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Music as ergogenic aid: comparative analysis of music tempos on selected physical fitness components of untrained collegiate students

La música como ayuda ergogénica: análisis comparativo de los tempos musicales en componentes seleccionados de la aptitud física de estudiantes universitarios no capacitados

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Abstract

The study aimed to investigate the effect of three different music tempos such as 44-77BPM, 78-120BPM, and 121-200BPM, on selected physical fitness components, which include flexibility, cardiovascular endurance, muscular endurance, muscular strength, reaction time, and agility. Specifically, it also compared the music tempos to each other based on their effectiveness as ergogenic aids on the said fitness components. The study includes 70 participants (male=47;female=23) who are untrained collegiate students through purposive sampling. Four groups were formed, assigned by different music tempos (No Music Group=17; 40-77BPM=18; 78-120BPM=18;121-200BPM=17). The pretest was conducted by administering the fitness test, which measures the physical fitness components of the participants. Before the post-test, participants listened to a playlist with a music tempo assigned to their group. After this, the post-test commenced. The data was analyzed using a paired T-test for within-group comparison and ANOVA for the group comparison. The No Music Group and the 44-77 BPM group did not demonstrate any notable enhancement in the physical fitness components. The 78-120BPM group showed a significant improvement in flexibility of the lower limbs (p=.03, t=2.44) and agility in changing direction (p=.00, t=4.76). Lastly, the 121-200BPM group demonstrated a significant increase in reaction time (p=.01,t=3.14) and agility in changing direction (p=.00,t=3.39) . As for group comparison, cardiovascular endurance was different among groups, suggesting the 121-200BPM group to be superior compared to another group (p=.01, t=4.02). Music with a tempo of 44-77 BPM should be used as post-workout recovery, while 78-120 BPM was observed to enhance flexibility and agility. Music in the 121-200 BPM range shows potential for improving reaction time and agility. Cardiovascular endurance was superior in the 121-200 BPM music tempo. Future studies should focus on the role of slower tempos in recovery, further investigate flexibility and agility across various BPM ranges, and ensure reliable performance evaluations through replication.

Keywords: music, physical fitness, untrained, ergogenic aid, psychology

Resumen

El estudio tuvo como objetivo investigar el efecto de tres diferentes tempos musicales, como 44-77 BPM, 78-120 BPM, y 121-200 BPM, sobre componentes seleccionados de la condición física, los cuales incluyen flexibilidad, resistencia cardiovascular, resistencia muscular, fuerza muscular, tiempo de reacción y agilidad. Específicamente, también se compararon los tempos musicales entre sí en función de su efectividad como ayudas ergogénicas en dichos componentes de la condición física. El estudio incluyó a 70 participantes (47 hombres y 23 mujeres) que son estudiantes universitarios no entrenados, seleccionados mediante muestreo intencional. Se formaron cuatro grupos, asignados a diferentes tempos musicales (Grupo Sin Música = 17; 44-77 BPM = 18; 78-120 BPM = 18; 121-200 BPM = 17). Se realizó una prueba previa administrando un test de aptitud física que midió los componentes de la condición física de los participantes. Antes de la prueba posterior, los participantes escucharon una lista de reproducción con el tempo musical asignado a su grupo. Después de esto, comenzó la prueba posterior. Los datos se analizaron utilizando una prueba T para muestras relacionadas para la comparación dentro de los grupos, y un ANOVA para la comparación entre los grupos. El Grupo Sin Música y el grupo de 44-77 BPM no mostraron ninguna mejora notable en los componentes de la condición física. El grupo de 78-120 BPM mostró una mejora significativa en la flexibilidad de los miembros inferiores (p = .03, t = 2.44) y en la agilidad para cambiar de dirección (p = .00, t = 4.76). Por último, el grupo de 121-200 BPM demostró un aumento significativo en el tiempo de reacción (p = .01, t = 3.14) y en la agilidad para cambiar de dirección (p = .00, t = 3.39). En cuanto a la comparación entre grupos, la resistencia cardiovascular fue diferente entre los grupos, sugiriendo que el grupo de 121-200 BPM fue superior en comparación con los otros grupos (p = .01, t = 4.02). Se sugiere que la música con un tempo de 44-77 BPM se utilice como recuperación post-entrenamiento, mientras que se observó que el tempo de 78-120 BPM mejora la flexibilidad y la agilidad. La música en el rango de 121-200 BPM muestra potencial para mejorar el tiempo de reacción y la agilidad. La resistencia cardiovascular fue superior con el tempo musical de 121-200 BPM. Futuros estudios deberían centrarse en el papel de los tempos más lentos en la recuperación, investigar más a fondo la flexibilidad y la agilidad en varios rangos de BPM, y garantizar evaluaciones de rendimiento confiables a través de la replicación.

Palabras clave: música, condición física, no entrenados, ayudas ergogénicas, psicología

Introduction

Ergogenic Aids

An ergogenic aid is a substance or method that enhances or improves performance, derived from the Greek words "ergon," meaning "work," and "genic," meaning generating or producing. The term "work generating" is a straight translation of this phrase. Within athletic performance, these aids enhance several physiological and psychological parameters like energy levels, productivity, muscle strength, and psychological well-being (Thein et al., 1995). Long ago, ancient Greek athletes consumed different animal parts to enhance their performance (Applegate & Grivetti,1997). These are still evident through caffeine and other methods of consuming or ingesting and performed to boost fitness (Aguiar et al., 2020). The athletic performance-enhancing approaches were categorized into five classifications. Nutritional ergogenic aids encompass dietary supplements offering supplementary energy or influencing metabolism to enhance performance (Schubert & Astorino, 2013). Utilizing specialized apparatus to enhance physical performance is called mechanical ergogenic aids (Mota & Marocolo, 2020). These encompass a variety of items,

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including the apparel worn during athletic activities and the devices utilized in sporting competitions. Pharmacological ergogenic aids use pharmaceutical substances, such as steroids, pain relief drugs, and diuretics, to enhance performance (Ahrendt, 2001). Manipulating an individual's physiological component to enhance performance is classified as a physiological ergogenic aid. Examples of such aids include blood doping (Andersen et al., 2022), human growth hormone (Birzniece et al., 2011), and oxygen supplementation (Wang et al., 2017). Finally, Psychological ergogenic aids encompass techniques such as visualization, stress management, and motivational tactics that can enhance performance (Thein et al., 1995). Ergogenic aids encompass a range of techniques and substances, both ancient and modern, that improve athletic performance by utilizing various approaches such as diet, drugs, mechanics, psychology, and physiology. These aids reflect the ongoing quest for achieving optimal sports performance.

