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Listening to preferred and loud music enhances taekwondo physical performances in adolescent athletes

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Abstract:	This study aimed to investigate the effects of warm-up music preference and loudness on physical performance, perceived exertion (RPE), and enjoyment in young taekwondo athletes. In a crossover counterbalanced design, taekwondo athletes (n=20; 10 male, 10 female) performed a battery of physical tasks specific to taekwondo under the following conditions: 1) No music (NM), 2) Preferred music-Soft (60 dB; PMS), 3) Preferred music-Loud (80 dB; PML), 4) Non-preferred music-Soft (60 dB; NPMS), and 5) Non-preferred music-Loud (80 dB; NPML). On each visit, participants completed a taekwondo-specific agility test (TSAT) along with the 10-second and multiple frequency speed of kick tests (FSKT-10s and FSKT-mult, respectively) with each corresponding music condition. Pre-exercise enjoyment was assessed using the physical activity enjoyment scale (PACES) after the warm-up, while RPE scores were obtained after each test. Results revealed that PML resulted in significantly better times during the TSAT compared to NM ($p<0.001$), PMS ($p=0.002$), NPMS ($p=0.001$), and NPML ($p=0.002$). Furthermore, listening to PML produced a greater number of total kicks during the FSKT-10s test compared to NM ($p=0.001$), PMS ($p=0.033$), NPMS ($p<0.001$), and NPML ($p<0.001$). Decrement index during the FSKT-10s was lower with PML versus all conditions ($p<0.001$). Additionally, pre-exercise enjoyment was significantly lower with NPML ($p=0.001$) and NPMS ($p=0.002$) compared to NM. Findings support ergogenic effects of listening to PML prior to taekwondo physical tasks which may have important implications for enhancing training and performance.

Listening to Loud Preferred Music Enhances Taekwondo Physical Performances in Adolescent Athletes

Abstract

In this study, we aimed to investigate the effects of warm-up music preference and loudness on physical performance, perceived exertion (RPE), and enjoyment in young taekwondo athletes. In a crossover counterbalanced design, 20 taekwondo athletes (10 male,10 female) performed a battery of physical tasks specific to taekwondo under the following five conditions: (a) No music (NM), (b) Preferred music-Soft (60 dB; PMS), (c) Preferred music-Loud (80 dB; PML), (d) Non-preferred music-Soft (60 dB; NPMS), and (e) Non-preferred music-Loud (80 dB; NPML). On each lab visit, participants completed a taekwondo-specific agility test (TSAT), a10-secondkick test (KSKT-10s) and a multiple frequency speed of kick tests (FSKT) within each music condition. Pre-exercise enjoyment was assessed using the Physical Activity Enjoyment Scale (PACES) after the warm-up, while we obtained RPE scores after each test. The PML condition resulted in significantly better agility test times on the TSAT compared to PMS ($p<0.001$), and NPML ($p<0.001$). Furthermore, PML led to a greater number of total kicks during the FSKT-10s test compared to the PMS ($p<0.001$), and NPML ($p<0.001$) conditions. The decrement index on the FSKT was lower in PML than in PMS and NPML conditions ($p<0.001$). For RPE, values were significantly lower with preferred than non-preferred music ($p<0.001$). These findings lend support to ergogenic benefits of listening to PML prior to taekwondo physical tasks, with important implications for enhancing taekwondo training and performance.

Keywords: Combat sports; ergogenic aid, warm-up, preference.

Introduction

Taekwondo is a combat sport that uniquely integrates physical fitness, technical-tactical skills, and psychological behaviors (Bridge et al., 2014). To succeed in taekwondo competition, combatants must be proficient in techniques and skills including functional agility, striking, and power development (Bridge et al., 2014). As taekwondo athletes execute high-intensity intermittent actions, which often lead to fatigue and physical strain (Da Silva Santos et al., 2016), coaches and athletes frequently search for alternative strategies to enhance training and competitive performance. While listening to music has been shown to enhance performance in a wide range of sports, less is known about how music influences taekwondo competitors, especially in sport-specific tasks.

Listening to music during exercise has been widely reported as an ergogenic aid which is able to improve several aspects of athletes' physical performance, including the enhancement of strength, power, endurance, and work rate (Terry et al., 2020). These phenomena likely manifest through multiple underpinning mechanisms in an amalgam of physiological and psychological domains (Ballmann, Cook, et al., 2021). Physiologically, listening to music during exercise has been reported to increase heart rate (Arazi et al., 2015; Yamashita et al., 2006), reduce blood lactate concentrations (Eliakim et al., 2007) and increase neuromuscular activation (Bishop et al., 2013). Psychologically, listening to music has been shown to increase dissociation from exertion, motivation, activity enjoyment, self-confidence, feelings of power, and self-regulated arousal (Ballmann, 2021; Ballmann et al., 2019; Chtourou, 2013; Stork et al., 2015). Since music is generally prohibited when competing (Chtourou et al., 2012), music listening has been restricted to warm-up activities, as a possible adequate alternative means of influencing sustained motivation during subsequent competitive bouts (Ballmann, Cook, et al., 2021; Meglic et al., 2021).

