Effects of 440-Hz vs. 432-Hz preferred music frequencies, during warm-up, on intermittent anaerobic speed test perfor-mance in men and women kickboxers: a double-blind crossover study (#108564)

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Effects of 440-Hz vs. 432-Hz preferred music frequencies, during warm-up, on intermittent anaerobic speed test performance in men and women kickboxers: a double-blind crossover study

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The present study assessed the effects of listening to preferred music during warm-up at different frequencies on physical performance and psychophysiological responses specific in male and female kickboxers. In a double-blind crossover study design, fifteen men and thirteen women kickboxers randomly performed the intermittent kickboxing anaerobic speed test (IKAST) after listening to preferred music around 440 Hz (PM44Hz), or 432 Hz (PM432Hz) frequencies or no music during warm-up. Physical performance indices and heart rate, blood lactate, rating of perceived exertion (RPE) and feeling scale (FS) were measured just after the test. Warm-up with PM440 Hz significantly improved IKAST performance indices with the highest maximum impact velocity and FS, lowest mean heart rate and RPE, followed by PM432 Hz for both genders compared to the control condition. For sex interaction, men had lower heart rate with PM440Hz, women the lowest with PM432Hz. In addition, women had higher positive feeling scale with PM440Hz, while men did not experience any significant change between the two musical conditions. PM440Hz during warm-up was found to be more effective in improving specific performance, positive mood with a potential dissociation from discomfort during the test. Also, women were more affected by the music frequency difference compared to men.

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Abstract

The present study assessed the effects of listening to preferred music during warm-up at different frequencies on physical performance and psychophysiological responses specific in male and female kickboxers.

In a double-blind crossover study design, fifteen men and thirteen women kickboxers randomly performed the intermittent kickboxing anaerobic speed test (IKAST) after listening to preferred music around 440 Hz (PM44Hz), or 432 Hz (PM432Hz) frequencies or no music during warm-up. Physical performance indices and heart rate, blood lactate, rating of perceived exertion (RPE) and feeling scale (FS) were measured just after the test.

Warm-up with PM440 Hz significantly improved IKAST performance indices with the highest maximum impact velocity and FS, lowest mean heart rate and RPE, followed by PM432 Hz for both genders compared to the control condition. For sex interaction, men had lower heart rate with PM440Hz, women the lowest with PM432Hz. In addition, women had higher positive feeling scale with PM440Hz, while men did not experience any significant change between the two musical conditions.

PM440Hz during warm-up was found to be more effective in improving specific performance, positive mood with a potential dissociation from discomfort during the test. Also, women were more affected by the music frequency difference compared to men.

Keywords: fast tempo music; tone frequencies; specific exercise; psychophysiological responses; physical performance

Introduction

Combat sports such as kickboxing are disciplines that are generally organized by weight, age and sex. In a competition, two kickboxers of the same weight and the same age class compete for points awarded in specified target areas in the form of punches and kicks, or for a technical knockout (KO). Success in kickboxing requires a combination of technical and tactical skills as well as mental, physical, and emotional preparation (Buse & Santana, 2008).

In order to optimize performance, athletes and their coaches use different types of ergogenic preconditioning strategies. Depending on the type of sport, coaches and athletes use different strategies or aids. One of them is music, which has proven to be effective and used in several sports (Ouergui et al. 2023a; Jebabli et al., 2023b; Blasco-Lafarga et al., 2022). In fact, the benefits of listening to music includes delayed perception of neuronal fatigue (Diehl et al., 2023), improved muscle efficiency (Centala et al., 2020), increased neuronal activity (Bigliassi et al., 2017), and improvements in mood (Jebabli et al., 2023a), attention (Patania et al., 2020), and self-efficacy (Pettit et al., 2020). While these findings have been documented in many sports the use of music's ergogenic properties in kickboxing remains a relatively unexplored territory.

However, this gap has been gradually filled by recent studies that investigated the impact of music in some other combat sports such as Taekwondo (Ouergui et al. 2023a,b; Delleli et al., 2024; Messaoudi et al., 2024). For example, Ouergui et al. (2023a) showed that the use of pre-selected music during warm-up in Taekwondo athletes would improve mood satisfaction and physical performance. Ouergui et al. (2023a) observed that listening to music with a tempo of 140 beats per minute, a sound volume of 80 decibels was the most favorable condition to obtain better physical performance as well as better punching speed. In addition, previous research suggests that it is beneficial to listen to music during warm-up phases in Taekwondo (Delleli et al., 2024; Messaoudi et al., 2024). Nevertheless, it remains ambiguous as to whether such effects can be carried over to kickboxing athletes.

