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Intensity of arm swing exercise with music-movement synchrony in untrained young adults

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Abstract

Introduction. The research aimed to study the intensity of arm swing exercise (ASE) with different tempi of music-movement synchrony in untrained young adults and to investigate the effect of different music tempi on heart rate and oxygen consumption.
Methods. Participants were 30 healthy volunteers (15 males and 15 females), 20.67 ± 1.37 years and low-to-moderate physical activity. They performed ASE synchronised with music at a tempo of 60 and 140 bpm with a random sequence. They were measured for heart rate and oxygen consumption using a Quark SPIRO (COSMED) before and after the ASE for 6 minutes of each tempo. They rested for at least 15 minutes between music tempi during the ASE. The intensity of ASE with music-movement synchrony of each tempo was calculated as a percentage of maximum heart rate (%HR_{max}) and percentage maximum oxygen consumption (%VO_{2max}).
Results. The %HR_{max} of all participants post-ASE at 60 and 140 bpm were 58.64 ± 8.82 and 60.12 ± 8.95%, respectively. The %VO_{2max} of all participants post-ASE at 60 and 140 bpm were 38.65 ± 11.36 and 40.17 ± 10.71%, respectively. There was no significant difference in HR and VO_2 of ASE between music tempi.
Conclusions. The ASE with music-movement synchrony at 60 and 140 bpm is a low-intensity aerobic exercise, so is a suitable choice for people with low physical activity. Furthermore, the faster tempo did not significantly alter the intensity, therefore, we recommend selecting the slower music tempo at 60 bpm to avoid repetitive shoulder joint injury.
Key words: arm swing exercise, oxygen consumption, exercise intensity, music rhythm

Introduction

People around the world have tended to decrease their physical activity since the COVID-19 pandemic, especially during the lockdown period [1, 2]. Physical inactivity affects the immune system, respiratory system, cardiovascular system, and musculoskeletal system [3]. Hence, the arm swing exercise, an exercise requiring less equipment, may be a suitable candidate for home-based exercise to increase physical activity. The arm swing exercise (ASE) originated in China and is a light-intensity aerobic exercise with 16–19% of maximum oxygen consumption [4]. It is evidently suitable for the elderly to mitigate the risk of cardiovascular diseases [5–7]. The exercise guideline for individuals with cardiovascular disease is low-to-moderate intensity, approximately 50–85% of maximum heart rate [8]. The intensity of ASE is determined by the number of arm swing repetitions in one minute [4, 7]. For individuals who must supervise the intensity, the rhythm of the arm swing is controlled by a metronome. The rhythm of ASE in experimental studies ranges from 60 to 90 beats per minute [4–7, 9, 10]. However, it is not attractive to do the regular ASE with a metronome. Instead, the rhythm of the music can motivate and encourage individuals to do the ASE regularly. Previous studies found that exercise with music demonstrated a significantly increased energy expenditure and heart rate compared to the group without music [11, 12]. However, there is a lack of evidence to investigate whether the intensity of the ASE synchronises with the rhythm of the music.

Therefore, the objective of the present study was to determine the intensity of arm swing exercise with rhythmic music at 60 and 140 bpm on oxygen consumption and heart rate in untrained young adults and to investigate the effect of different music tempi on the heart rate and oxygen consumption.

Subjects and methods

Study design and participants

A total of 30 participants were recruited for this study. The inclusion criteria were: (1) Healthy and with no underlying diseases (15 males and 15 females), (2) Young adults (18–23 years old), and (3) Normal body mass index (BMI = 18.5–22.9 kg/m^2). We applied the alternative weight status classification according to the Regional Office for the Western Pacific (WPRO) standard for Asian populations [13]. The physical activity of the study participants was assessed as low- moderate using the Baecke habitual physical activity questionnaire [14]. They possessed normal shoulder range of motion and no musculoskeletal or cardiovascular disorders that would limit the performance of an arm swing exercise. However, if they were unable to swing their arms at a speed of at least 80% of 60 and 140 bpm or had shoulder pain, they were excluded from this study.

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Sample size calculation

A statistical formula for comparing the mean of two independent groups was applied to calculate the sample size using the G*Power software. The decision was made to require 80% power with a significance level of 0.05. The previous study reported that the power of the test was 1.54 [4], therefore the total sample size was 16. However, this study recruited 30 participants according to the Central Limit Theorem, as the objective of this study was to compare the cardiopulmonary response between two differences in musical rhythm speed. Therefore, a large enough sample size was important for the internal validity [15].