Warm-up or pre-task music has been investigated in various modes of exercise, sometimes with conflicting results (Ballmann, Cook, et al., 2021; Fox et al., 2019; Karow et al., 2020). For example, listening to music during a warm-up has been shown to improve affect, autonomic control, and physical performance during intense exercise (Chtourou et al., 2017; Chtourou et al., 2012). Furthermore, Meglic et al. (2021) showed enhanced power output during repeated sprints following a warm-up with music. In contrast, others have reported warm-up music to have little to no effects on high-intensity exercise performed by both males and females (Eliakim et al., 2007; Fox et al., 2019). While these disparities between investigations are not fully understood, previous investigators (Eliakim et al., 2007; Fox et al., 2019) used pre-determined (i.e. researcher chosen) music, thereby eliminating any influence of the participants' involvement in selecting their musical preference. Musical preference has been shown to largely determine the ergogenic potential of music listening (Ballmann, Cook, et al., 2021). This can be so individualized a choice that a song that inspires one athlete may have minimal impact on another (Clark et al., 2021). Compared to non-preferred music, preferred warm-up music may raise the anticipatory response to exercise, leading to both more effort and more muscle force development (Ballmann, Cook, et al., 2021; Meglic et al., 2021). Furthermore, among physically active males and females, listening to preferred warm-up music has been shown to improve rowing performance while concomitantly increasing motivation (Ballmann, Cook, et al., 2021; Karow et al., 2020). Similar findings have been documented in resistance exercise, namely bench press (Ballmann, Cook, et al., 2021; Ballmann, Favre, et al., 2021). However, studies exploring warm-up music preference have been limited and even less is known about its efficacy when applied to sport-specific skills.

While the existing literature on warm-up music preference has generally shown that listening to preferred music aids performance, previous studies have not fully accounted for such variations in inherent characteristics of music as tempo and volume. Music volume (loudness) has been shown to potently influence arousal, rate of perceived exertion (RPE), and motivation (Nixon et al., 2022). Loud pre-task music has been shown to significantly influence affective parity and arousal for both simple motor tasks (i.e., handgrip strength) and complex ones (i.e., running speed) (Edworthy & Waring, 2006; Karageorghis et al., 2018). There is very limited evidence of the effects of music listening and of music loudness and volume on taekwondo athletes' performance. Hammad et al. (2019) showed that, despite lowering RPE, listening to music did not improve power or anaerobic capacity during sprinting in taekwondo athletes. However, in this single past study of music effects on taekwondo athletes, it is important to note that the performance test used was not taekwondo-specific and may not readily translate to taekwondo competition. To date, there have been no concerted empirical attempts to elucidate the effects of listening to music on taekwondo-specific tasks.

Our purpose in this study was to assess the effects of music preference (i.e., preferred vs non-preferred music) and loudness (i.e., 60dB vs 80dB) during warm-up music listening on young male and female taekwondo athletes' subsequent specific physical performance, ratings of perceived exertion (RPE) and physical enjoyment. We hypothesized that listening to loud preferred warm-up music would result in greater task performances and increased activity enjoyment, relative to other combinations of soft and non-preferred music listening conditions. However, since it has been well established that music listening during warm-up versus during performance has a diminished effect on the dissociation of unpleasant affect from exercise (Chtourou et al., 2012; Edworthy & Waring, 2006; Fox et al., 2019), even when music was preferred by participants (Karow et al., 2020; Meglic et al., 2021), we hypothesized that warm-up music would not affect RPE scores in either preferred or non-preferred conditions.

Method

Participants

We performed an a priori power analysis using the G*Power software (Version 3.1.9.4, University of Kiel, Kiel, Germany) using the F test family of statistical inference testing (analyses of variance [ANOVA]: repeated measures, within factors). We set our presumed effect size at f = 0.25 and set α=0.05. The analysis revealed that a total sample size of 20 participants would be adequate to detect group differences with an actual statistical power of 80.23%.

Accordingly, 20 taekwondo athletes, 10 males (*M* age = 17.70, *SD* =0.82 years; *M* body mass= 60.8, *SD* = 11.6 kg; *M* height = 1.72, *SD* = 0.10 m) and 10 females; (*M* age = 17.30, *SD* =0.48 years; *M* body mass = 57.5, *SD* =8.5 kg; *M* height = 1.64, *SD* =0.07 m) participated in this study. All participants had at least six years taekwondo experience, were currently training ≥3 times per week, and were free from disease and hearing impairments. We selected a culturally homogenous sample to minimize differential cultural background effects on the participants' psychophysical reactions to music (Karageorghis, 2020). For female participants, athletes were invited to participate in the study when they were in the early stages of their follicular phase of menstruation. Throughout the trial, participants were instructed to follow the same dietary and sleep habits. Strenuous physical activity had been abstained for 24 hours before each experimental session.