In addition, previous studies show that any ergogenic effect of music in physical performance depends on auditory characteristics such as the type of music, tempo, volume, duration, or the timing of music exposure (Karageorghis & Priest, 2012; Jebabli et al., 2022, 2023a). These studies reported that the optimal effect of music on physical performance relies on specific characteristics, including high musical volume (80 dB) and fast tempo (≥120 BPM) (Jebabli et al. 2022, 2023ab, Karageorghis et al. 2018; Ouergui et al. 2023a,b). Despite these results, we do not know exactly the relational effect between musical tempo and frequency on athletic performance and psychophysiological responses. In other word, the synergistic integration between frequency and rhythm of music remains unknown. However, music tuned to different frequencies such as 440 Hz and 432 Hz has attracted attention for its distinct positive effects on public health (Calamassi et al., 2019; Halbert et al., 2018; Suarez et al., 2024).

Theoretically, the basic source of musical sound is given by the frequency in Hertz (Gray, 1999). These frequencies theoretically define the pitch and timbre of the sound produced (Rutherford-Johnson et al., 2017). The frequency around 440 Hz or the pitch of A-440 Hz has been accepted as a standard reference for tuning many musical instruments. In fact, in 1975, ISO had already issued 440 Hz as the standard tuning frequency for most musical compositions. This frequency corresponds to pitch class A4. Thus, such standardization has become an international reference point in musical tuning, influencing a wide range of performances and musical records.

Music at 440 Hz with fast tempos and standards frequencies is crisp and clear, increasing concentration and intensity in workouts, anaerobic performance by increasing heart rate and perceived exertion, especially during high-intensity training sessions (Ouergui et al., 2023a,b ; Jebabli et al., 2023a). On the other hand, music at 432 Hz is generally considered more harmonious and relaxing, recently, it has also begun to be introduced during recovery and mental preparation phases, with claims of reducing anxiety, improving relaxation and increasing the mind-body connection (Fauble, 2016). However, no studies have compared the effects of 440 Hz vs. 432 Hz music in physical performance; an area in which research is particularly worthy of interest.

Therefore, the aim of the present study was to investigate the effects of listening to preferred music at different frequencies (i.e., 440 Hz vs. 432 Hz) during warm-up on specific physical performance in kickboxing. Based on the above objectives, it was hypothesized that: (a) listening to preferred music at a fast pace with frequencies around 440 Hz and 432 Hz improves specific physical performance in Kickboxing for both sexes (b) listening to preferred music at 432 Hz is more effective in reducing RPE compared to the preferred music condition at 440 Hz (c) the effect of preferred music on physical performance has the same degree of improvement for both sexes.

Materials & Methods

Study design

This study is a randomized, double-blind, crossover trial examining the impact of listening to preferred music at frequencies of 440 Hz or 432 Hz during warm-up on physical performance and psychophysiological responses in kickboxing. Participants were exposed to three conditions: (1) listening to preferred music around 440 Hz (PM-440Hz) during warm-up, (2) listening to preferred music around 432 Hz (PM432Hz) during warm-up, and (3) a control condition with no-music during warm-up. Prior to the experimental procedures, the kickboxers were thoroughly familiarized with the testing protocols. Each athlete completed the Intermittent Kickboxing Anaerobic Speed Test (IKAST) (Gençoğlu et al., 2023) under each condition in separate sessions, with a 48-hour recovery period between sessions.

Before each testing session, participants underwent a standardized 10-minute warm-up protocol according to van den Tillaar et al. (2019), which included 5 min jogging (60–65% of maximal heart rate), 4 minutes of running (three runs of 60 m at 75, 85 and 95% of maximal self-estimated intensity; recovery: 1 min between each run), and one minute of lateral movements and dynamic stretching. After this, two minutes of passive recovery was followed before the specific warm-up was continued under one of the three conditions. All testing sessions were conducted at the same time of day (3PM ± 1 hour) to control for diurnal variations in performance and in the same gym with a moderate temperature (23–25˚C).

Participants were instructed to avoid vigorous exercise for 48 hours prior to each testing session. They were also advised to maintain their usual hydration, dietary habits, and sleep patterns, and to refrain from consuming any ergogenic supplements (e.g., caffeine, vitamins) in the 24 hours leading up to each session.