Music

Regarding the type of ergogenic aid mentioned above, music can be classified as a psychological ergogenic aid. Music has a pluralistic concept as it cannot contained in one or more definitions. It lacks a sole definition as it varies across disciplines, previous literature, and contexts (Currie & Killin, 2016). It is a part of human culture where, and every culture offers different uses for it. It was described as a dynamic phenomenon constantly changing as it reflects culture and spiritual practices (Kossanova et al., 2016). It was considered a cultural identity and an art form that organizes sounds meaningfully and aesthetically (Antony et al., 2018). This was also a way to indirectly communicate emotions (Umurzakov, 2022) and was used in celebrations, from religious ceremonies to entertainment (Wu, 2022). The capability of it to be a medium of expression paves the way for one to express one's ideas and perceptions through organized sound with rhyme (Kabatas, 2020). This simple sound arrangement is considered a universal language that passes through disciplines such as physics, mathematics, and art (Chetia et al., 2020). It is also used for intrapersonal communication as it shapes the inner emotional experiences of individuals (Umurzakoy, 2022), which leads to arousing sensations in the human mind and body (Gupta et al., 2021). These were all made

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possible by music just by being an organized sound with the accompaniment of melody, harmony, and rhythm (Bell et al., 2016). Combining the elements above makes this sound meaningful to the point that it reflects the culture and one's feelings and gives the mind and body internal sensations (Wu, 2022). Not only these, but it also served as therapy across different situations (Vereshchahina-Biliavska et al., 2023). *Music is* a multifaceted and dynamic phenomenon that transcends cultural, emotional, and disciplinary boundaries, providing a universal means of expression, communication, and therapy.

Music and Emotions

Despite being considered a psychological ergogenic aid as it changes the psychological flow of an individual in a given time, music first changes an individual's biological aspect. The activities of the parts of the central nervous system, such as the amygdala and hippocampus, which are responsible for emotion processing, are modulated by music (Koelsch, 2014). It significantly affects emotion through its influence on the nervous system, particularly the brain, which can lead to improving mood and physiological health (Darki et al., 2022). Oxytocin, a hormone linked to social bonding, trust, and emotional regulation, was found to be increased on its release by exposure of an individual to music (Harvey,2020). On genetic makeup, it was found that music can influence gene expression related to cognitive and emotional regulation (Kanduri et al., 2015; Nair et al., 2020). In clinical settings, music was used to implement changes in the emotions of the individuals. It was used to regulate mood (Raglio et al., 2015) as it can reduce stress(Pokharel, 2021). It can also strongly impact positive and negative mood changes for average individuals (Ahmad & Rana, 2015) and those with musical inclinations (Chang et al., 2020). However, although music has been established to enhance mood, how an individual uses music can negatively and positively affect their mental health (Carlson et al., 2015). The listener's context and individuality heavily influence its impact on emotion (Pesek et al., 2017). In the end, it was mentioned that music reflects cultural contexts. With this, its impact on the psychological aspect of an individual may differ across cultures (Campbell et al., 2020). While music universally influences individuals' biological and psychological aspects, its

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effects on emotion and mental health vary significantly depending on individual context, cultural background, and how music is utilized. The perception of music's emotional impact varies significantly depending on the listener's context and personal factors.

Music with 40-77 BPM as Ergogenic Aid

The utilization of music whose beat is from 40 to 77 was widely used as an ergogenic aid for Athletic performance on various parameters. Anaerobic capacity refers to the total endurance of an individual in performing explosive movements. A study among physical education students revealed that music with bears above per minute has failed to improve absolute peak and mean power (Atan,2013). This was also found when 70 beats per minute music was used to improve post-exercise recovery. Lactate clearance was found to be insignificantly improved (Atan, 2022). As for post-exercise recovery, 40-70 bpm music fails to lower the heart rate after an anaerobic exercise (Atan,2022). However, the bpm range effectively improved the subjective recovery of runners (Jones et al., 2017). In addition to proper nutrition, 60-bpm music used as an ergogenic aid effectively improved post-exercise recovery (Zhou, 2021). Cardiorespiratory was also studied as a parameter to be improved by the said bpm range. Slow music lowers cardiorespiratory parameters such as heart rate during exercises (Torkamandi et al., 2020). However, in a study, IT INCREASES recovery. However, the cardiorespiratory parameters were not improved among runners (Jones et al., 2017). While music within the 40-77 bpm range may have some benefits in improving subjective recovery and lowering heart rate during exercise, it appears to have limited effects on enhancing anaerobic capacity, lactate clearance, and overall cardiorespiratory parameters, indicating its potential as a recovery aid rather than a performance enhancer.

Music with 78-120 BPM as Ergogenic Aid

Previous studies on music within the 78-120 bpm range showed that it can effectively enhance various aspects of athletic performance. Music at 85-90 bpm significantly increased absolute and relative peak power during resistance exercises

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without affecting fatigue levels (Brohmer et al., 2006). However, another study reported no significant changes in power output or fatigue when participants exercised to their favorite music at 120 bpm (Pujol et al., 1999). Motivational music at 85-90 bpm improved aerobic performance and lowered perceived exertion, highlighting its role in enhancing endurance *(Ghadery et al., 2009).*In contrast, music within the 94-141 bpm range could act as a distraction, reducing work output during CrossFit® sessions (Brupbacher et al., 2014). For cardiovascular endurance, synchronous music at 80-97 bpm extended time to exhaustion and improved mood and running economy in elite triathletes (Terry et al., 2012).

Similarly, progressive music (60-120 bpm) increased oxygen consumption, heart rate, and time to exhaustion during exercise, further supporting the ergogenic benefits of music within this tempo range (Torkamandiet al., 2020). With this, studies on music within the 78-120 bpm range demonstrated that it can enhance athletic performance, particularly by increasing power output, improving aerobic endurance, and extending time to exhaustion. While music in this range generally benefits performance, certain tempos may distract during high-intensity activities, highlighting the need to match the music tempo to the specific exercise for optimal results.