We provided participants and their parents a complete overview of the aims, advantages, and potential risks associated with the investigation, after which athletes (if older than 18 years old) or their parents (when athletes were younger than 18 years old) signed a written informed consent form. All athletes younger than 18 years old signed an informed assent. The study was conducted according to the Declaration of Helsinki, and the protocol was fully approved by a local research ethics committee (CPP SUD n° 0332/2021).

Procedures

Warm-Up Music

Participants were asked to provide their most preferred and non-preferred music genres freely, and their preferences were documented. For the preferred music conditions, participants selected a single favorite song with a fast tempo in their preferred genre (*M*= 130, *SD* = 8 bpm). For the non-preferred conditions, we selected a song from the participant's least favorite music that was tempo matched to the preferred music condition. All music was played through headphones. Considering loudness conditions, we used 60 decibels (dB) for "soft" and 80dBfor "loud" (Nixon et al., 2022). We monitored the decibel level of the music using the application Decibel: dB sound level meter (developer Vlad Polyanskiy). The iterated combinations of music type and volume resulted in four experimental conditions, and we added a no-music control condition to derive the following five conditions: (a) No music (control; NM); (b) preferred music- loud volume (80dB, PML);(c) preferred music- soft volume(60dB; PMS);(d) non-preferred music- loud volume (80 dB, NPML);and (e) non-preferred music- soft volume (60 dB, NPMS).

Experimental Design and Procedure

We utilized a randomized and counterbalanced crossover study design. After a familiarization session with the testing procedures and the scales, participants performed a standardized warm-up session consisting of running at 9 km/h for10 minutes while listening to corresponding music conditions before performing the tests. For the NM condition, participants were equipped with headphones, but no-music was played to assure the same testing conditions(Tounsi et al., 2019). We played music on repeat to ensure it played throughout the warm-up. After the warm-up, we measured enjoyment through the Physical Activity Enjoyment Scale (PACES; (Kendzierski & DeCarlo, 1991). Participants then performed the taekwondo-specific agility test (TSAT;(Chaabene et al., 2018), the 10-second frequency speed of kick test (FSKT-10s;(Da Silva Santos et al., 2015) and its multiple version (FSKT-mult;Da Silva Santos et al., 2016). After each test, athletes were instructed to report their RPE using a 1-10 scale(Borg et al., 1987). All testing sessions were performed, with a 48hour interval between sessions, at the same time of day (17h00-19h00) to avoid any individualized diurnal influence on performance variation.

Physical Tasks

Taekwondo-Specific Agility Test (TSAT)

The TSAT was completed as previously described by (Chaabene et al., 2018). Briefly, the athlete started the test from a guard position with both feet behind the taekwondo start/finish line. When signaled, they moved as quickly as possible to a center point three sparring partners around them, with one partner on each side of them at ~180 degrees and the third directly in front of them at ~90 degrees. Then, the participant delivered a single roundhouse kick with their dominant leg to each partner on either side and a double roundhouse kicked to the third partner as quickly as possible. The athlete then returned to the center point to finish the test (Chaabene et al., 2018). Time to completion was measured using photocells (Brower Timing Systems, Salt Lake City, UT, USA). Each athlete performed three attempts, and we used the fastest single time for analysis. The ICC for test–retest trial for the present study was 0.86.

The Frequency Speed of Kick Test 10s (FSKT-10s)

The KSKT-10s test was conducted as previously described by (Da Silva Santos et al., 2015). The athlete was required to achieve the maximum number of *bandal-chagui* (upward kicks) techniques within a 10-second period against an immoveable bag by alternating between the dominant and non-dominant legs. The performance was recorded as the total number of techniques during the 10s (Da Silva Santos et al., 2015). The ICC for test–retest trial in the present study was 0.83.

The Frequency Speed of Kick Test (FSKT-mult)

We used the same procedure as for the FSKT-10s for the FSKT-mult; however the FSKT-mult was completed repeatedly. Using the *bandal-chagui* techniques, athletes performed five sets of the FSKT-10s with a 10-second inter-set interval. The number of kicks performed in each set and the total number of kicks over the five sets were used to determine the performance decrement index (DI) (Da Silva Santos et al., 2016).Equation 1 details the DI:

DI (%) = [1 - ((FSKT1 + FSKT2 + FSKT3 + FSKT4 + FSKT5) / (Best FSKT set × Numbers of sets))]×100

Performance was represented by the total number of techniques during the five sets and by the DI. The ICC for the test–retest trial for the total number of kicks in the five sets in the present study was 0.77.