The study's design and progression are depicted in *Figure 1*, which provides a Consolidated Standards of Reporting Trials (CONSORT) flow diagram, and *Figure 2* details the methodological rigor.

Participants

A priori power analysis was conducted using G*Power software (Version 3.1.9.4, University of Kiel, Kiel, Germany) with the F test family (ANOVA: repeated measures, within factors). The sample size calculation, using G*Power 3.1.9.7 software (Franz Faul, University of Kiel, Kiel, Germany), was based on a statistical power of 0.80, a significance level of 0.05, and an effect size of 0.25. The analysis indicated that 28 participants were needed to achieve 80% power.

Twenty-eight kickboxers (15 men and 13 women) volunteered to participate in the study (*Table 1*). All participants were recruited from the same local training club and met the following inclusion criteria: 1) at least 4 years of kickboxing experience; 2) no muscular or joint injuries; and 3) for women, no menstrual-related dysfunctions (such as amenorrhea) and no use of hormonal contraception in the 2 months prior to the study.

After a thorough explanation of the study's objectives and potential risks, athletes provided written informed consent. The study adhered to the most recent Declaration of Helsinki guidelines for human research and received approval from the local ethics committee at the High Institute of Sport and Physical Education of Kef on March 9, 2022 (approval number UR22JS01 / ISSEP-015-22) prior to the commencement of data collection.

Musical Characteristics

Participants were asked to select their preferred favorite music. Using the Audacity application, the tempo of each chosen song was adjusted to a fast tempo of 140 beats per minute (bpm) and set to a volume of 80 dB. Each song was played for 10 minutes per session, during warm-up, through the same wireless headphones (AirPods Pro, Apple, US) for all participants. The music was recorded at two different frequencies, 440 Hz and 432 Hz in WAV format using the Audio Processing Object (APO) software. To ensure the double-blind procedure, the recordings at different frequencies (440 Hz; 432 Hz) were made by an independent researcher who was not directly involved in the present study.

Measurements

The specific anaerobic speed test in kickboxing (IKAST) involved 5 repetitions of a combination of 4 techniques: (1) right-left punch, (2) right roundhouse kick, (3) right-right punch, and (4) left roundhouse kick. This sequence was performed over five sets with a 10-second rest between each set (Gençoğlu et al., 2023). The total execution time of the test was used as a measure of physical performance.

Performance indices assessed included: the total duration of strikes (total time), the best set (the peak time for kicks and punches recorded in a single set), and the fatigue index. The fatigue index, indicating the relative decrease in power, was calculated using the following formula:

Fatigue Index (%)= [1−(peak time×5total duration of strikes across all sets)]×100

Additionally, the maximum speed of the best technical impact was determined. All physical indices (duration and maximal speed) during the test were analyzed from video recordings using Kinovea software (version 0.9.5). Videos were recorded at a resolution of 1080p (1920 × 1080, 16:9) and 48 frames per second (FPS) using the GoPro4 session camera.

During the test, a heart rate monitor (Polar Team 2, Polar Electro Oy, Finland) recorded both peak heart rate (HRpeak) and mean heart rate (HRmean). Participants' overall physical exertion was assessed immediately after the test using the Rating of Perceived Exertion (RPE) scale (6-20 Borg scale; Borg, 1982). Additionally, the feeling scale was used to assess affective responses by using an 11-point bipolar numeric rating scale [ranges from -5 (very unpleasant) to +5 (very pleasant)] measuring current mood after testing (Hardy and Rejeski, 1989).

The intra-class correlation coefficients (ICC) for test-retest reliability were 0.91 for total time, 0.89 for best time and 0.87 for fatigue index.

Statistical Analysis

Normality of data distribution was assessed and confirmed using the Shapiro-Wilk test. Test-retest reliability for all variables was evaluated using Cronbach's intraclass correlation coefficient (ICC) and the coefficient of variation (CV).

To investigate the effect of condition and sex, a 2 (sex) x 3 (test condition: repeated measures) ANOVA was conducted to analyze differences among conditions for average and peak hear rates, blood lactate, maximal speed impact, total and best set time, fatigue index, RPE and feeling scale. To assess difference between the sets of the IKAST and conditions a 2 (sex) x 3 (test condition) x 5 (set 1-5) ANOVA of repeated measures was conducted. When significant differences were detected, post-hoc comparisons were performed with Holm-Bonferoni correction. Effect size was evaluated with Eta partial squared where $0.01< \eta^2<0.06$ constitutes a small effect, $0.06< \eta^2<0.14$ a medium one and $\eta^2>0.14$ a large effect (Cohen, 1988). Where the sphericity assumption was violated, the Greenhouse–Geisser adjustments of the p-values were reported. The level of significance was set at $p < 0.05$. All data analyses were performed using JASP v. 0.17.3 (University of Amsterdam, Amsterdam, Netherlands). Data were presented as means and standard deviations (SD).

