

Original Research

Analysis of cardiopulmonary function, energy metabolism, and exercise intensity and time according to the number of repetitions of Taekwondo Taeguk Poomsae in Taekwondo players

Won-Sang Jung^{1,†}, Hwang-Woon Moon^{2,†}, Jeong-Weon Kim³, Hun-Young Park^{1,4}, Jong-Beom Park⁵, Sang-Hwan Choi⁵, Jae-Don Lee⁵, Sang-Seok Nam^{5,*}

¹Physical Activity and Performance Institute, Konkuk University, 05029 Seoul, Republic of Korea

²Department of Sports Outdoors, Eulji University, 13135 Gyeonggi-do, Republic of Korea

³Graduate School of Professional Therapy, Gachon University, 13120 Gyeonggi-do, Republic of Korea

⁴Department of Sports Medicine and Science, Konkuk University, 05029 Seoul, Republic of Korea

⁵Taekwondo Research Institute, Kukkiwon, 06130 Seoul, Republic of Korea

*Correspondence: playdata.n@gmail.com (Sang-Seok Nam)

† These authors contributed equally.

Abstract

Background: This study aimed to compare and analysis of cardiopulmonary function, energy metabolism, and exercise intensity and time according to the number of repetitions of Taekwondo Taeguk Poomsae in Taekwondo players.

Methods: The participants were 29 healthy men (19.5 ± 1.2) who could perform Taekwondo Taeguk Poomsae 1 to 8 Jang.

Results: Minute ventilation, oxygen consumption, and carbon dioxide excretion, which assess cardiopulmonary function, were highest in 1st repetition of Taeguk 6–8 Jang and 5th and 10th repetitions of Taeguk 4 and 5 Jang, respectively. The respiratory exchange ratio was highest in 1st repetition of Taeguk 1 Jang and 5th and 10th repetitions of Taeguk 8 Jang. Regardless of the number of repetitions, carbohydrate oxidation was highest in Taeguk 8 Jang, and energy consumption was highest in Taeguk 5–8 Jang. The amount of fat oxidation was higher in 1st repetition of other Taeguk Poomsaes than in 1st repetition of Taeguk 1 and 2, and a similar occurrence was observed with 5th repetitions. However, at the 10th repetition, Taeguk 8 Jang was the lowest. Regarding exercise intensity and time, the percentage heart rate maximum exercise intensity for 1st repetition of the Poomsaes was 54%–63%, for 5th repetitions was 69%–82%, and for 10th repetitions was 72%–87%. The time duration according to the number of repetitions was 0.31 to 0.66 minutes for 1st repetition, 2.05 to 3.79 minutes for 5th repetitions, and 4.22 to 7.70 minutes for 10th repetitions.

Conclusions: This study suggests that as the number of repetitions of Taekwondo Taeguk Poomsae increased, the cardiopulmonary function, exercise intensity, and energy metabolism increased. In particular, cardiopulmonary function and exercise intensity were similar for all but Taeguk Poomsae 1 Jang, but the energy consumption was higher in Taeguk 5–8 Jang than in Taeguk 1–4 Jang.

Keywords

Taekwondo; Taeguk Poomsae; Number of repetitions; Cardiopulmonary function; Exercise intensity; Energy metabolism

1. Introduction

Taekwondo has developed into a popular sport worldwide as Korea's representative traditional martial arts, and it is currently estimated that more than 100 million people are trained in 210 member countries worldwide [1]. Taekwondo comprises of Poomsae, where individuals can independently hone their offensive and defensive skills, Kyorugi, where an individual faces off against his or her opponent, and breaking, a technique that allows an individual to independently assess his or her Taekwondo skill. Among these, Poomsae focuses on training an individual's movement direction and gaze, body center movement, speed and force control, and breathing [2]. Taekwondo has been reported to be an effective exercise for enhancing immunity and improving physical and mental health, and it is suitable for various age groups from children to the elderly [3, 4]. Previously, however, only Taekwondo Kyorugi events were adopted as official competitions in international competitions, to assess the physical and physiological profiles [5], training methods [6], and between Taekwondo competition recovery patterns [7] of Taekwondo athletes. Although Poomsae was recently adopted as an official competition event for international competitions, its value as a daily sport, aimed at maintaining and promoting the health of ordinary people, has not been established.

In recent years, the prolonged spread of the coronavirus disease (COVID-19) has further threatened social life and caused health problems [8, 9] that progress to chronic diseases through the interaction of genetic, behavioral, socioeconomic, and environmental factors along with the continued increase of overweight and obese populations worldwide [10]. To address this challenge, studies on interventions such as exercise and diet are being performed, and energy consumption during exercise is considered as a physiological index of exercise programs for maintaining [8, 11] and promoting general health and weight loss. Various training programs have been proposed for Taekwondo Poomsae [11], but research on these training programs is insufficient.

People train in Taekwondo, a martial art, for various purposes, such as health promotion, weight loss, and confidence, and it mostly consists of basic movements, mitt kicks, Poomsae, and Kyorugi [12–15]. Students who enroll to be trained in Taekwondo are primarily trained in Poomsae, which is a combination of hand and foot techniques and is systematically designed to improve various attack and defense skills [16]. Therefore, Taekwondo Poomsae is considered the most basic training method of Taekwondo, and it is necessary to develop training programs to efficiently achieve various training goals of trainees. To achieve this, it is necessary to establish a physiological basis of Taekwondo Poomsae.