The Physical Activity Enjoyment Scale (PACES)

The PACES was used to detect the participants' level of pleasure and enjoyment following the warm-up(Kendzierski & DeCarlo, 1991). This scale contains 18 items - 11 "negative" and 7 "positive" items, all related to the participants 'enjoyment. Participants self-reported their responses through 7-point Likert scale questions(Kendzierski & DeCarlo, 1991). Scores were derived from the sum of the participant's total responses such that the overall score could range from 18 to 126.

Ratings of Perceived Exertion (RPE)

We assessed perceived exertion using the Borg CR 0-10 scale (Borg et al., 1987) . This scale ranges from "0" to "10," with corresponding verbal descriptors, that gradually increase with the intensity of perceived sensational (0=Nothing at all; 0.5=Extremely weak; 1=Very weak; 2=Weak; 3-4=Moderate; 5-6=Strong; 5-6=Severe; 7-9=Very strong; and 10=Extremely strong). Cronbach's Alpha reliability coefficient was 0.948 in the present study.

Data Analysis

Statistical analyses were performed using SPSS 20.0 statistical software (IBM corps., Armonk, NY, USA). Data are presented as means (and standard deviations). The Shapiro-Wilk test was used to confirm normality, and the Levene test was used to verify the homogeneity of variances. Mean differences between each experimental and control condition for each outcome were measured and used for the analysis. A three-way repeated measures ANOVA (2 Loudness × 2 Music Preferences × 2 Sexes) was used to compare results on the TSAT, FSKT-10s, PACES and RPE, while the FSKT-mult outcomes (total number of techniques and decrement index) were compared using a multivariate analysis of variance (MANOVA). If the ANOVA or the MANOVA indicated significant differences (only significant differences are currently reported), a Bonferroni post hoc test was used to detect differences in means. Partial eta squared (η_p^2) effect size values were reported and classified as 0.01 = small, 0.06 = medium, 0.14 = large (Cohen, 1988). Moreover, standardized effect size analysis (Cohen's d) was used to interpret the magnitude of differences between variables and considered as: trivial (≤ 0.20); small ($0.20<d\leq 0.60$); moderate ($0.60<d\leq 1.20$); large ($1.20<d\leq 2.0$); very large ($2.0<d\leq 4.0$); and extremely large (>4.0) (Hopkins, 2002). In addition, the upper and lower 95% confidence intervals of the difference ($95\%CI_{dif}$) were calculated for the corresponding variation. The level of statistical significance was set at $p \leq 0.05$.

Results

Table 1 presents the physical performances as mean differences between each experimental and control condition.

*** Please insert table 1 near here***

Taekwondo Specific Agility Test

On the TSAT, there was a main effect of Loudness ($F_{1,17}$= 30.71; $p<0.001$; η_p^2= 0.644), with 80dB inducing better performances than 60dB (95%CI_{dif} = -0.7 to -0.3; d = -1.08 ; $p< 0.001$). There was a main effect of Music preferences ($F_{1,17}$= 10.88; $p=0.004$; η_p^2= 0.390), with preferred music inducing better performances than non-preferred (95%CI_{dif} = -0.4 to -0.1; d =-0.65 ; $p=0.004$). There was a significant interaction effect between Loudness and Music preferences ($F_{1,18}$= 6.15; $p=0.024$; η_p^2= 0.266), with NPML inducing better performance than NPMS(95%CI_{dif} = -0.4 to -0.1; d = -0.75 ; $p=0.001$) and PML resulting in better performances than PMS (95%CI_{dif} = -1.0 to -0.4; d = -1.66; $p<0.001$). Moreover, PML induced better performances than NPML (95%CI_{dif} = -0.7 to -0.2; d = -1.17; $p<0.001$).

The Ten Seconds Frequency Speed of Kick Test

There was a main effect of Loudness ($F_{1,18}$= 9.67; $p=0.006$; η_p^2= 0.350) with 80dB resulting in better performances than 60dB (95%CI_{dif} = 1.5 to 7.6; d = 0.51 ; $p=0.006$). There was a main effect of Music preferences ($F_{1,18}$= 16.98; $p=0.001$; η_p^2= 0.485) with preferred music inducing better performances than non-preferred (95%CI_{dif} = 13.5 to 10.9; d = 0.86 ; $p=0.001$). Moreover, there was an interaction effect between Loudness and Music preferences ($F_{1,18}$= 22.04; $p<0.001$; η_p^2= 0.550) with PML inducting better performances than PMS (95%CI_{dif} = 5.2 to 13.5; d = 1.15; $p<0.001$) and PML resulted in better performances than NPML (95%CI_{dif} = 7.7 to 16.4; d = 1.59 ; $p<0.001$).