Results

A significant sex effect for total time, best time and maximal impact speed ($F \geq 21.4$, $p < 0.001$, $\eta^2 \geq 0.45$) was observed, while significant effects of warm-up condition were found upon all parameters ($F \geq 21.0$, $p < 0.001$, $\eta^2 \geq 0.15$), except fatigue index ($F = 0.57$, $p = 0.57$, $\eta^2 = 0.01$) and lactate ($F = 2.0$, $p = 0.145$, $\eta^2 < 0.01$). In additions, significant interaction effects on maximal impact velocity, feeling scale and mean heart rate were found. however, with small effect sizes ($F \leq 7.5$, $p < 0.001$, $\eta^2 < 0.05$).

Post hoc comparison revealed that men were faster in the best set and total time and had a higher impact speed than women in all conditions (*Table 2*). After the warm-up with PM440Hz, both men and women performed the IKAST significantly faster in the best set and total time with highest feeling scale and lowest RPE followed by the warm-up with PM432Hz for only feeling scale compared to control condition. Furthermore, the control condition had significantly higher mean heart rate and peak heart rate of the warm-up and a lower maximal impact speed compared to and PM440Hz. An interaction effect was visible as women had a significantly higher feeling scale after PM440Hz condition compared to the PM432Hz condition, which men did not have, while the opposition was found in the maximal impact speed where men had a significantly higher speed after PM440Hz compared to the PM432Hz condition and women did not. Furthermore, the mean

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heart rate was significantly the highest during the control condition, while no significant difference between the other two conditions was found, which was caused by the interaction effect between sex in PM440Hz and PM432Hz conditions: men had a significant lower mean heart rate after PM440Hz condition compared to PM432Hz condition, while the women had the lowest mean heart rate after the warm-up with PM432Hz condition compared with PM440Hz condition (*Table 2*).

When evaluating the development over the five sets of the IKAST between the conditions, a significant effect of set ($F = 267$, $p < 0.001$, $\eta^2 = 0.01$), condition, ($F = 5982$, $p < 0.001$, $\eta^2 = 0.08$), sex ($F = 23.1$, $p < 0.001$, $\eta^2 = 0.42$) and condition*set ($F = 21.2$, $p < 0.001$, $\eta^2 < 0.01$), set*sex ($F = 7.2$, $p < 0.001$, $\eta^2 < 0.01$), set*sex*condition ($F = 2.9$, $p = 0.005$, $\eta^2 < 0.01$) interaction effects were found. Post hoc comparison revealed that the set times were significantly longer when using the control condition in each set followed by PM432Hz and the shortest sets at PM440Hz condition. In the control and PM440Hz conditions, the time increased from set to set when evaluated for all subjects together, but only from set 2 to 3 in PM432Hz, followed by a decease and increase in set 4 and 5 for this condition (*Figure 3A*). Furthermore, men were faster than women in all sets in all conditions, in which both men and women increased times from set to set in control condition. While women also did this in PM440Hz condition, men did not increase the time between set 4 and 5 significantly. Furthermore, in PM432Hz condition both groups increase from set 2 to 3 and between set 4 and 5, while the women significantly decrease time from set 3 to 4 whereas men did keep the same time between these two sets (*Figure 3B*).

Discussion

The primary aim of this study was to assess the effects of listening to preferred music at different frequencies (440 Hz vs. 432 Hz) during warm-up on specific physical performance and psychophysiological responses in amateur kickboxers. The main findings of this study were that after the warm-up with PM440Hz both men and women performed the IKAST significantly faster (shorter total and best times) with highest feeling scale and lowest RPE followed by the warm-up with PM432Hz and thereafter significantly again by the control condition. Furthermore, the control condition had significantly higher mean and peak heart rate of the warm-up and a lower maximal impact speed. For the sex interaction, men had a lower heart rate during PM440Hz, women the lowest during PM432Hz. Additionally, women had a higher positive feeling scale during PM440 Hz, while men did not experience a significant change between the two music conditions.