Music with 121-200 BPM as Ergogenic Aid

Previous studies on the effects of music within the 121-200 bpm range show significant impacts on anaerobic capacity, muscular strength, cardiovascular performance, and recovery. Fast music (145 bpm) improved anaerobic power, sprint, agility, and muscular endurance, while light music (120 bpm) had minimal effects (Arazi et al., 2017). Lower RPE during leg press exercises and walking was observed with music at 90-150 bpm, indicating its benefits in reducing perceived exertion (Patania et al., 2020). Self-selected music over 120 bpm enhanced endurance performance during resistance exercises (Bartolomei et al., 2015), while music at 120-130 bpm significantly increased absolute and relative peak power (Işık et al., 2015). Fast-tempo music (140 bpm) improved mean power output in anaerobic rowing (Pusey et al., 2023) and peak anaerobic power on athletes (Eliakim et al., 2007; Meglic et al., 2021). Also, high-tempo music during warm-ups improved short-term performance

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(Jarraya et al., 2012). However, no significant changes in power or fatigue were observed with fast rhythm music (200 bpm) during resistance exercises (Atan, 2013). In terms of muscular strength, fast-tempo, loud music (126 bpm) enhanced grip strength (Karageorghis et al., 2018), and stimulant music (134 bpm) led to better strength performance than sedative music (Feiss et al., 2021). Regarding cardiovascular performance, fast-tempo music significantly improved anaerobic performance during warm-ups. It positively affected heart rate and fatigue index (Puad et al., 2020), while fast music increased heart rate and RPE during resistance exercises (Arazi et al., 2015). In recovery, fast-tempo music improved the subjective recovery experience without affecting cardiorespiratory markers (Jones et al., 2017). Lastly, music between 94-141 bpm may act as a distraction in certain contexts, reducing work output in CrossFit® sessions (Brupbacher et al., 2014), but positively influences perceived exertion and performance during progressive exercise (Mohammadzadeh et al., 2008). In conclusion, while music within the 121-200 bpm range demonstrates various benefits for anaerobic capacity, muscular strength, cardiovascular performance, and recovery, its effectiveness can depend on tempo and context, with some tempos enhancing performance and others potentially acting as distractions.

Gaps and Aims of the Study

Ergogenic aids, substances, or methods that improve athletic performance can be classified into nutritional, mechanical, pharmacological, physiological, and psychological categories, with music being a psychological ergogenic aid. Music affects biological and psychological aspects, influencing brain activity, emotion regulation, and gene expression. However, its impact varies across cultures and individual contexts. Music with 40-77 BPM shows limited benefits for athletic performance, primarily aiding in subjective recovery rather than enhancing anaerobic capacity or cardiorespiratory parameters. Music within the 78-120 BPM range can improve power output and aerobic endurance and extend exercise time, although it may distract during high-intensity activities. Music with 121-200 BPM enhances anaerobic power, strength, and cardiovascular performance. However, its effects depend on the context and specific tempo, with some tempos improving performance while others may hinder

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focus. With this, existing gaps were found in the literature. Although music as an ergogenic aid was studied on physical fitness parameters like anaerobic and aerobic capacity, power, and muscular strength, parameters such as flexibility, endurance, reaction time, and agility were not yet explored. Also, a comparison among different music tempos on their effect on fitness still needs to be done. With these two gaps, the study aimed to investigate the effect of three different tempos on flexibility, cardiovascular endurance, plank test, muscular strength, reaction time, and agility of untrained individuals. Also, a comparative analysis was conducted among 40-77 bpm, 78- 120 bpm, and 121- 200 bpm as music tempos that affected the aforementioned physical fitness components.

Methodology

Sampling and Participants

The study consists of 70 untrained collegiate students from a State University in the Philippines who were selected through purposive sampling. The following inclusion criteria were set for the participant selection: (1) a bonafide student of the locale of the study, (2) does not have any formal and competitive athletic training, (3) without any medical problem that can be worsened or triggered by physical activity. As for the exclusion,(1) the participants should enrolled at least 8 units during the data gathering procedure.Table 1 below shows the sex distribution of each group in the study. The No Music group comprised five females (7.14%) and 12 males (17.14%), making up 24.29% of the 70 participants. For the 40-77 BPM group, there were five females (7.14%) and 13 males (18.57%), accounting for 25.71% of the total participants. The 78-120 BPM group had eight females (11.43%) and ten males (14.29%), representing 25.71% of the total participants. Lastly, the 121-200 BPM group included five females (7.14%) and 12 males (17.14%), comprising 24.29% of the total participants. In total, 70 participants in the study were distributed across four groups representing different intervention categories.

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Table 1. Sex distribution of the participants per group

Sex	NMG	40-77BPM	78-120BPM	121-200BPM	Total
Female	5(7.14%)	5(7.14%)	8(11.43%)	5(7.14%)	23(32.86%)
Male	12(17.14%)	13(18.57%)	10(14.29%)	12(17.14%)	47(67.14%)
Total	17(24.29%)	18(25.71%)	18(25.71%)	17(24.29%)	70(100%)

Table 2 represents the participants' demographic profiles regarding height, weight, and body mass index per group. The No Music group had a mean height of 166.41 ± 9.60 cm and a mean weight of 66.47 ± 12.55 kg. Consequently, this group's Body Mass Index (BMI) was 23.86 ± 3.20. For the 40-77 BPM group, the mean height was 169.22 ± 9.15 cm, and the mean weight was 64.67 ± 12.75 kg. The BMI for this group was 22.52 ± 3.73. The 78-120 BPM group had a mean height of 163.00 ± 9.78 cm and a mean weight of 57.06 ± 10.60 kg, resulting in a BMI of 21.34 ± 2.56. Lastly, the 121-200 BPM group had a mean height of 169.29 ± 8.21 cm and a mean weight of 65.65 ± 13.32 kg, with a BMI of 22.79 ± 3.58. In totality, the participants had a mean height of 166.96 ± 9.38 cm and a mean weight of 63.39 ± 12.64 kg. The Body Mass Index of all participants was reported to be 22.61 ± 3.35.

Table 2. Demographic profile of the participants per group

Sex	NMG	40-77BPM	78-120BPM	121-200BPM	Total
Height	166.41±9.60	169.22±9.15	163.00±9.78	169.29±8.21	166.96±9.38
Weight	66.47±12.55	64.67±12.75	57.06±10.60	65.65±13.32	63.39±12.64
Body Mass Index	23.86±3.20	22.52±3.73	21.34±2.56	22.79±3.58	22.61±3.35

Instruments

The following instruments were selected because of their rigid reliability and validity. Also, practically was considered in the usage of instruments to quantify the mentioned physical fitness components.