Procedures and instruments

Before the test, the participants were asked to avoid vigorous exercise and caffeine. They should sleep at least 6 hours the night before the testing, and if the females were menstruating, the test was postponed. The researcher measured the shoulder joint's range of motion for an arm swing exercise using a goniometer. The range of motion for the shoulder joint during an arm swing exercise was 30° forward and 60° backward. Participants were trained to perform ASE with musical rhythm at 60 and 140 bpm before the test, to be able to synchronize with the beat. In the rehearsal session, they were instructed to stand with their feet shoulder width apart (Figure 1). Then, they were instructed to stand with their feet shoulder width apart and relax their arms, forearms, and hands in the pronation position (Figure 1). Their trunk was to be kept straight while relaxing the head and neck. The toes were pushed down against the floor. After that, they swung both arms forward to 30° and backward to 60° continuously for 6 minutes (Figure 1). The arms movement was synchronized with the music starting at a predetermined tempo, which was tested with a metronome at 60 and 140 bpm, with the order randomised for each participant.

Before the commencement of this study, all recruited participants were thoroughly informed about the overall process. They were asked to do a 5-minute warm-up exercise. Ten electrodes were placed on the participant's chest wall for monitoring via electrocardiography (ECG). The participants also wore a face mask that was connected to a gas analyser machine (Quark SPIRO, COSMED, Italy) to assess oxygen consumption. The heart rate and oxygen consumption were recorded before performing the arm swing exercise in a standing position. After finishing the arm swing exercise, the heart rate and oxygen consumption were immediately recorded again. Then, the participants were asked to cool down for 5 minutes and rest for 15 minutes. Finally, they performed the arm swing exercise again at the other tempo.

Data and statistical analysis

All statistical analyses were performed with SPSS version 25 (IBM, Armonk, NY, USA). The Shapiro-Wilk test was applied to examine the normal distribution of the data. Data were shown in mean ± *SD* and number (%). The maximum heart rate was calculated by Tanaka's formula (Equation 1) [16]. The maximum oxygen consumption of each participant was calculated by Equation 2 [17]. The percentage of maximum heart rate and the percentage of oxygen consumption for all participants were calculated by multiplying the maximum heart rate and the maximum oxygen consumption with the post-ASE heart rate and oxygen consumption for each tempo, respectively. The two-sample *t*-test was used to examine the differences in heart rate pre- and post-arm swing exercise between 60 bpm and 140 bpm. The two-sample *t*-test was also applied to investigate differences in $\%HR_{max}$ and $\%VO_{2max}$ post-arm swing exercise between the females and males. The Mann-Whitney test was used to examine differences in oxygen consumption pre- and post-arm swing exercise between 60 bpm and 140 bpm. A value of $p < 0.05$ was considered as significant.

$$\text{Maximum heart rate} = 208 - 0.7 \cdot \text{age} \qquad (1)$$

$$\text{Maximum oxygen consumption} = 15.3 \cdot (\text{maximum heart rate}) / (\text{resting heart rate}) \qquad (2)$$

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics committee of Walailak University (approval No.: 56/059).