As shown in the present study it seems that warm-up with PM440Hz resulted in the fastest IKAST performances compared with PM432Hz and control conditions in both men and women kickboxers. Given that most musical compositions globally use a standard frequency of 440 Hz as a tuning reference and by the fact that participants are generally exposed from birth to music whose vibrations and harmonics are determined exclusively at 440 Hz. This makes this frequency more "familiar" to them as shown by the best improvement upon IKAST performance (*table 2* and *figure 1*). This was in accordance with improvement in repeated sprint performances after listening to the preferred music of 440Hz during warm-up (Chtourou et al., 2012; Eliakim et al., 2007). This improvement is likely attributable to several factors including enhanced muscle efficiency (Centala et al., 2020), increased neuronal activity (Bigliassi et al., 2017), improved attention (Patania et al., 2020), and greater self-efficacy (Pettit et al., 2020).

However, to the best of our knowledge, this is the first study to focus on the effects of 432 Hz music on physical performance. Previous research has demonstrated, for therapeutic purposes, that 432 Hz music reduces stress, anxiety and enhancing sleep quality in patients with various chronic diseases (Calamassi & Pomponi, 2019; Di Nasso et al., 2016; Dubey et al. 2019). From these findings, we can see that the relaxing effect of 432 Hz music does not have a stimulating effect on attention, which could limit its impact on improving anaerobic performance. Yet, lower peak heart rates were observed after the warm-up with PM432Hz. This could be an indication that this frequency has a more relaxing effect upon the heart than the PM440Hz condition, which also caused a lower peak heart rate (*Table 2*). Previous studies have suggested that low-frequency music may have a potential effect on reducing heart rate and promoting relaxation (Calamassi & Pomponi, 2019; Halbert et al., 2018). However, this effect was only evident in sedentary participants at rest and did not extend to conditions involving physical activity, highlighting the need for further investigation into the effect of preferred low-frequency music on heart rate responses during exercise.

The lower peak heart rate together with the lower mean heart rates during the preferred music conditions were not caused by performing at a lower intensity as IKAST performance was better after these two types of warm-ups. Furthermore, lactate levels and the fatigue index were similar to the control condition indicating that the kickboxers exercised with the same intensity. Previous studies suggested that listening to music may offer improved distraction from fatigue-related symptoms by modulating beta frequency activity in the brain (Bigliassi et al., 2019), which influence mental state during intense physical activity. Other studies reported that music can enhance muscle blood flow and thus affect lactate clearance during high-intensity exercise (Ghaderi et al. 2015; Jebabli et al., 2023a). However, no such effects were observed in the present study, which may also be due to differences in the types of exercise and music characteristics such as rhythm, volume, type, frequency and melody.

The warm-ups with preferred music caused higher level of performance afterwards with similar fatigue responses (lactate and fatigue index). However, the psychophysiological responses were positively altered after listening to music during warm-up, regardless of the frequency, for both sexes, as observed by improves positive mood with lower ratings of perceived exertion (RPE) compared to no-music condition (*Table 2*). These findings are consistent with previous researches demonstrating the reducing effect of music on RPE (Ballmann et al., 2019; Ballmann, 2021). This phenomenon may be due to enhanced dissociation from discomfort and exertion during exercise following exposure to preferred music during the warm-up phase. Music is well-established as an effective external distractor that reduces sensations of fatigue (Ballmann et al., 2019; Potteiger et al., 2000; Bigliassi et al., 2019). For instance, Ballmann et al. (2019) found that RPE was lower in participants who performed the Wingate test while listening to their preferred music.

Besides the positive effect of listening to music in both sexes on mood state, our results showed that the frequency difference only influenced the women as they had a significantly more positive feeling mood after listening to PM440Hz music compared with PM432Hz during the warm-up. While men had a reduced RPE after PM440Hz condition compared to PM432Hz condition, women had similar reductions after both music warm-ups which was in accordance with Rhoads et al. (2021) who reported that women had lower RPE values during music conditions compared to the control condition. These different responses between sexes can perhaps be explained by the evidence that women tend to show greater emotional responses to musical stimuli than men (Nater et al., 2006). It is not yet clear how these differences arise, but there are indications that there are sex differences in how the brain responds to music (Koelsch et al., 2003). These small but important differences in brain activation during exercise with music may allow women to better dissociate physical and psychological fatigue. Consistent with this hypothesis, Carlson et al. (2015) found that women's prefrontal cortex activity while listening to music better maintained attention to negative thoughts than men.