The Multiple Frequency Speed Kicks Test

Total Number of Kicks

On the FSKT-mult, there was a main effect of Loudness ($F_{1,18}$= 14.37; $p=0.001$; η_p^2= 0.444), with 80dB inducing better performance than 60dB (95%CI_{dif} = 1.7 to 6.1; d = 0.48; $p=0.001$). There was a main effect of Music preferences ($F_{1,18}$= 21.93; $p<0.001$;

η_p^2= 0.549) with preferred music inducing higher performance than non-preferred music (95%CI_{dif} = 3.5 to 9.1; d =0.56; p<0.001).There was an interaction effect between Loudness and Music preferences ($F_{1,18}$= 7.17; p=0.015; η_p^2= 0.285) with PML resulting in better performance than NPMS (95%CI_{dif} = 5.3 to 11.8; d =1.42; p<0.001) and PMS than NPMS (95%CI_{dif} = 0.5 to 7.4; d = 0.55; p=0.026). Moreover, PML induced better performance than PMS (95%CI_{dif} = 3.7 to 8.7; d =-0.81; p<0.001).

Decrement Index

There was a main effect of Loudness ($F_{1,18}$= 63.90; p< 0.001; η_p^2= 0.780), with 80dB resulting lower DI than 60dB (95%CI_{dif} = -4.1 to -2.1; d = -1.08; p<0.001). There was a main effect of Music preference ($F_{1,18}$= 26.05; p<0.001; η_p^2= 0.591) with preferred music inducing lower DI than non-preferred (95%CI_{dif} = -3.3 to -1.4; d = -0.73; p<0.001).There was a main effect of Sex ($F_{1,18}$= 5.15; p= 0.036; η_p^2= 0.223) with males inducing lower DI than females (95%CI_{dif} = -3.5 to -0.1; d = -0.17; p=0.036). There was an interaction effect between Sex and Music preference ($F_{1,18}$= 6.87; p= 0.017; η_p^2= 0.277) with male inducing lower DI than females with preferred music (95%CI_{dif} = -4.7 to -1.4; d = -0.79 ; p=0.001). There was an interaction effect between Loudness and Music preference ($F_{1,18}$= 15.37; p=0.001; η_p^2= 0.461) with PML inducing lower DI than NPML (95%CI_{dif} = -5.7 to -2.6; d = -1.62 ; p<0.001) and PML resulted in lower DI than PMS (95%CI_{dif} = -5.5 to – 4.6; d = -2.19 ; p<0.001).

The Physical Activity Enjoyment Scale

On the PACES, there was a main effect of Music preferences ($F_{1,18}$= 7.99; p=0.011; η_p^2 =0.307), with preferred music inducing lower values than non-preferred music (95%CI_{dif} = 1.5 to 10.4 d =0.68 ; p=0.011) (Figure 1).

Please insert figure 1 near here

Ratings of Perceived Exertion

For RPE values recorded after FSKT-10s, there was a main effect of Music preferences ($F_{1,18}$= 22.30; $p<0.001$; η_p^2 =0.553), with preferred music induced lower values than non-preferred(95%CI_{dif} = -1.6 to -0.6 d =-0.99 ; $p<0.001$) (Figure 2). Neither the main effect for Loudness nor the interaction effect of Music preferences and Loudness were significant.

*** Please insert figure 2 near here***

Discussion

In the present study, we assessed the effect of warm-up music preference (i.e., preferred vs. non-preferred) and music volume (i.e., loud vs. soft) on taekwondo-specific physical performance, RPE, and physical enjoyment in male and female young taekwondo athletes. We found that PML music resulted in superior performance during the FSKT-10s, FSKT-mult and TSAT compared to the PMS, and NPML conditions. Furthermore, RPE decreased with preferred, compared to non-preferred, music. While both males and females benefited from listening to preferred music by lowering DI, males had significantly lower DI than females. While precise mechanisms for these findings are not fully clear, our findings are among the first to suggest that warm-up music preference and music volume interact to determine sport-specific performance, whereby listening to preferred and loud music appear to result in the greatest benefit. Combining these music qualities may serve as a feasible strategy for taekwondo athletes to boost their performance in training and competition.

Warm-up music preference has been shown to mediate ergogenic benefits during subsequent exercise bouts (Ballmann, Cook, et al., 2021; Karageorghis et al., 2021). In the present study, listening to PML during warm-up improved taekwondo-specific agility performance, completed kicks during single (FSKT-10s), and repeated bouts (FSKT-mult) of kicking compared to the PMS and NPML conditions. These findings are supported by previous literature showing the benefits of warm-up music on repeated sprint ability and running speed (Edworthy & Waring, 2006; Meglic et al., 2021; Tounsi et al., 2019). Specifically, Karow et al. (2020) showed that a 5min warm-up while listening to preferred music improved subsequent 2000-m rowing performance in active male and female participants. Additionally, during high-intensity repeated exercise (i.e., 3 x 15 s all-out cycle ergometer bouts), Meglic et al. (2021) reported that three minutes of standardized cycling warm-up at 50 W while listening to preferred music resulted in increases in power and total work. Common among these investigations, which also supports the current data, is that non-preferred music also resulted in a lack of benefit or performance decrement.