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Sit and Reach Test

The Sit and Reach Test measures the flexibility of the hamstring. To perform the sit-and-reach test, tape a measuring stick to the floor with a 24-inch (61 cm) piece of tape across at the 15-inch (38 cm) mark. After a warm-up that includes non-ballistic exercises for the hamstrings and lower back, the athlete sits shoeless with legs extended, feet 12 inches (30 cm) apart, and reaches forward along the measuring stick. The best of three trials is recorded to the nearest 0.25 inches or 1 cm, with a score of less than 15 inches (38 cm) indicating the athlete could not reach their toes (Haff & Triplett, 2016). Numerous studies established it to have a moderate criterion-related validity for measuring the flexibility of the lower extremities muscle (.46 to .67 correlation coefficients) (Mayorga-Vega et al., 2014)

Ruler Drop Test

The ruler drop test was a simple field test to assess reaction time, which was widely used by children and adolescents (Aranha et al., 2017). This was done by holding the ruler vertically between the thumb and index finger of the participant's hand, with the zero mark aligned at the top of the participant's fingers. The ruler is released without warning, and the participant must catch it quickly. The distance the ruler falls before being caught is recorded, with this distance being used to calculate the reaction time (Latorre-Román et al., 2018). Practice drop was given to the participants before the testing (Del Rossi et al., 2014). In a study, it had good reliability for a population with and without cognitive impairment (ICC GWCI = 0.84; ICC GCI = 0.80)(Ferreira et al., 2021)

Three-minute step test

A three-minute step test was utilized as a field test for cardiovascular endurance. The three-minute step test involves the participant stepping up and down a 15 cm step at a set pace for three minutes, following a pattern of "up-up, down-down." Heart rate, oxygen saturation, and perceived exertion are measured before and immediately after the test, with heart rate recovery recorded one minute after to assess cardiovascular fitness. This simple test requires minimal equipment and effectively evaluates

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cardiovascular health (Sudano et al., 2014; Holland et al., 2011). The testing was found to be a valid and reliable tool for assessing not only cardiovascular endurance but also functional exercise capacity (Barrón et al., 2021)

Plank test

The plank test measures the muscular endurance of the abdomen by isometrically contracting the core (Tong et al., 2014; Laurson et al., 2022). It was done by holding a push-up position until failure. The total time the participants hold the position is the score on the test. The reliability of the field test was found to be high, particularly in test-retest reliability, with a coefficient of 0.915 (Bohannon et al., 2017).

1 Repetition Max Bench Press

One Repetition Max is a test that measures the muscular strength of a certain muscle group (Barbalho et al., 2018). It is done by doing compound exercises such as squats, bench presses, and deadlifts with an individual's maximum weight in a single repetition. It is scored by the total weight an individual carries for a single repetition, which makes him unable to do another Repetition. The testing has established reliability and reproducibility in older adults with kappa indices ranging from .93 to .95 and an interclass correlation coefficient of .99. (Balbaho et al., 2018). Also, It was highly accurate and effective in assessing bench press performance for recreational individuals (Bianco et al., 2015)

Hexagon Jump Test

The Hexagon Jump test is an instrument to quantify agility regarding change of direction. This is done by creating a hexagon shape on the floor with a 60.5 cm length. The participants start at the shape's center and jump past the first side. After this, he jumps back in the middle and executes another jump towards the next side. This will continue until a complete three full revolution is done. It is scored by measuring the time the individual completes the number of revolutions. This testing was found to have excellent reliability in quantifying agility as a practical and effective instrument (Beekhuizen et al., 2009). Also, it has excellent test-retest reliability for both same-day

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intraclass correlation coefficient (ICC) model 3,1 = 0.938 and between-day ICC (3,1) = 0.924 analyses.

Data Gathering Procedure

Standardization of Diet and Exercise

Before conducting the fitness tests, measures were taken to ensure that the participants' exercise and diet were not influenced by external factors such as their current training program and dietary habits. The participants were instructed to refrain from moderate to vigorous physical activity for 48 to 72 hours. By implementing this approach, the study aimed to promote the recovery of the muscular system and prevent any potential decline in fitness performance (Carroll et al., 2017). Additionally, it is strongly advised to avoid consuming beverages that can impact performance, such as stimulants like coffee and energy drinks (Blanchard & Sawers, 2004; Magkos & Kavouras, 2005) and alcohol (Jones, 2010). By implementing these protocols, we were able to effectively address and mitigate any potential concerns regarding the external validity. Also, the same warm-up and stretching exercises were implemented for the groups involved in the study.

Music Setup

The study has four groups exposed to different music tempos as an ergogenic aid before administering fitness testing. The selection of music tempo ranges was set into three equal ranges from 40 to 200 beats per minute. The first group was participants who were not exposed to any music tempo. The second group was exposed to a song playlist with 40-77 beats per minute. As for the third group, music with 78-120 beats per minute was used as an ergogenic aid. Lastly, the fourth group was exposed to 121-200 beats per minute playlist. MixMeister BPM Analyzer was utilized to identify the tempo of the songs. The participants listened synchronously to the playlist for 10 minutes before administering the fitness tests after the standardized warm-up and stretching exercises. After two fitness tests, each group's exposure to music was repeated until all four other fitness tests were done. Table 3 shows the song playlist used in the study.

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Table 3. Song Playlist per Group

No Music Group	40-77 BPM Group	78-120 BPM Group	121-200 BPM group
	What's Up - 4 Non Blondes	Highway to Hell - AC/DC	I Need a Hero - Bonnie Tyler
	Don't Let Me Down - The Beatles	Elevate - DJ Khalil feat. Denzel Curry	Rapstar - Polo G
	I Won't Give Up - Jason Mraz	Numb - Linkin Park	Karma Chameleon - Culture Club
	Unchained Melody - The Righteous Brothers	Eye of the Tiger - Survivor	Wake Me Up Before You Go-Go - Wham!

Fitness Tests Arrangement

The study fitness tests were administered to the participants with a pattern to minimize compounding effects on prior tests. A standardized whole-body warm-up and dynamic stretching were implemented to prepare the participants' bodies. The sequence of the fitness test was based on the fatigue factor that may arise from the tests. It follows an order from non-fatiguing to most fatiguing tests to lessen the compounding effect of prior testing (Haff & Triplet, 2016). Considering this arrangement, the instruments were administered: Sit and Reach Test, Ruler Drop test, Hexagon Jump test, 1RM bench Press, Plank test, and Three minute Step test. After every two fitness tests, exposure to music was done until all of the tests were finished.

Testing Proper

The pretesting of the study commenced by explaining the instructions and procedure for the data gathering procedure. Also, the fitness tests were demonstrated on the participants' behalf to familiarize them. After this, a standardized warm-up and stretching exercises were implemented on all participants. Each group was administered the aforementioned fitness tests. The arrangement of test administration was strictly followed. The participants were given a recovery period of 5 to 15 minutes to rest after testing. If the participants were not yet recovered from the testing, they were given extended time for recovery. An individualized recovery period was done to safeguard the participants' safety (Cortis et al., 2010). On the post-testing, strict protocols were

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observed. The groups were arranged separately. Each group was exposed for 10 minutes to the playlist of music with the tempo that was assigned to their group. The Sit and Reach Test and Ruler Drop test will follow this up. After this, the second music exposure was done, and the Hexagon Jump and 1RM bench press were administered. The last exposure to music was done, which was concluded by endurance tests such as the Plank test and the Three-minute Step test.