Other sex differences found in the present study were the faster execution time and higher maximal impact speed of men compared to women. This is expectable as men are stronger and faster than women (Nikolaidis et al., 2016). However, the development in execution times over the sets were similar for the men and women kickboxers (*Figure 1*) indicating that the warm-ups have similar effect on the physical performance in both sexes. Although the maximal impact speed did not significantly increase in the women, while it did in men causing a significant interaction effect, this had only a very small effect size (0.01) and thereby not so important. The same was found for mean heart rates in which a significant interaction effect was found as both reduced mean heart rates after a warm-up with listening to music, but men had the lowest heart rate after PM432Hz condition, while women had it after PM440Hz warm-up. The difference was only on average 1 beat/min and had a very small effect size and thereby not so important.

Finally, we acknowledge some limitations of the present study. Indeed, the absence of indices such as neural activation that provide more details on how each sex responds to exercise after listening to preferred music at different frequencies. Similarly, the IKAST applied in this study was an anaerobic test specific to kickboxing that does not reflect the global and cumulative psychophysiological stress developed by kickboxers during competition. In this context, further studies are needed to determine the effect of preferred music at different frequencies on physical and psychophysiological responses during a simulated kickboxing combat.

Conclusions

Listening to preferred music with at high tempo (140 beats/min), high (80 dB) loudness with frequencies of both 440 and 432Hz are both effective for kicking performance in men and women kickboxers. However, the standard frequency around of 440 Hz applied during warm-up was more effective to improve specific performance, positive mood with potential dissociation from discomfort during test, with some sex difference in positive mood as women were affected by the difference in frequency and men not. The practical results of these findings highlight the benefits of listening to music in warm-up has been shown to improve physical performance and positive mood, while decreasing subjective fatigue, so that coaches have a practical approach to help athletes better prepare for competition and make the training experience more enjoyable and pleasant.

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Table 1(on next page)

Characteristics of the participants.

values are mean ± standard deviation (n = 28).

Table 1. Characteristics of the participants.

sex	N	Age (years)	Body mass (kg)	Height (m)	BMI ($kg·m^{-2}$)	Kickboxing experience (years)
Men	15	19.53±2.23	67.63±7.91	1.78±0.08	21.36±1.05	4.47±0.9
Women	13	18.08±1.12	56.71±11.53	1.63±0.09	21.15±2.99	3.96±0.9
Overall	28	18.86±1.92	62.56±11.06	1.71±.11	21.27±2.13	4.23±0.92

Note: values are mean ± standard deviation (n = 28).

Table 2 (on next page)

Effects of listening to preferred music at frequencies around 440 Hz or 432 Hz and no music during warm-up on physical performance and psychophysiological responses on men and women in kickboxing.

Data are shown as the Mean (Standard deviation); P value (Eta partial squared); * indicates a significant difference with all other conditions for both men and women ($p<0.05$); ‡ Indicates a significant difference with other conditions for this sex ($p<0.05$); † indicates a significant difference between men and women ($p<0.05$).

Table 2. Effects of listening to preferred music at frequencies around 440 Hz or 432 Hz and no music during warm-up on physical performance and psychophysiological responses on men and women in kickboxing.