While the physiological determinants of current performance enhancement remain largely speculative, improvements from PML music may manifest in alterations of neural activation from the music itself or the volume. Pre-task music may result in increased neural activity, specifically in brain regions responsible for motor control (Bishop et al., 2013). Indeed, Putkinen et al. (2021) showed increased motor and insular cortex activation while listening to music, which are important for motor control (Putkinen et al., 2021). The changes in neural activation elicited by listening to music have been shown to be heavily dependent on the individual's musical preference where a greater emotional connection to preferred music may alter responses(Holler et al., 2012). Intrinsic characteristics of music may affect the way listeners assess the potential impact of a musical stimulus, and this may determine their expectations (Ballard et al., 1999). Specifically, listeners may exhibit a strong association between goal attainment and music preference (Schäfer, 2016), as specific music is capable of fulfilling the listener's expectations (Ballard et al., 1999). The overall strength of past positive functional experiences with music may improve the degree to which music assists the listener in achieving specific goals in particular situations (Schäfer, 2016). In the present study, the higher performances under the preferred condition may have also influenced expectations on the recorded effects. Possibly, this may have led to heightened sympathetic responses that could have altered muscular force output. Listening to music during a warm-up has been shown to raise plasma catecholamine concentrations (i.e. norepinephrine, epinephrine) which may increase muscle activation, redistribute blood flow towards skeletal muscles, and alter metabolic responses during subsequent exercise (Yamashita et al., 2006). Similar responses may have been initiated by the loud volume of the music in this study. Loud music volume has been shown to increase heart rate and ventilation, while simultaneously decreasing heart rate variability, indicating enhanced sympathetic output (Koelsch & Jancke, 2015). Similarly, louder music has also been shown to increase self-selected running speed and heart rate during endurance-based exercise (Edworthy & Waring, 2006). While not confirmed, the loud volume may have also exacerbated the sympathetic responses leading to heightened arousal and muscular force. This is partially supported by our finding that PML elicited better performance than PMS, even when the song/music played was the same. Previous findings have also suggested that increases in motivation and intent to give effort may also be enhanced by preferred music and louder volumes (Ballmann, 2021; Nixon et al., 2022). Interestingly, these feelings of increased motivation may last throughout the exercise bout, even if the preferred music is listened to only during the warm-up (Karow et al., 2020). Similar findings have been shown with louder volumes albeit only investigations utilizing in-task (i.e., during exercise) music have been conducted to date (Nixon et al., 2022). Since improvements in motivation may lead to greater sustained effort, it is plausible that PML music may have allowed participants to maintain performance as evidenced by lower DI. Thus, improvements in agility and technique from listening to warm-up music appear to be synergistically controlled by music preference and volume which ultimately alters exercise responses. But future studies manipulating other intrinsic characteristics of music (i.e., music, lyrical content) will be necessary to identify how each factor of music truly contributes to changes in performance.

Psychologically, music has been repeatedly shown to promote feelings of well-being (Karageorghis et al., 2021), improve emotional state (Chtourou, 2013), reduce perceived exertion (Terry et al., 2020), and increase self-confidence (Chtourou, 2013). Regarding physical enjoyment, current findings showed that, regardless of volume, non-preferred warm-up music induced higher enjoyment than preferred music did. This is in opposition to previous work in which listening to self-selected music was reported to induce higher levels of enjoyment (Stork et al., 2015). Noticeably, unpleasant sounds and music have been suggested to lower enjoyment and alter perceptive responses to other pleasurable stimuli (i.e., food, beverage, smell) (Spence, 2014). However, these findings may not translate if music is only played during the warm-up (Aloui et al., 2015). Arguably, the impacts of music on psychological states varied as a function of familiarity with music (Park et al., 2019). Particularly, listening to known music repeatedly tends to decrease listeners' attention; while, engaging in unexpected music can keep participants' interest (Malekmohammadi et al., 2023). For instance, frequent exposure to unusual music raises levels of self-reported arousal and enjoyment (van den Bosch et al., 2013). Consequently, the recorded result in the present study might be linked to reduced intentional resources necessary to improve enjoyment.

Exercisers' exhaustion brought on by high-intensity exercise, cannot be avoided; but it is possible to alter how exercisers perceive fatigue and give it a more favorable appraisal (Karageorghis & Priest, 2012). In this regard, music has been reported as an ergogenic aid that enhances exercise performance by either postponing exhaustion or boosting work capacity (Karageorghis & Priest, 2012). In the present study, preferred music enhanced performance while reducing RPE values. Although the timing of music playing is a moderating factor, the current findings supported the suppressor effect of preferred music on RPE (Ballmann et al., 2019). Such a decrease in fatigue perception may explain, in part, the lower performance during the non-preferred conditions. The key mechanism for performance enhancement during exercise while listening to music is the dissociation from internal features of exercise (Ballmann, 2021). However, not playing music during exercise may remove the external distraction to giving effort. The mechanism behind warm-up music suppressor effects is not clear, but its extension to subsequent tasks could be related to an improvement in auditory imagery (Bishop et al., 2013). This hypothesis needs verification from future neuroscientific evidence.