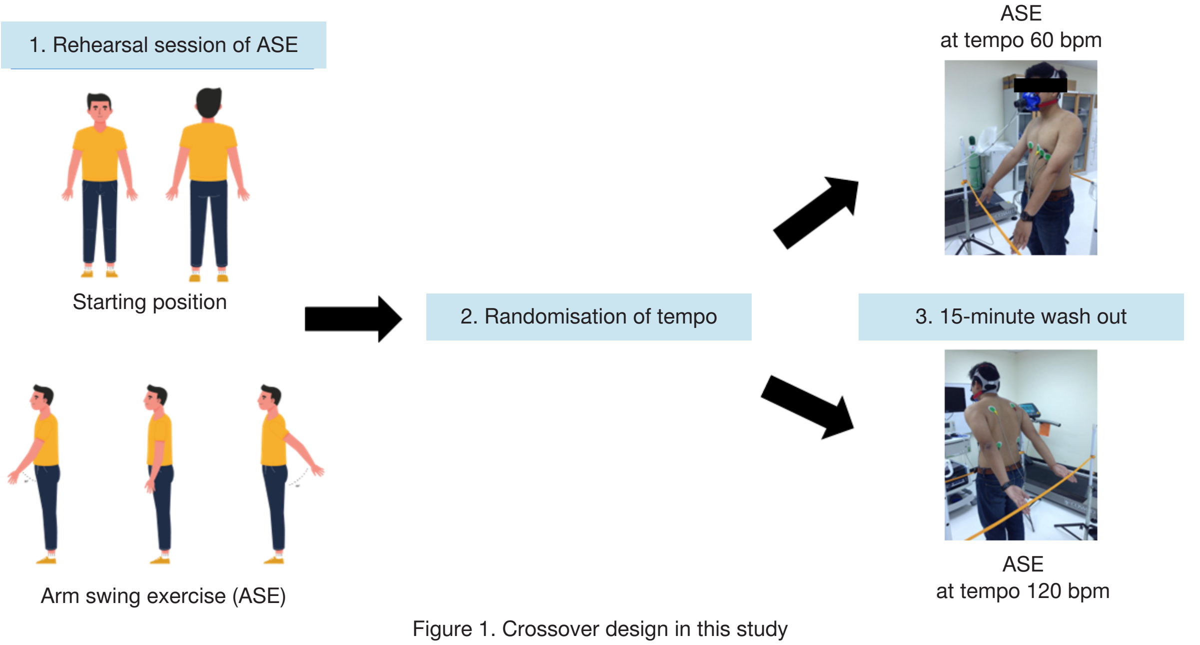


Figure 1. Crossover design in this study

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Basic data on the profiles of the participants are shown in Table 1. All of them were healthy and there were no limitations for the arm swing exercise. There were 30 participants (15 males and 15 females) in this study. There was no significant difference in age, BMI, or resting heart rate between the males and females. However, weight, height, and VO_2 during standing demonstrated a significant difference between the males and females ($p < 0.05$).

Heart rate and oxygen consumption

The heart rate (HR) and oxygen consumption (VO_2) of the participants in pre- and post-arm swing exercise (ASE) conditions with music-movement synchrony at tempos 60 bpm and 140 bpm are shown in Figure 2. There was no statistically significant difference in their resting heart rates and oxygen consumption during standing before the arm swing exercises at 60 and 140 bpm. After they performed the arm swing exercises for 6 minutes, their heart rate increased to 113.30 ± 17.10 bpm when they swung their arms at 60 bpm. After swinging their arms at 140 bpm, their heart rate increased to 116.50 ± 17.14 bpm. There was no statistically significant difference in heart rate between arm swings at 60 and 140 bpm. Their oxygen consumption after performing the arm swing exercise also demonstrated no significant differences between tempi. Their oxygen consumption increased to 12.43 ± 3.13 ml/kg/min when they swung their arms at 60 bpm and 12.92 ± 2.87 ml/kg/min at 140 bpm.

Percent maximal heart rate and percent maximal oxygen consumption

The mean, maximum, and minimum percentage maximal heart rate ($\%HR_{max}$) and percentage maximum oxygen consumption ($\%VO_{2max}$) of the total, female, male post-arm swing exercise with music-movement synchrony at 60 bpm and 140 bpm are shown in Table 2 and Figures 3 and 4. The $\%HR_{max}$ of all participants of ASE with music at 60 bpm was lower than at 140 bpm with 58.64 ± 8.82 and 60.12 ± 8.95%, respectively. There was no significant difference in $\%HR_{max}$ between the females and males. The $\%VO_{2max}$ of all participants of ASE with music at 60 bpm and 140 bpm were 38.65 ± 11.36 and 40.17 ± 10.71%, respectively. The $\%VO_{2max}$ of the males post-ASE with music at both tempi were significantly higher than the $\%VO_{2max}$ of the females.

Table 1. Basic profile of participants

Characteristics	Total (*n* = 30) (mean ± *SD*)	Females (*n* = 15) (mean ± *SD*)	Males (*n* = 15) (mean ± *SD*)	*p*-value
Age (years)	20.67 ± 1.37	20.47 ± 1.36	20.87 ± 1.41	0.435
Weight (kg)	57.37 ± 6.53	52.92 ± 3.76	61.8 2 ± 5.64	< 0.001*
Height (cm)	165.00 ± 7.71	159.30 ± 4.50	170.70 ± 5.69	< 0.001*
BMI (kg/m^2)	20.95 ± 1.35	20.86 ± 1.31	21.03 ± 1.44	0.734
Resting heart rate (beats/min)	91.70 ± 11.40	90.13 ± 10.75	93.27 ± 12.18	0.461
Oxygen consumption during standing (ml/kg/min)	7.74 ± 1.77	6.75 ± 1.53	8.80 ± 1.39	< 0.001*

