars	5 sessions of 10 minutes of walking	Yes	Association of pace and high volume provided the most significant differences in the variables of the running speed and heart rate (P <0.05).
Yamashita, *et al.* (2006)	8	M	Healthy	Own Choice	Submaximal cycling for 30 minutes	Yes	The music has positively influenced performance by decreasing the perception of stress in lower submaximal exercise intensities (40% VO2max) (P <0.05).
Potteiger, *et al.* (2000)	27	14M and 13F	Active	Fast Music, Classical Music and Own Choice	20 minutes walk to 70% of VO2 peak	Yes	Each type of music resulted in different data regarding the condition without music(P <0.05), caused by a distraction mechanism.
Szmedra, *et al.* (1998)	10	M	Trained	Control Condition andClassical Music Condition	15 minutes at 70% VO2max	Yes	Decreased perception of effort (10%), blood lactate (22.5%) and catecholamines (17.5%) in the music condition (P <0.05).
Brownley, *et al.* (1995	16	4M and 12F	Trained and untrained	Fast Music and Sedative Music	Running with low, moderate and high intensity	Yes	The untrained subjects responded significantly more to music than the trained (P <0.05).

EE: Ergogenic Effect.

per minute, socio-cultural characteristics, volume, melody, harmony, language and music preference) should be taken into account. Given this context, the same author creates the Brunel Music Rating Inventory - 2 (BMRI - 2), which consists of a questionnaire that evaluates the motivational quality of music for its application as an ergogenic agent and is very important to take it in consideration in the music choice[59].

Type of test / exercise

When we consider the type of test, the choice depends on the specific physical ability to be assessed (e.g., isometric strength, cardiorespiratory fitness and power). From this perspective, the music seems to influence more strongly tests/exercises with submaximal characte-

Table 2. Effect of music on maximal exercise.

Investigators	N	Gender	Population	Type of music	Test type	EE?	Comments
Tate, *et al.* (2012)	24	9M and 15F	Swimmers	Self-Select	4 freestyle of 50 meters more a freestyle of 800 meters	Yes	Improvements on performance of swimmers were found (P<0,05).
Biagini, *et al.* (2012)	20	M	Resistance-trained college	Self-Select	Bench press and Squat Jump	Yes	Performance was increased (explosive exercise – power) (P<0,05).
Terry, *et al.* (2011)	11	6M and 5F	Triathletes	Motivational and Synchronized	99% of VO_2 peak until exhaustion	Yes	Affect responses and mood has better outcomes using music (Cohen's d was used, showing a good effect size)
Nakamura, *et al.* (2010)	15	M	Healthy	Favorite Music, Non-Favorite Music and Control	Cycling at 100% Critical Power to Exhaustion	Yes	Greater distance as well as lower rate of perceived exertion for the Favorite Music condition in relation to Non-favorite condition (P <0.05).
Karageorghis, *et al.* (2009)	30	15M and 15F	Active	Synchronized Motivating and Synchronized not Motivating	Walk to exhaustion	Yes	The motivational synchronized music demonstrated an ergogenic effect on the exercise, increasing the time until exhaustion (P <0.05).
Mohammadzadeh, *et al.* (2008)	24	18M 6F	Trained and untrained	'Trelinum album Sash"	Bruce test	Yes	Significant difference in the perception of the untrained subjects in music condition (P <0.05).
Eliakim, *et al*. (2007)	24	12M and 12F	Volleyball players	Time after Time: California Dream and Heaven	Wingate Test	Yes	Music affected warm-up condition and had a beneficial effect on anaerobic performance (P<0.05).
Macone, *et al*. (2006)	27	14M and 13F	Active	'Wim Mertens - Struggle for Pleasure"	Walking at 75% of HR reserve until exhaustion	Yes	Psychological variables had different responses such as: state of anxiety, fatigue, stress, depression and confusion minimized. Women exercised more with the presence of music (P<0.05).
Crust L. (2004)[a]	15	F	Healthy	Familiar and unfamiliar music	BalkeWalking Test	No	No significant differences were detected (P<0.05).
Crust L. (2004)[b]	27	M	Healthy	Own Choice	Isometric task - shoulder abduction with elbow extension	Yes	Greater time to exhaustion in the subjects who listened to music that motivated them(P <0.05).
Bourdeaudhuij, *et al.* (2002)	30	10M and 20F	Obese Children	Own Choice	Treadmill test until exhaustion	Yes	Performance was increased (ran longer) being a positive effect on perseverance (P<0.05).
Elliott, *et al.* (2004)	18	8M and 10F	Previous experience	Motivational and Non-motivational music	12-minute test on the bike	Yes	Greatest total distance in conditions with music and significant differences between motivational music and the control session (P<0.05).
Yamamoto, *et al.* (2003)	6	M	Healthy	Fast Pace and Slow Rhythm	Supramaximal cycling in 45 Seconds	No	The norepinephrine concentration was lower in slow music condition compared to the fast pace (P <0.05) and fast pace music increased the concentration of epinephrine compared to slow music (P <0.05).
Szabo, *et al.* (1999)	24	12M and 12F	Students	Slow, Fast, Fast to Slow and Slow to Fast	Maximal incremental	Yes	In the slow to fast music condition the results were revealed in the workload and efficiency (P <0.05).
Pujol, *et al.* (1999)	15.	12M and 13F	Active	Equal Length Music	Wingatetest	No	Average output power, maximum power, minimum power and fatigue index showed no significant difference.
Copeland, *et al.* (1991)	24	11M and 13F	Healthy	Fast and Slow Music	Walk / Run to exhaustion	Yes	Greater time to exhaustion, as well as lower rate of perceived exertion for the condition B (slow and low music volume) compared to the control condition (P <0.05).