In terms of sex-music interactions, our findings supported the suggested moderating effects of gender (Karageorghis et al., 2021; Rhoads et al., 2021). Specifically, the current study reported that males had a lower DI than females in the preferred music conditions. This result was similar to the results of a previous study (Manca et al., 2020) showing that listening to loud music (i.e., 85dB) while running increased ground reaction force in males with no effect in females. However, these findings were inconsistent with others investigating the variation in sex-specific responses to music stimulus before (Eliakim et al., 2007; Tounsi et al., 2019) or during exercise (Rhoads et al., 2021). In fact, performing repeated Wingate tests while listening to self-selected music reduced the fatigue index in female, but not in male exercisers (Rhoads et al., 2021). Considering warm-up music, motivational music was shown to induce shorter sprint time in female soccer players than their male counterparts, with no impact on performance decrement in both sexes (Tounsi et al., 2019). Moreover, Eliakim et al.(2007) showed that sex did not influence the effect of music on the fatigue index during the Wingate test. As the level of activation is dependent on music preference and listening timing (Ballmann, Cook, et al., 2021; Smirmaul, 2017), this divergence in results could be related to these intrinsic components.

Limitations and Directions for Further Research

While the present investigation revealed important findings regarding the optimization of performance using loud preferred warm-up music, we acknowledge some limitations in this research. We did not assess the participants' subjective perceived arousal and motivation induced by music. Moreover, we did not measure physiological biomarkers to explain the results, especially, the difference in sex responses to music stimulus. In addition, although we manipulated music preference and loudness, we did not fully control for other confounding factors (e.g., lyrics and melodies) that could have influenced music effects. Furthermore, since measuring sound level with a smartphone application is would help calibrate the accuracy of sound level measurements (Nast et al., 2014), future investigators might use a smartphone application without acoustic coupler to monitor sound level . Finally, our exclusive focus on taekwondo athletes limits generalization of these findings to other populations. Future investigators are encouraged to expand this research hto other athletes and use specific testing procedures to simulate the requirement of typical competition.

Conclusion

Listening to preferred and loud music is an effective tool to improve taekwondo physical performance during specific tasks. Moreover, independent of loudness preferred warm-up music act as suppressor stimulus on RPE. However, preferred warm-up music reduced the DI in both males and females; with males presenting lower values either at low or high volume.

Allowing athletes to listen to their preferred music at 80dB loudness during warm-up could help them to perform better on subsequent tasks. Moreover, coaches should help their athletes to select motivational music according to the exercise requirements, accounting for their choice. Imposing a musical track is not recommended and seems not to be an effective strategy for all listeners, as non-preferred music negatively affected fatigue perception. Thus, music choices prior to giving physical effort should be individualized to each athlete's preferences in order to optimize training and performance.

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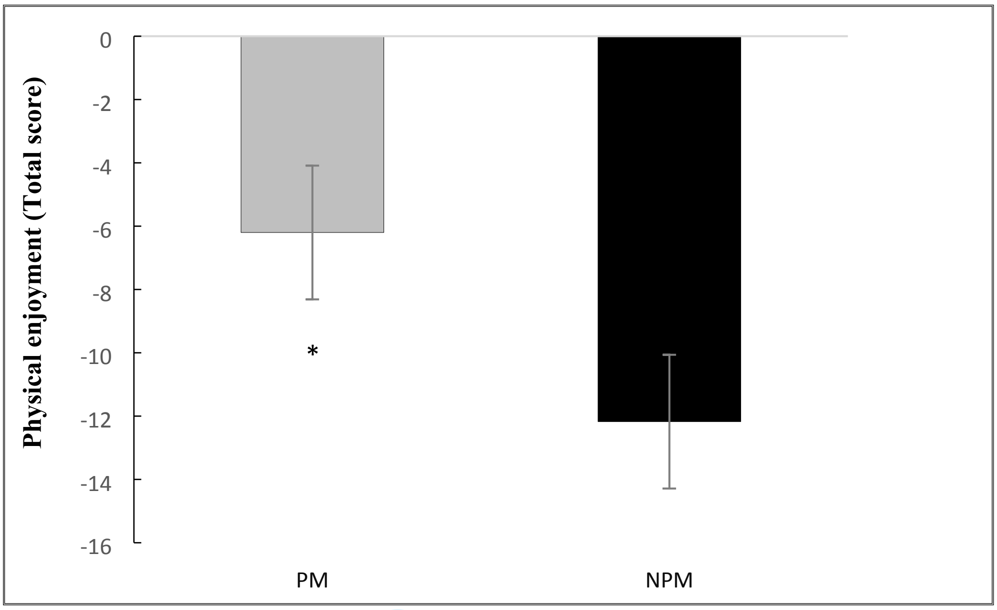

Figure 1. Physical enjoyment mean difference values from control condition recorded during preferred (PM) and non-preferred music (NPM). * p=0.011.