* significant difference between females and males ($p < 0.05$)

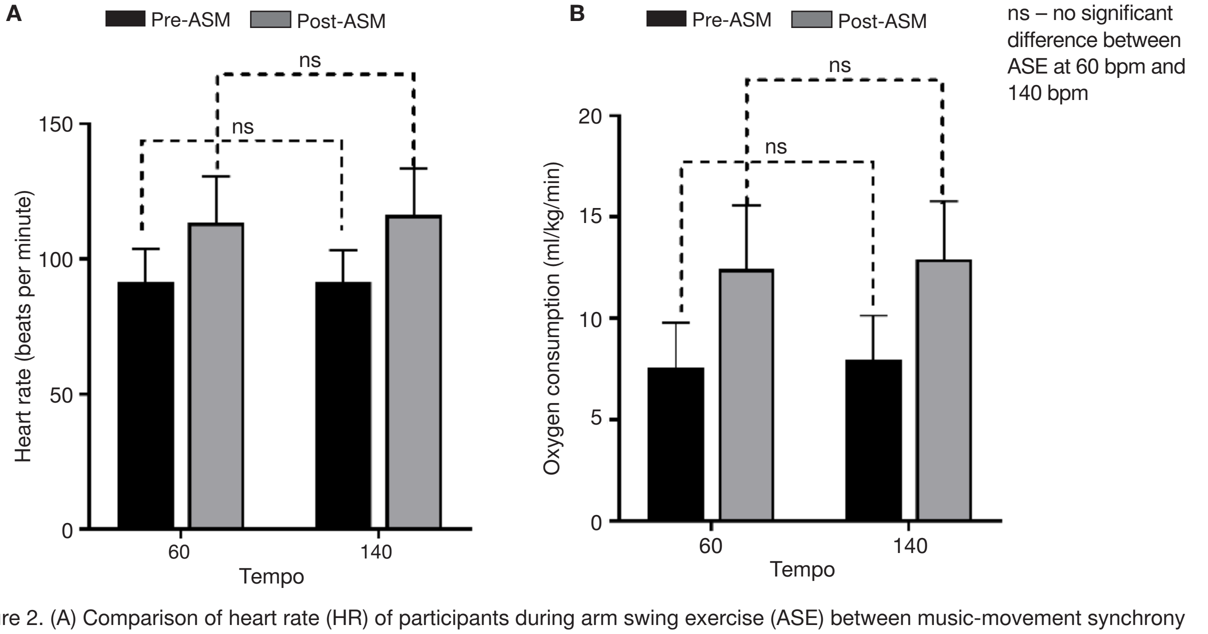
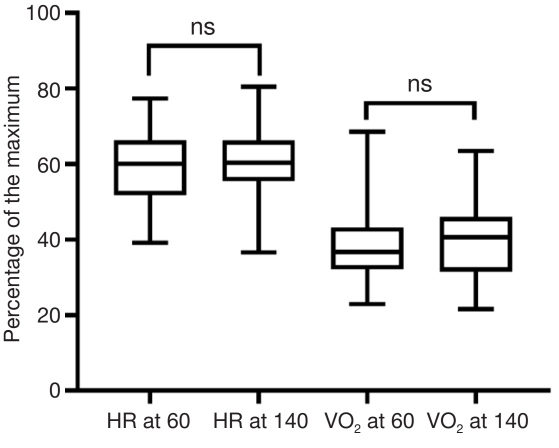


Figure 2. (A) Comparison of heart rate (HR) of participants during arm swing exercise (ASE) between music-movement synchrony at 60 bpm and 140 bpm using two-sample *t*-test ($p \geq 0.05$) and (B) comparison of oxygen consumption (VO_2) of participants during arm swing exercise (ASE) between music-movement synchrony at 60 bpm and 140 bpm using Mann-Whitney test ($p \geq 0.05$)