Data analysis

The study utilized a paired t-test for within-group comparison of the four groups implemented by music tempos as a psychological ergogenic aid. The post-test data of each group was also compared with that of the other group. With this, an analysis of variance was used. Lastly, the significance level of .05 was set. P-values equal to or less than the set significance level were interpreted as significant.

Potential Ethical Issue

The participants received an in-depth overview of the study, encompassing a conversation regarding their rights concerning the study's framework. Subsequently, participants were requested to give informed consent by filling out a consent letter. Following that, a Physical Readiness Questionnaire was given to determine if there were any hidden medical issues among the participants. In summary, the collected information was managed with the highest level of confidentiality and shared with the owner when requested.

Results

Table 4 shows the within-group comparison of the No Music Group. It was found that all of the fitness parameters tested without using music as a psychological ergogenic aid did not yield significant improvement. The flexibility of the lower extremities of the participants ($SART^{pretest}$ = 45.29±9.15; $SART^{Posttest}$= 49.24 ±14.87) displayed an insignificant improvement (t=1.42; p=0.17). This was also the same scenario for cardiovascular endurance ($3MST^{Pretest}$=151.18±62.05; $3MST^{Posttest}$= 129. 41±29.32) which was observed to increase (t=1.28; p=.22) insignificantly. The core's

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muscular endurance was increased (PT ^{Pretest}= 97.55±55.66; PT ^{Posttest}= 108.64±45.31). However, it was statistically insignificant (t=1.20; p=.25). The muscular strength of the upper extremities (1RM ^{Pretest}= 71.69±18.64; 1RM ^{Posttest}= 74.16±17.11) was also found to be insignificantly increased (t=1.00; p=.33). The reaction time was found decreased (RDT ^{Pretest}= 12.26±6.345; RDT ^{Posttest}= 9.46±2.45). However, this was an insignificant increase on the said fitness parameter (t=1.70; p=.11). Lastly, the agility (HJT ^{Pretest}=14.32±1.78; HJT ^{Posttest}= 13.46±2.65) was investigated to be insignificantly increased (t=1.47; p=.16).

Table 4. Within Group Physical Fitness Components Comparison of NMG

Physical fitness test	Pretest	Post-test	t-value	p-value
SART	45.29±9.15	49.24±14.87	1.42	.17
3MST	151.18±62.05	129.41±29.32	1.28	.22
PT	97.55±55.66	108.64±45.31	1.20	.25
1RM	71.69±18.64	74.16±17.11	1.00	.33
RDT	12.26±6.34	9.46±2.45	1.70	.11
HJT	14.32±1.78	13.46±2.65	1.47	.16

Note: SART= Sit and Reach Test; 3MST= Three-minute Step Test; PT=Plank Test; 1RM=One Repetition Maximum; RDT=Ruler Drop Test; HJT=Hexagon Jump Test

Table 5 shows the within-group comparison of the 40-77 BPM Group. It was found that all of the fitness parameters tested with 40-77 BPM songs as a psychological ergogenic aid did not yield significant improvement. The flexibility of the lower extremities of the participants (SART Pretest = 47.64 ± 10.27; SART $^{Post-test}$ = 48.11 ± 10.69) displayed an insignificant improvement (t = 0.40; p = 0.69). This was also the same scenario for cardiovascular endurance (3MST ^{Pretest} = 135.22 ± 45.46; 3MST ^{Posttest} = 127.89 ± 31.02), which was observed to decrease insignificantly (t = 0.59; p = 0.56). The core's muscular endurance remained relatively stable (PT ^{Pretest} = 92.22 ± 42.86; PT Pos^{t-test} = 92.63 ± 27.52), but this slight increase was statistically insignificant (t = 0.03; p = 0.97). The muscular strength of the upper extremities (1RM ^{Pretest} = 75.07 ± 25.93; 1RM P^{osttest} = 72.46 ± 21.24) was also found to be insignificantly decreased (t = 0.95; p = 0.35). The reaction time was found to have increased (RDT ^{Pretest} = 12.62 ± 5.94; RDT $^{Post-test}$ = 14.42 ± 8.84); however, this was an insignificant change in the said fitness

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parameter (t = 0.89; p = 0.38). Lastly, the agility (HJT ^{Pretest} = 14.42 ± 3.01; HJT ^{Posttest} = 14.78 ± 2.62) was investigated to be insignificantly increased (t = 0.50; p = 0.62).

Table 5. Within Group Physical Fitness Components Comparison of 40-77 BPM Group

Physical fitness test	Pretest	Post-test	t-value	p-value
SART	47.64±10.27	48.11±10.69	.40	.69
3MST	135.22±45.46	127.89±31.02	.59	.56
PT	92.22±42.86	92.63±27.52	.03	.97
1RM	75.07±25.93	72.46±21.24	.95	.35
RDT	12.62±5.94	14.42±8.84	.89	.38
HJT	14.42±3.01	14.78±2.62	.50	.62

Note: SART= Sit and Reach Test; 3MST= Three-minute Step Test; PT=Plank Test; 1RM=One Repetition Maximum; RDT=Ruler Drop Test; HJT=Hexagon Jump Test

Table 6 shows the within-group comparison of the 78-120 BPM Group. It was found that only the flexibility of the lower extremities and the agility of the participants who listened to 78-120 BPM songs as a psychological ergogenic aid yielded significant improvement. The flexibility of the participants (SART ^{Pretest} = 46.11 ± 8.06; SART ^{Posttest} = 48.33 ± 8.21) displayed a significant improvement (t = 2.44; p = 0.03). This was not the case for cardiovascular endurance (3MST ^{Pretest} = 144.67 ± 45.94; 3MST ^{Posttest} = 147.78 ± 36.44), which was observed to increase insignificantly (t = 0.30; p = 0.77). The core's muscular endurance showed a decrease (PT ^{Pretest} = 96.78 ± 56.37; PT ^{Posttest} = 82.72 ± 40.16); however, this was statistically insignificant (t = 1.21; p = 0.24). The muscular strength of the upper extremities (1RM ^{Pretest} = 59.46 ± 14.07; 1RM $^{Post\text{-}test}$ = 60.59 ± 16.80) was also found to have an insignificant increase (t = 0.43; p = 0.67). The reaction time decreased (RDT ^{Pretest} = 11.12 ± 6.43; RDT $^{Post\text{-}test}$ = 8.78 ± 2.94); however, this was an insignificant change in the said fitness parameter (t = 1.79; p = 0.09). Lastly, the agility (HJT ^{Pretest} = 14.65 ± 1.77; HJT ^{Posttest} = 12.92 ± 1.81) was observed to have a significant increase (t = 4.76; p = 0.00).