EE: Ergogenic Effect.

Table 3. Effect of music in time-trial exercises.

Investigators	N	Gender	Population	Type of music	Test type	EE?	Comments
Lim *et al.* (2009)	11	M	Active	The "Lucozade Hydro Active ® Workout Music"	10-km Time-trial cycling	Yes	The subjects increased their average speed (from 1 to 1.25 + Km.hr-1) (P <0.05) in the condition they knew that music would be introduced in the last 5 km, and modify their pacing strategy.
Atkinson *et al.* (2004)	16	M	Active	"Trance" (Tempo = 142 bpm, Volume = 87 dB).	10-km Time-trial cycling	Yes	Despite no differences in the perception, the total time of test was lower in the condition with music (P <0.05).

EE: Ergogenic Effect.

ristics[60,61], expressed by increased tolerance to exercise or amount of work done in the same time, and a possible explanation is given by the hypothesis of parallel processing, since the submaximal task afferent signals allows music to compete with the signs of fatigue or pain[15]. In sports domain with collective characteristics there is a weak trend from studies to use this ergogenic agent during training to motivate athletes, mainly on maximal load day of periodization.

Future prospects

Most studies have demonstrated the positive effect of music as an ergogenic aid for physical exercise. This practice is not new, since the music has been used for a long time, even without scientific support. So far, music has shown an ergogenic effect on performance during exercise[39,54]. Studies in several models (for example, isometric and / or acyclic), protocols (e.g., intermittent, continuous and incremental) and intensity domains are needed to explain the ergogenic effect of certain variables. Additionally, studies of populations from different degrees of physical fitness (e.g., sedentary, active, and trained athletes) are also important, since the level of physical fitness might influence the answers.

However, there is a large amount of questions about music as a possible ergogenic agent. Among them, what is the most important musical component? Does this ergogenic effect is really dependent of physical fitness level? Does the music sync is based on heart rate, rhythm of pedaling/stride or both? Does high intensity sound can increase performance due to increased afferent stimulation of the song? Will the pacing strategy be changed by the music? How does music and physical exercise are processed in parallel by brain?