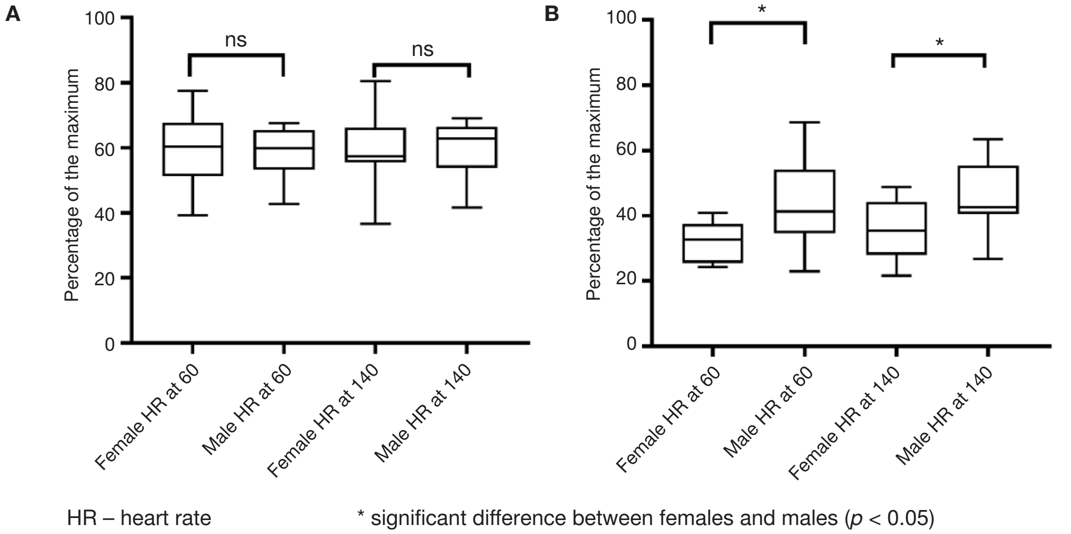
Table 2. Mean, maximum, and minimum of percentage maximum heart rate (%HR_{max}) and percentage maximum oxygen consumption (%VO_{2max}) of total, female, male post-arm swing exercise with music-movement synchrony at 60 bpm and 140 bpm

Variables	Music tempo at 60 bpm			Music tempo at 140 bpm		
	Total (*n* = 30)	Females (*n* = 15)	Males (*n* = 15)	Total (*n* = 30)	Females (*n* = 15)	Males (*n* = 15)
Mean of %HR_{max} (mean ± *SD*)	58.64 (8.82)	59.04 (10.12)	58.23 (7.63)	60.12 (8.95)	60.28 (10.19)	59.95 (7.87)
Maximum of %HR_{max}	77.36	77.36	67.50	80.48	80.48	69.06
Minimum of %HR_{max}	39.18	39.18	42.63	36.60	36.60	41.60
Mean of %VO_{2max} (mean ± *SD*)	38.65 (11.36)	32.37 (5.94)	44.94 (12.15)	40.17 (10.71)	35.37 (8.58)	44.98 (10.71)
Maximum of %VO_{2max}	68.52	40.86	68.52	63.48	48.78	63.48
Minimum of %VO_{2max}	22.93	24.32	22.93	21.60	21.60	26.76



HR – heart rate, VO_2 – oxygen consumption
ns – no significant difference between ASE at 60 bpm and 140 bpm

Figure 3. Mean, maximum, and minimum of percent maximal heart rate (%HR_{max}) and percent maximal oxygen consumption (%VO_{2max}) of participants post-arm swing exercise with music-movement synchrony at 60 bpm and 140 bpm



HR – heart rate
VO_2 – oxygen consumption
* significant difference between females and males ($p < 0.05$)
ns – no significant difference between females and males

Figure 4. Comparison of percent maximal heart rate (%HR_{max}) (A) and percent maximal oxygen consumption (%VO_{2max}) (B) between female and male post-arm swing exercise with music-movement synchrony at 60 bpm and 140 bpm using two-sample *t*-test

Discussion

The current study investigated the intensity of arm swing exercise synchronised with different music tempi in untrained individuals with low-to-moderate physical activity levels. All were healthy and there was no limitation for the arm swing exercise. As they were sedentary individuals, their resting heart rate was in the high range (91.70 ± 11.40 bpm). We found that some participants were outliers, with heart rates higher than 100 bpm. The mean total resting heart rate was 87.02 ± 8.33 bpm after the outliers were removed. The oxygen consumption during standing was 7.74 ± 1.77 ml/kg/minute, therefore the resting VO_2 of the participants was high when compared to healthy young adults. The probable reason is the standing position of measuring the VO_2 in this study. Barkley and Penko in 2009 [18] reported that the resting VO_2 in the supine position was 3.7 (0.4) ml/kg/min, while the VO_2 while playing a video game in a sitting position was 4.7 (0.8) ml/kg/min.