Parameter	sex	No music	440Hz	432Hz	Condition	sex	Condition×sex
Total time (s)	Men	50±2.65†	46.78±2.66†	47.87±2.60†	<0.001 (0.08)	<0.001* (0.43)	0.82 (<0.01)
	Women	53.66±2.27	51.26±2.26	52.35±2.20			
	Both	51.63±3.33*	48.86±3.33*	49.95±3.29*			
Best time (s)	Men	9.72±0.51†	9.24±0.52†	9.47±0.50†	<0.001* (0.09)	<0.001* (0.42)	0.70 (<0.01)
	Women	10.58±0.46	10.11±0.46	10.32±0.44			
	Both	10.11±0.65*	9.64±0.65*	9.87±0.67*			
Fatigue index (%)	Men	-1.25±0.37	-1.26±0.35	-1.03±0.41	0.56 (0.01)	0.061 (-0.51)	0.38 (0.02)
	Women	-1.40±0.34	-1.39±0.33	-1.43±0.77			
	Both	-1.31±0.36	-1.32±0.34	-1.28±0.46			
Maximal impact speed (km/h)	Men	41.59±2.73†	42.24±2.69†	42.18±2.69†	<0.001* (<0.01)	<0.001* (0.45)	<0.001* (<0.01)
	Women	37.01±2.63	37.48±2.64	37.48±2.64			
	Both	39.47±3.51*	40.03±3.57	40.00±3.54			
Mean heart rate (beats/min)	Men	168±5.2‡	165±5.17‡	166.0±5.2‡	<0.001* (0.06)	0.81 (<0.01)	<0.001* (0.01)
	Women	168.5±4.4‡	166.4±4.5‡	165.46±4.4‡			
	Both	168.2±4.8*	165.6±4.8	165.8±4.8			
Peak heart rate (beats/min)	Men	183.1±3.4	182.4±2.5	180.1±3.4	<0.001* (0.15)	0.93 (<0.01)	0.23 (<0.01)
	Women	183.8±3.1	181.5±2.9	180.6±3.2			
	Both	183.4±3.2*	182.0±2.6*	180.4±3.2*			
Lactate (mmol/L)	Men	5.74±0.73	5.68±0.63	5.70±0.65	0.15 (<0.01)	0.67 (<0.01)	0.99 (<0.01)
	Women	5.62±0.91	5.55±0.89	5.58±0.92			
	Both	5.69±0.80	5.62±0.75	5.64±0.77			
Feeling scale (-5 to +5)	Men	2.4±0.63‡	3.73±0.80	3.80±0.94	<0.001* (0.45)	0.47 (<0.01)	<0.001* (0.05)
	Women	2.15±0.69‡	4.15±0.69‡	3.08±0.76‡			
	Both	2.29±0.66	3.93±0.77	3.46±0.92			
RPE (1-10)	Men	8.40±0.83‡	6.87±0.92‡	7.47±1.19‡	<0.001* (0.33)	0.29 (0.02)	0.27 (<0.01)
	Women	8.23±0.83‡	6.62±0.87	6.85±1.07			
	Both	8.32±0.82	6.75±0.89	7.18±1.16			

Data are shown as the Mean (Standard deviation); P value (Eta partial squared); * indicates a significant difference with all other conditions for both men and women ($p<0.05$); ‡ Indicates a significant difference with other conditions for this sex ($p<0.05$); † indicates a significant difference between men and women ($p<0.05$).

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Figure 1

Figure 1. Diagram depicting the consolidated standards for reporting trials in the study.

Note: PM-440Hz, listening to preferred music around 440 Hz; PM432Hz, listening to preferred music around 432 Hz.