Recommendations and orientations

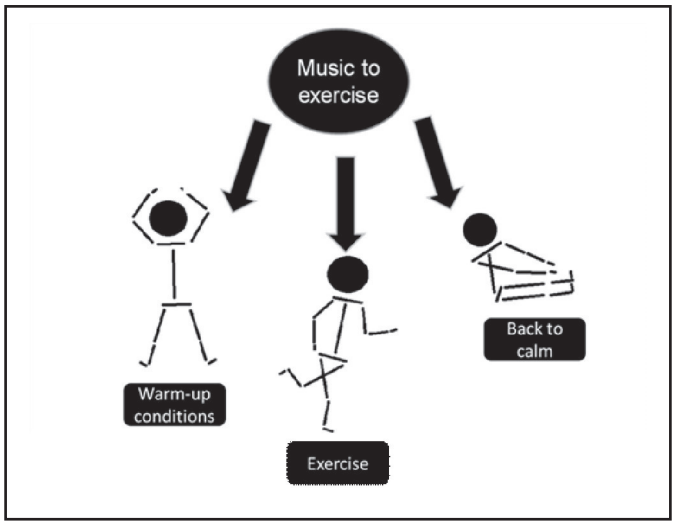
After reviewing the information submitted by the articles that met our initial inclusion criteria, we found that music acts efficiently as an ergogenic aid, particularly at submaximal exercise intensities. Although the mechanisms and assumptions are not fully elucidated, this tool can be used as a performance enhancer or to minimize the sensation of fatigue during physical activities, and make its practice more enjoyable. We must pay attention to the music featuring (type, tempo, pace and preference), using predominantly the type of music that is more enjoyable and motivational for the individual in the performance of physical activity in question[55]. Regarding the moment of using the music as an ergogenic, most studies apply it during the exercise. However, it is not uncommon to see it been used prior to the competition in the sports environment. Given the scarcity of studies evaluating the moment of application, only the ergogenic effect of music applied during exercise has a greater volume of evidence, closer to the context related to their use during physical activities.

Based on the already cited knowledge and in the studies that aimed to test the music and its effects in the most several exercise models, we propose recommendations and orientations for the practice according to the intensity levels and effort duration. To submaximal activities always that possible the music should be used the music simultaneously to the exercise, this way the possible mechanisms can interfere decreasing the perception of effort followed by an increase in the performance[9]. Also use the music that please the individual in style and type of music, always taking in consideration a high volume, but without injuring the ear, between 75 and 80 decibels[16] is enough, aiming to increase the cerebral stimulus received, it is an important thing to respect, once that the competition to our brain process will occur during the exercise. Still aim for music with high beats, around 120 and 140 bpm to exercises with higher intensity, it will make that your steps in running or the act of pedal in a cycling synchronize together, making plausible the staying of your pace stable with a low probability in change your rate perceived of exertion[31], in the case of tasks around 70% of maximum aerobic capacity, studies have shown that beats around 115 to 125 are more appropriated[58], this can bring synchronizer capacity of music in activities such as walking and cycling, as said before. Lastly and not less important chose inspiring music, that will bring good memories and positive emotion for the practice[40], some studies show us that inspirational songs are capable to make us to fatigue less during the exercise and more, can make the activity to appear less longer[47].

The Figure 4 illustrate some possible conditions that music can act and assist the exercise, increasing arousal or decreasing the anxiety in previous moment to exercise (warm-up conditions), acting in parallel to exercise, increasing performance and/or decreasing the rate perceived

exertion/fatigue sensations and making the back to calm more efficient, speeding up the process to normal physiologic conditions.

Figure 4. Illustrative representation to use music in three exercise conditions.



The recommendations to maximal activities and sports have very similar orientations, however many times those activities do not allow making use of the music during it, in this case explore the warm-up time to use music with motivational purpose, rising the will and the activation for the practice, also the music can does not change the final performance in maximal activities but can change the fatigue level for example in training session permitting a good reason to use this ergogenic effect without controversial problems. In some cases the music can be used to decrease the activation and the excitement, reducing the anxiety and improving the concentration, for such make use of the music with low beats per minute, around 70 to 80 before or after the exercise, with relax songs and respecting the same orientation to volume.

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