The intensity of ASE with both music tempi was 58–60% of the maximal heart rate and 38–40% of maximal oxygen consumption in untrained young adults. According to ACSM's guideline for exercise testing and prescription [19], our study demonstrated a percentage of maximal heart rate in the range of light intensity. Previous studies illustrated a low intensity of ASE, as the $\%HR_{max}$ ranged between 44 and 60% [4, 6, 7, 9, 10]. Interestingly, the $\%HR_{max}$ and $\%VO_{2max}$ in the young adults in the current study performing ASE with the music tempo at 60 bpm were higher than those performing ASE with the metronome tempo set at 60 bpm from the previous study [4]. The previous study demonstrated that $\%HR_{max}$ and $\%VO_{2max}$ were 47.99% and 19.12%, respectively.

Improvements in sports performance have been linked to music [20–22]. Improved mood, arousal management, dissociation, and a reduced feeling of effort are all benefits of music in the exercise and sports setting. Furthermore, listening to music while participating in sports might help to focus attention and divert it from exhaustion and discomfort [11, 20–22]. Previous studies demonstrated that exercising with music increased the heart rate and exercise duration [11, 12, 26]. Music can motivate young adults to exercise for longer periods of time, which is a stress reliever. The mechanism of music remains unclear, however, there is evidence to support that music influences the cognitive, sensory motor, and psycho-emotional systems to aid in the synchronisation of repetitive movement patterns during exercise [27, 28]. Nonetheless, the effect of music may be specific to the type of exercise. Listening to music while performing the Wingate anaerobic test did not increase anaerobic performance in people over the age of 18, according to a systematic review and meta-analysis [29]. Therefore, the value and health benefits of music cannot be overstated, with robust experimental research needing to be done to explain the effect of music on the intensity of exercise.

This study shows the intensity of ASE in female and male young adults (Table 2 and Figure 4). Although there was no significant difference between the females' and males' $\%HR_{max}$ of ASE in both tempi, the males' $\%VO_{2max}$ demonstrated significance higher than the females' $\%VO_{2max}$. According to previous studies, the exercise capacity in males is higher than in females [30–32]. The current study found a significant difference in weight, height and VO_2 during standing between the males and females. The previous study demonstrated that the sex difference affected aerobic capacity. One of the main explanations was differences in BMI and body fat. In the current study, no significant difference was found in BMI between the males and females, however, this study did not measure the body fat.

The different speeds of the tempo synchronised during ASE showed no significant difference in exercise intensity. The previous study also found that an increasing number of arm swings did not alter the target heart rate [33]. Even though the ASE did not cause adverse effects [7, 9, 10], the high-speed tempo may increase the risk of repetitive injury to the shoulder joint. Therefore, we recommend selecting the preferred music tempo synchronised with ASE in the range of 60–140 bpm.

Limitations

There were limitations to the current study. First, we used a single group research design to investigate the intensity of ASE with musical synchrony. Therefore, the true effects of ASE with musical synchrony could not be determined. To confirm these results, a randomised controlled study should be undertaken. Second, this study did not measure the body fat. Therefore, the further study should take into account the body fat, since it may affect the exercise capacity. The last limitation is the small sample size, which might introduce a bias in interpretation, especially when comparing the heart rate and oxygen consumption between the females and males. Therefore, more comprehensive future studies with larger samples are recommended to verify the impacts of confounding factors on arm swing exercise before any firm conclusions can be drawn.

Conclusions

Arm swing exercises are low-intensity aerobic exercises that can increase cardiovascular function and gas exchange. They may be a candidate for home-based exercise in home isolation during the pandemic of COVID-19 for healthy sedentary young adults. In addition, ASE with music makes it more relaxing and motivating to exercise. Furthermore, the faster tempo did not significantly alter the intensity of aerobic exercises, therefore, we recommend selecting the slower music tempo at 60 bpm to avoid repetitive shoulder joint injuries and to prevent shoulder instability.

This exercise is a feasible activity in young adults and further study is strongly recommended as a possible exercise practiced in older but healthy persons in order to implement a standard guideline of the physical arm swing exercise for all age groups in the future.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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