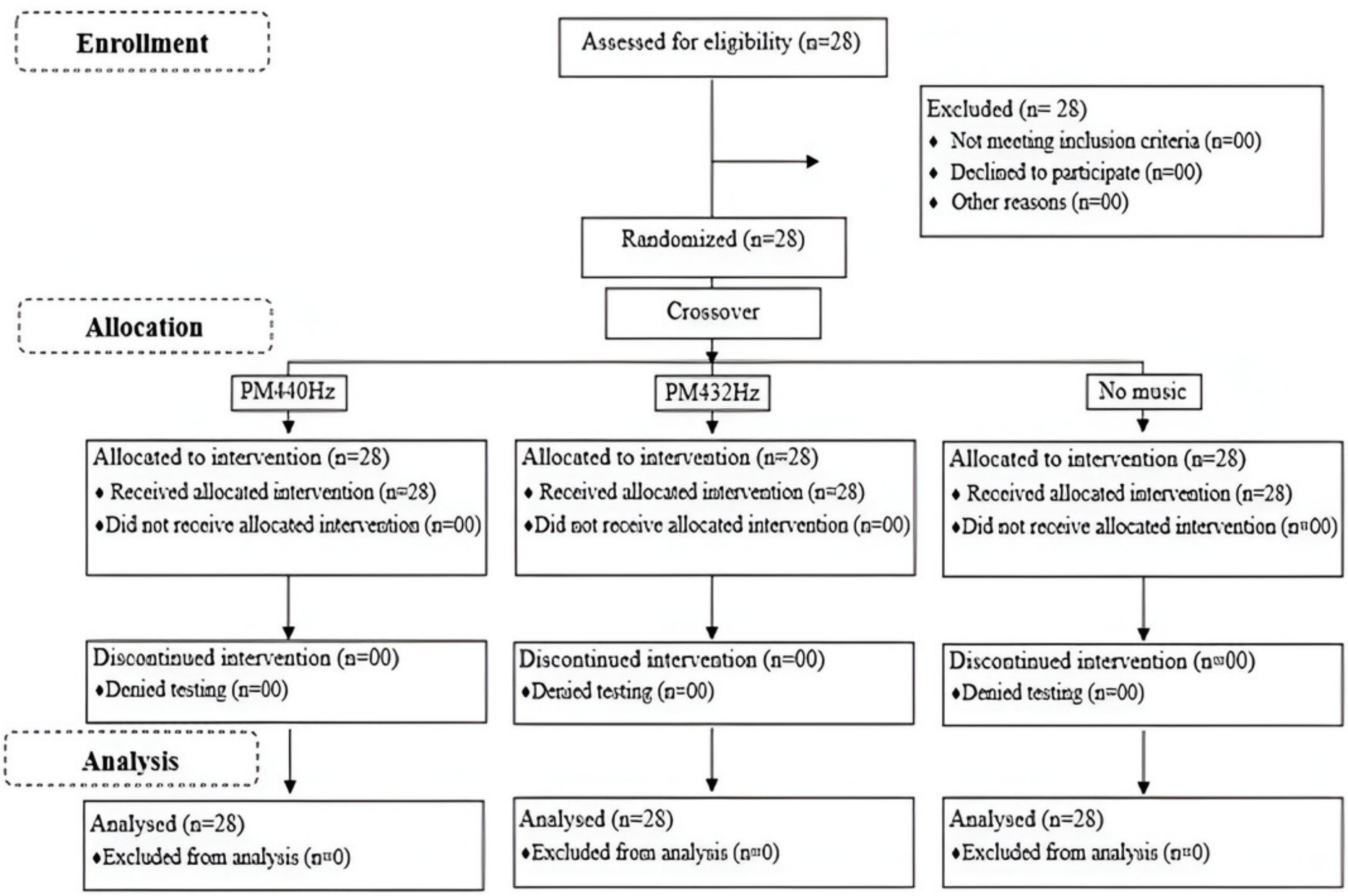

Figure 2

Figure 2. Study design.

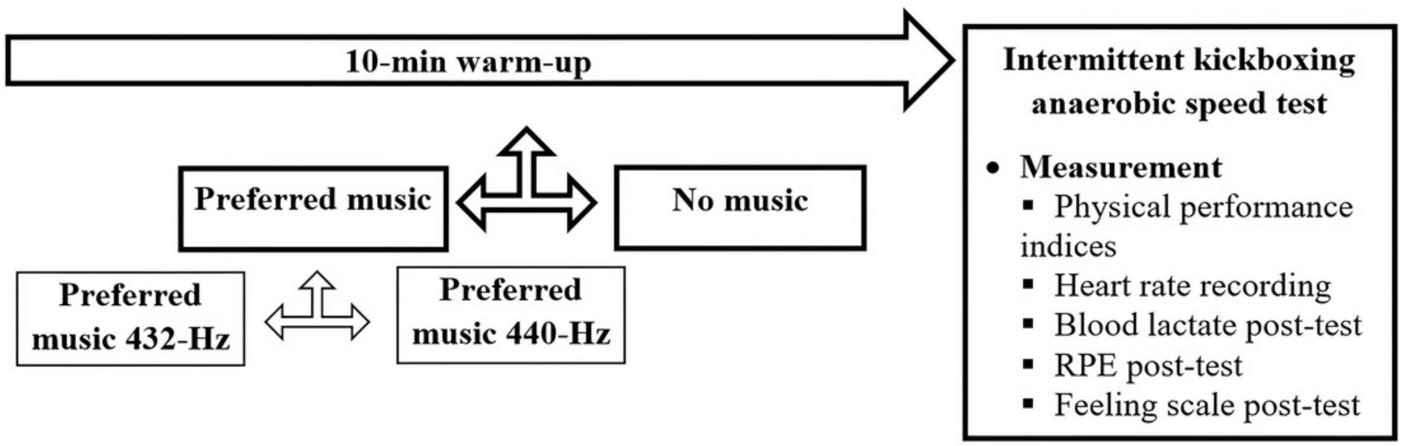

Figure 3

Figure 3. Mean (±SEM) effects of listening to preferred music at frequencies around 440 Hz or 432 Hz and no music during warm-up per set for A) all subjects and B) separated for men and women.

Note: * indicates a significant difference between the conditions for all sets; †indicates a significant difference between men and women for all conditions and sets (p<0.05); → indicates a significant difference between this set with the next one (p<0.05).