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Table 6. Within Group Physical Fitness Components Comparison of 78-120 BPM Group

Physical fitness test	Pretest	Post-test	t-value	p-value
SART	46.11±8.06	48.33±8.21	2.44	.03
3MST	144.67±45.94	147.78±36.44	.30	.77
PT	96.78±56.37	82.72±40.16	1.21	.24
1RM	59.46±14.07	60.59±16.80	.43	.67
RDT	11.12±6.43	8.78±2.94	1.79	.09
HJT	14.65±1.77	12.92±1.81	4.76	.00

Note: SART= Sit and Reach Test; 3MST= Three-minute Step Test; PT=Plank Test; 1RM=One Repetition Maximum; RDT=Ruler Drop Test; HJT=Hexagon Jump Test

Table 7 shows the within-group comparison of the 121-200 BPM Group. It was found that only the reaction time and the agility of the participants who listened to 121-200 BPM songs used as a psychological ergogenic aid yielded significant improvement. The flexibility of the participants (SART Pretest = 45.00 ± 8.65; SART Post-test = 47.59 ± 8.31) displayed an improvement, though it was statistically insignificant (t = 1.92; p = 0.07). This was also the case for cardiovascular endurance (3MST Pretest = 135.59 ± 48.08; 3MST Posttest = 125.65 ± 23.11), which was observed to decrease insignificantly (t = 0.75; p = 0.47). The core's muscular endurance increased (PT Pretest = 94.22 ± 59.98; PT Posttest = 109.53 ± 85.70); however, this was statistically insignificant (t = 1.50; p = 0.15). The muscular strength of the upper extremities (1RM Pretest = 76.02 ± 23.80; 1RM Post-test = 67.32 ± 17.09) was observed to have a decrease, which was not statistically significant (t = 1.58; p = 0.13). The reaction time significantly decreased (RDT Pretest = 14.37 ± 6.82; RDT Posttest = 10.41 ± 4.37), significantly improving this fitness parameter (t = 3.14; p = 0.01). Lastly, the agility (HJT Pretest = 15.07 ± 2.36; HJT Posttest = 13.53 ± 2.11) was found to significantly improve (t = 3.39; p = 0.00).

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Table 7. Within Group Physical Fitness Components Comparison of 121-200 BPM group

Physical fitness test	Pretest	Post-test	t-value	p-value
SART	45.00±8.65	47.59±8.31	1.92	.07
3MST	135.59±48.08	125.65±23.11	.75	.47
PT	94.22±59.98	109.53±85.70	1.50	.15
1RM	76.02±23.80	67.32±17.09	1.58	.13
RDT	14.37±6.82	10.41±437	3.14	.01
HJT	15.07±2.36	13.53±2.11	3.39	.00

Note: SART= Sit and Reach Test; 3MST= Three-minute Step Test; PT=Plank Test; 1RM=One Repetition Maximum; RDT=Ruler Drop Test; HJT=Hexagon Jump Test

Table 8 shows the comparison of the tested fitness parameters among the groups. It was investigated that only the cardiovascular endurance data (3MST ^{NMG} = 129.41 ± 29.32; 3MST $^{40\text{-}77\ BPM}$ = 127.89 ± 31.02; 3MST $^{78\text{-}120\ BPM}$ = 147.78 ± 36.44; 3MST $^{121\text{-}200\ BPM}$ = 125.65 ± 23.11) were found to be significantly different among the groups (f = 4.02; p = .01). In the flexibility of the lower extremities (SART ^{NMG} = 49.24 ± 14.87; SART $^{40\text{-}77\ BPM}$ = 48.11 ± 10.69; SART $^{78\text{-}120\ BPM}$ = 48.33 ± 8.21; SART $^{121\text{-}200\ BPM}$ = 47.59 ± 8.31), it was found that there was no significant difference among the four groups (f = .07; p = .98). As for muscular endurance of the core (PT ^{NMG} = 108.64 ± 45.31; PT $^{40\text{-}77\ BPM}$ = 92.63 ± 27.52; PT $^{78\text{-}120\ BPM}$ = 82.72 ± 40.16; PT $^{121\text{-}200\ BPM}$ = 109.53 ± 85.70), there were insignificant differences among the groups (f = 1.99; p = .12). The muscular strength of the upper extremities (1RM ^{NMG} = 74.16 ± 17.11; 1RM $^{40\text{-}77\ BPM}$ = 72.46 ± 21.24; 1RM $^{78\text{-}120\ BPM}$ = 60.59 ± 16.80; 1RM $^{121\text{-}200\ BPM}$ = 67.32 ± 17.09) was also found to be insignificantly different among the groups (f = 1.03; p = .39). Lastly, there was also an insignificant difference in the reaction time (RDT ^{NMG} = 9.46 ± 2.45; RDT $^{40\text{-}77\ BPM}$ = 14.42 ± 8.84; RDT $^{78\text{-}120\ BPM}$ = 8.78 ± 2.94; RDT $^{121\text{-}200\ BPM}$ = 10.41 ± 4.37) (f = 1.99; p = .12), and in the agility of the participants (HJC ^{NMG} = 13.46 ± 2.65; HJC $^{40\text{-}77\ BPM}$ = 14.78 ± 2.62; HJC $^{78\text{-}120\ BPM}$ = 12.92 ± 1.81; HJC $^{121\text{-}200\ BPM}$ = 13.53 ± 2.11) (f = 2.08; p = .11).

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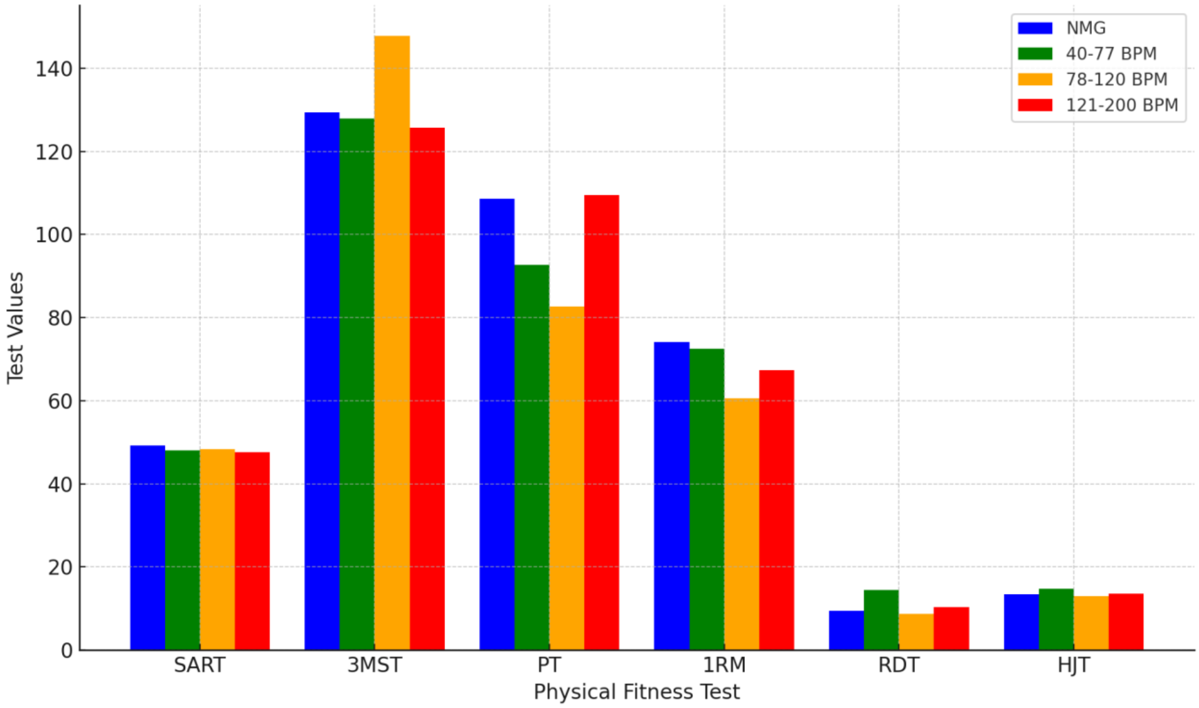
Table 8. Physical Fitness Components Comparison among Groups