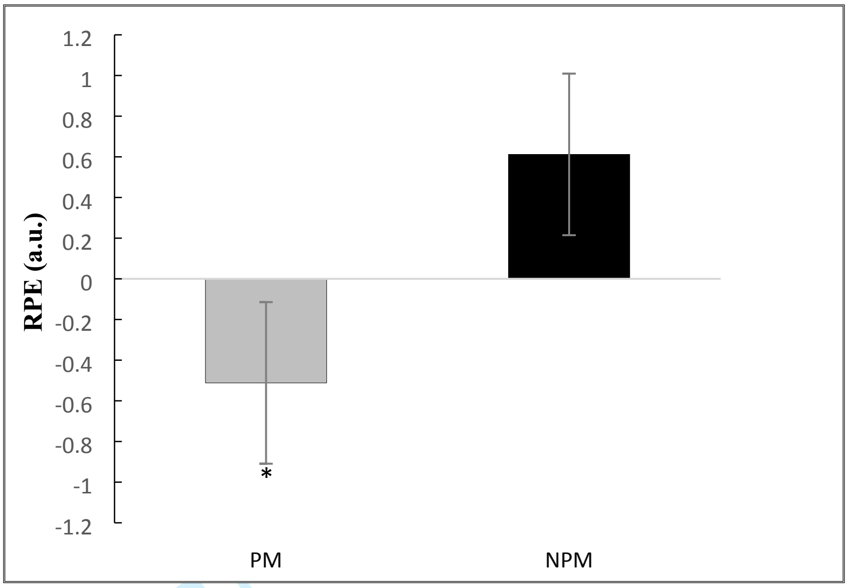

Figure 2. Rating of perceived exertion (RPE) mean difference from control condition values recorded during preferred (PM) and non-preferred music (NPM). * *p*<0.001.a.u: arbitrary unit

Table 1. Changes in physical performances between the control and experimental conditions (Values are M (SD); n=20). * indicates significantly different from soft (*p*<0.05). # indicates significantly different from NPM (*p*<0.05). + indicates significantly different from PML (*p*<0.05). $ indicates significantly different from NPMS (*p*<0.05). † indicates significantly different from females (*p*<0.05).¶ indicates significantly different from females with PM (*p*<0.05).

		Preferred music		Non-preferred music		Overall
		Loud (80dB)	Soft (60dB)	Loud (80dB)	Soft (60dB)	
TSAT (s)	M (n=10)	-1.0(0.32)	-0.28(0.41)	-0.42 (0.46)	-0.16(0.42)	-0.18(0.77)
	F (n=10)	-0.83(0.48)	-0.30(0.43)	-0.48(0.38)	-0.1(0.6)	-0.15(0.79)
	Overall	-0.91(0.41)$^{*\#}$	-0.24(0.41)$^{\#+}$	-0.45(0.41)$^{*+\$}$	-0.1(0.51)	-0.17(0.77)
FSKT-10s (n)	M (n=10)	3.9(1.9)	1.1(2.0)	0.5(1.8)	0.3(1.7)	1.4(2.3)
	F (n=10)	3.1(1.4)	1.7(1.6)	1.2(1.5)	1.5(1.3)	1.9(1.6)
	Overall	3.5(1.7)$^{*\#}$	1.4(1.8)$^{\#+}$	0.8(1.6)$^{*+}$	0.9(1.6)	1.7(2.0)
FSKT-mult (kicks' number) (n)	M (n=10)	11.8(10.6)	4.5(9.5)	0.7(10.2)	-2.4(7.1)	3.6(10.5)
	F (n=10)	7.8(3.0)	2.7(6.4)	1.7(4.9)	1.6(6.4)	3.4(5.8)
	Overall	9.8(7.8)$^{*\#}$	3.6(7.9)$^{\#+\$}$	1.2(7.8)*	-0.4(6.9)$^{+}$	3.5(8.4)
FSKT-mult (DI) %	M (n=10)	-8.9(2.0)¶	-3.9(2.3)¶	-3.1(2.7)	-2.6(3.8)	-4.6(3.7)†
	F (n=10)	-5.9(1.5)	-0.8 (1.5)	-3.5(3.3)	-1.0(1.8)	-2.8(2.9)
	Overall	-7.4(2.3)$^{*\#}$	-2.4(2.4)$^{\#+}$	-3.3(2.9)$^{*+}$	-1.8(3.0)	-3.7(3.4)

TSAT: taekwondo specific agility test; FSKT-10s: 10s frequency speed of kick test; FSKT-mult: multiple frequency speed of kick test; DI: decrement index; M: male; F: female. PM: Preferred Music- Loud (PML); Preferred Music- Soft (PMS); Non-preferred music- Soft (NPMS); Non-preferred music- Loud (NPML); No music (NM).