Physical fitness test	NMG	40-77BPM	78-120BPM	121-200BPM	f-value	p-value
SART	49.24±14.87	48.11±10.69	48.33±8.21	47.59±8.31	.07	.98
3MST	129.41±29.32	127.89±31.02	147.78±36.44	125.65±23.11	4.02	.01
PT	108.64±45.31	92.63±27.52	82.72±40.16	109.53±85.70	1.99	.12
1RM	74.16±17.11	72.46±21.24	60.59±16.80	67.32±17.09	1.03	.39
RDT	9.46±2.45	14.42±8.84	8.78±2.94	10.41±437	1.99	.12
HJT	13.46±2.65	14.78±2.62	12.92±1.81	13.53±2.11	2.08	.11

Note: SART= Sit and Reach Test; 3MST= Three-minute Step Test; PT=Plank Test; 1RM=One Repetition Maximum; RDT=Ruler Drop Test; HJT=Hexagon Jump Test

Discussion

Limitations

The investigation of the effect of different music tempos on several physical fitness components has limitations. The music used as an ergogenic aid focused only on the song playlist's beats per minute or tempo. Aspects such as lyrics, meaning of the song, and genre were not considered when collecting songs for the playlist. Also, the

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music preferences of the participants were not considered in selecting songs that can affect physical fitness, such as muscular endurance (Ballmann et al., 2018; Nakamura et al., 2010) and power (Meglic et al., 2021). As for the fitness testing used in the study, only one field test was used per fitness component involved in the study. This may limit the results to only particular testing. The aforementioned limitations were explained for the study result to be in-depth and meaningful.

Within Group Comparison of No Music and 44-77 BPM Group

Paired T-test was used to analyze each group's data for within-group comparison. The No Music Group and 44-77 BPM music tempo did not improve the physical fitness components investigated in the study. The aforementioned music tempo was established to be a good ergogenic aid to improve post-activity recovery from training. This bpm range improved subjective recovery for runners (Jones et al., 2017) and aided post-exercise recovery when combined with proper nutrition (Zhou, 2021). Also, it can lower heart rate during exercise (Torkamandi et al., 2020). However, this music tempo was ineffective in improving athletic parameters such as anaerobic capacity, peak or mean power (Atan, 2013), and cardiorespiratory parameters (Jones et al., 2017). Previous literature suggests that this music tempo range should be used as a post-recovery rather than a pre-physical activity ergogenic aid. In the present study, it was implemented before the physical activity, contrary to its established use as a post-workout aid. This implies that the music tempo is not effective when used as a pre-workout aid as it is more effective as a post-workout aidGuided by the previous studies and the result of the study, future studies should focus on the usage of this music tempo as a post-activity aid which facilitates recovery.

Within Group Comparison of 78-120 BPM Group

As for the 78-120 BPM group, a significant increase in performance was observed in the flexibility of the lower extremities and change of direction agility. Previous studies suggest that this music tempo significantly improves various fitness parametersers. Music at 85-90 bpm increased peak power during resistance exercises without affecting fatigue (Brohmer et al., 2006). At 85-90 bpm, motivational music

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improved aerobic performance and reduced perceived exertion (Ghadery et al., 2009). Synchronous music at 80-97 bpm extended endurance and improved mood in triathletes (Terry et al., 2012), while progressive music (60-120 bpm) increased oxygen consumption, heart rate, and endurance (Torkamandi et al., 2020). However, there were studies which was contradicted by the present study result. A study established no significant changes in power or fatigue at 120 bpm (Pujol et al., 1999). The same case was seen on music at 94-141 bpm; it reduced work output during the CrossFit® session (Brupbacher et al., 2014). Music in the 78-120 BPM range enhances flexibility, agility, and endurance, though some studies report no significant or negative effects at certain tempos.

From another perspective, flexibility was increased because of the pain-soothing property of music listening. It was argued that flexibility was not improved by physical changes in the muscle-tendon unit but by changes in pain perception(Muanjai et al., 2017). This was observed during stretching to the point of pain and discomfort. Also, stretching at higher intensities, even beyond the pain threshold, significantly increases flexibility (Hatano et al., 2022; Iwata et al., 2019; Takeuchi et al., 2020). As for music and its pain reduction properties, numerous studies established that listening to music significantly improved pain thresholds. It significantly reduces pain intensity and emotional distress from pain across different settings (Lee, 2016; Timmerman et al., 2023; Ting et al., 2022). Specifically, there is a reduction of pain responses among individuals with normal levels of general and pain-specific anxiety (Choi et al., 2018). With this, the use of opioids and other analgesics after surgery and painful procedures were reduced (Lee, 2016; Cepeda et al., 2006). With this literature, it can be indirectly explained that music listening might affect flexibility through its pain reduction property, as flexibility improvement was more of a change in pain perception rather than a change in muscle-tendon unit. As for agility, a study on highly motivating music and the V-cut test was done. It was found that the implementation of music did not significantly increase (Blascoe-Lafarga et al., 2021). This previous study contradicted the improvement brought by the aforementioned music tempo and change of direction agility. Flexibility improvements may result from music's pain-reducing properties rather than muscle changes, while agility may also benefit from certain music tempos,

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although some studies show no significant effects. This implies that the music tempo can be used as an aid in activities and sports that demand flexibility and agility. Also, the present study result should be validated through replication of the study, particularly focusing on flexibility and agility. Future studies can widen the investigation on flexibility and the music tempo by including different types of flexibility, such as dynamic and static. As for agility, future studies can focus on its variation, such as change of direction and reactive agility.

Within Group Comparison of 121-200 BPM Group

Lastly, the 121-200 BPM group was observed to significantly increase performances on reaction time and change of direction agility. Previous studies support that music within the 121-200 bpm range generally improves performance in various physical activities. Fast music (~145 bpm) enhances anaerobic power, sprint speed, agility, and muscular endurance (Arazi et al., 2017). Music between 90-150 bpm has been found to lower perceived exertion (RPE) during leg presses and walking, making exercise less strenuous (Patania et al., 2020). Additionally, self-selected music over 120 bpm boosts endurance during resistance exercises (Bartolomei et al., 2015), while music at 120-130 bpm significantly increases absolute and relative peak power (Isik et al., 2015). Fast-tempo music (~140 bpm) improves power output in anaerobic activities such as rowing and enhances peak anaerobic power in athletes (Pusey et al., 2023; Eliakim et al., 2007; Meglic et al., 2021). In terms of strength, fast, loud music (~126 bpm) improves grip strength (Karageorghis et al., 2018), and stimulant music (~134 bpm) yields better strength performance than sedative music (Feiss et al., 2021). Cardiovascular performance also benefits from fast music, particularly during anaerobic warm-ups, positively affecting heart rate and fatigue index (Puad et al., 2020). Furthermore, fast-tempo music enhances the subjective recovery experience, although it does not significantly affect cardiorespiratory markers (Jones et al., 2017). Music between 94-141 bpm also improves perceived exertion and performance during progressive exercise (Mohammadzadeh et al., 2008). However, the present study contradicts previous literature about the aforementioned music tempo. In a study, fast music (200 bpm) has shown no substantial effects on power or fatigue during resistance

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exercises (Atan, 2013). Additionally, music in the 94-141 bpm range may distract during CrossFit® sessions, reducing work output (Brupbacher et al., 2014). Music within the 121-200 bpm range significantly enhances performance in physical activities such as reaction time, agility, anaerobic power, and endurance. However, effects can vary depending on context, with some studies reporting no impact on power or fatigue during resistance exercises and reduced work output in CrossFit® sessions.

As for reaction time, previous studies suggest that listening to music can improve reaction not only as a physical fitness component but also as a sensory component. It was found that musicians have faster auditory and multisensory compared to non-musicians, suggesting that long-term music exposure can improve sensory integration and reaction time(Landry & Champoux, 2017; Brochard et al., 2004; Khemthong et al., 2021). This was the same for the elderly individuals who underwent musical training (Khemthong et al., 2021). As for agility as an improved fitness component of the aforementioned music tempo, the present study result contradicts the previous study. A study was conducted on the impact of highly motivating music in relation to the V-cut test, focusing on agility. The findings indicated that the use of music did not lead to a significant increase (Blascoe-Lafarga et al., 2021). This earlier research challenged the enhancements suggested by the previously mentioned music tempo and agility in changing direction. Studies suggest listening to music can improve reaction time and sensory integration, especially in musicians and the elderly. However, its impact on agility is less conclusive, with some research showing no significant effect on agility performance. The result of the study should be replicated on the part of its investigation on reaction time and agility. The study observed improvement in reaction time and agility, which implies that the music tempo can be used for physical activities that require the said fitness parameter. Through this, the result will be validated. Future studies should focus on the investigation of reaction time in athletic settings. This can be achieved through different tests for reaction time. As for agility, variation of agility should be focused on future studies.

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Comparison of the Groups

After group comparisons using one-way ANOVA revealed that cardiovascular endurance enhancement due to music as an ergogenic aid was superior to the 121-200BPM music tempo. This was compared to 40-77BPM, 78-120BPM, and no music. Several studies established the superiority of higher music tempo to cardiovascular endurance. Fast-tempo music (170-190 bpm) reduced perceived exertion and increased heart rate, particularly during endurance activities compared to high-intensity exercises (Patania et al., 2020). Also, a study found that fast-tempo music (140 bpm) also increased heart rate, though its effect on endurance performance was minimal (Aburto-Corona et al., 2020).

Similarly, fast-tempo music was linked to higher cardiovascular responses, such as increased heart rate and blood pressure (Bernardi et al., 2009). Several studies have shown that fast-tempo music (140-190 bpm) generally increases heart rate and cardiovascular responses, particularly enhancing perceived exertion during endurance activities, though its impact on endurance performance varies. Although the previous study supports the result of the present study, it is very important to note that the instrument used in quantifying cardiovascular endurance uses heart rate. A lower heart rate in the test signifies better performance on cardiovascular endurance. It can be implied that when choosing a music tempo to improve cardiovascular endurance, 121-200bpm songs should be selected. The result needs validation through replication focusing on cardiovascular endurance. Also, future studies should consider the criteria of performance used by the testing that will be used.

Conclusion

The paired t-test was employed to examine the within-group data for each group. The No Music Group and the 44-77 BPM music tempo group did not demonstrate any notable enhancement in the physical fitness components examined in the study. Nonetheless, the group with a music tempo ranging from 78 to 120 BPM showed a notable improvement in flexibility of the lower limbs and agility in changing direction. Furthermore, the group with a music tempo ranging from 121 to 200 BPM demonstrated a notable enhancement in reaction time and agility in changing direction.

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As a result of ANOVA, cardiovascular was found to be different among groups. The 121-200BPM music tempo was superior to 40-77BPM, 78-120BPM, and no music.

The results indicate that music with a tempo of 44-77 BPM is not useful as a pre-workout support but could be more advantageous for recovery after a workout. The music tempo ranging from 78 to 120 BPM seems to significantly boost performance in activities or sports that demand flexibility and agility. The noted enhancement in reaction time and agility among those exposed to music within the 121-200 BPM range suggests that this specific tempo could benefit physical activities requiring these fitness attributes. Furthermore, it is recommended that to enhance flexibility, reaction time, and agility, one should choose music within the 78-200 BPM range.

Building on earlier research and the findings of this study, subsequent investigations should delve into the possible application of 44-77 BPM music as an aid for recovery after workouts. Additional research could explore flexibility within the 78-120 BPM range by analyzing various forms of flexibility, including dynamic and static types. Future research should delve into various facets of agility, including change of direction and reactive agility. In the same vein, for the 121-200 BPM range, additional research could investigate its impact on various forms of flexibility and agility. Also, genre-based comparison should be done to explore if music genres differed in their effect on athletic performance. To ensure the reliability of group comparisons, this study's findings need to be confirmed through replication, especially emphasizing cardiovascular endurance. Future research should also consider the standards applied for performance evaluation to guarantee reliability and precision.

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