Considering previous studies on Poomsae performance, changes in heart rate, oxygen intake, and lactic acid has been reported sporadically. The exercise intensity, energy consumption, and relative exercise intensity according to a 1-time performance of Taegeuk Poomsae were reported to be approximately 65%–85% of the maximum oxygen intake ($\text{VO}_{2\text{max}}$), although there were some differences in $\text{VO}_{2\text{max}}$

observed between the age levels of the study participants [17–20]. As described above, although most of the studies described the physiological basis of a 1-time performance of Taegeuk Poomsae, it is necessary to review the physiological basis of the quantification of the energy consumption characteristics of several repetitions of Taegeuk Poomsae.

Most previous studies on one-time Poomsae training reported on exercise intensity and energy metabolism, but these reports are insufficient to provide the general public with a scientific basis of the repeated performance of Taegeuk Poomsae. Moreover, Taekwondo is a popular sport worldwide, and it is not limited to only Korea, and to highlight its effectiveness in public health, a specific measure of the quantified energy metabolism for repeated training activities in Taekwondo is needed. In this study, the effect of repeated Taekwondo Taegeuk Poomsae performance on cardiopulmonary function, energy metabolism, exercise intensity and time was analyzed to confirm its effectiveness. Therefore, the purpose of this study was to compare and analysis of cardiopulmonary function, energy metabolism, and exercise intensity and time according to the number of repetitions of Taekwondo Taegeuk Poomsae in Taekwondo players.

2. Methods

2.1 Participants

The study participants are Taekwondo players (19.5 ± 1.2) who have been enrolled in the Taekwondo department with more than 5 years of experience. The inclusion criteria for the study were individuals who were proficient in implementing Taegeuk Poomsae (Jang 1–8) and had no musculoskeletal disease, no cardiovascular disease, and no neurological or psychiatric disease. The number of participants required for this study was calculated using the G*power 3.1 program, and in Cohen [21], the effect size large was applied by referring to the effect size test of One-way ANOVA. Accordingly, 26 people were calculated as a result of calculating based on the significance level of 0.05, the power ($1-\beta$) of 0.80 and the effect size of 0.40. However, 30 people were recruited in consideration of 10% dropouts.

This study was approved by the Institutional Review Board (IRB) of Eulji University (EUIRB2019-80), and an informed consent was obtained from each participant after the purpose, contents, and methods of the study were explained in details.

2.2 Study design

The participants performed a body composition test before starting the program, and subsequently performed a graded maximal exercise test (GXT) using a treadmill (TaeHa 6025, Kyungki-do, Korea). After a period of rest, the participants performed Taegeuk Poomsae 1 to 8 Jang while wearing a gas analyzer (K4B², COSMED, Rome, Italy) and heart rate monitor (S610i, Polar Electro Oy, Kempele, Finland). Each Taekwondo Taegeuk Poomsae was repeated 10 times at a speed of 60 bpm using a metronome, and the order for each Taekwondo Taegeuk Poomsae was performed in a crossover design. The order for Taegeuk Poomsae 1 to 8 Jang of the

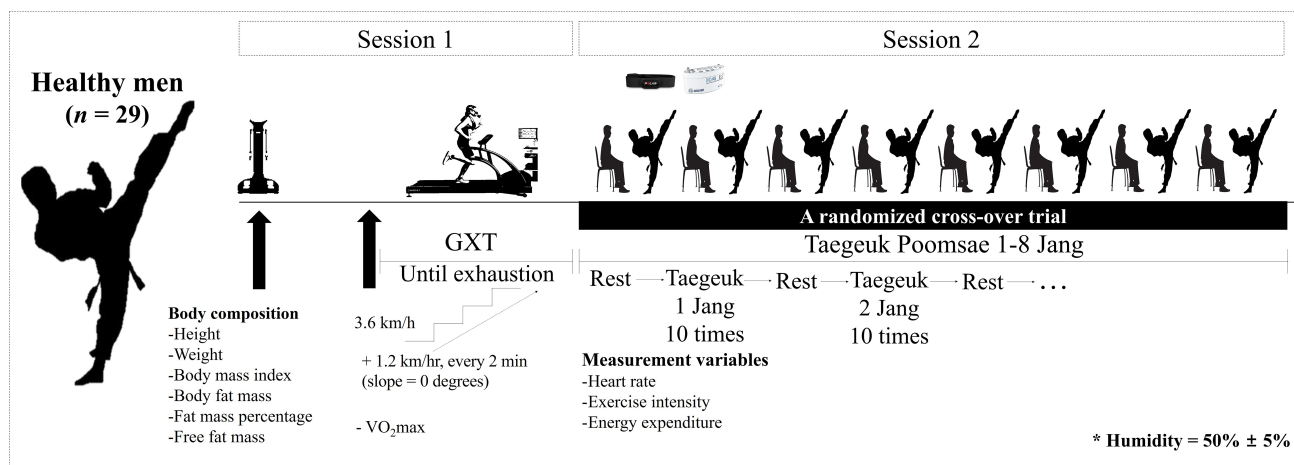


FIG. 1. Study design. VO_2max , maximal oxygen uptake.

was divided into 8 groups, and 29 people were randomly distributed equally, and the participants starting from 1 Jang ended at 8 Jang, and the starting from 2 Jang ended at 1 Jang. The rest of the order were carried out in the same manner. The training effect was avoided by a one-week interval between the Poomsae measurements (Fig. 1).

2.3 Body composition measurement

Body composition was measured using bioelectric impedance analyzer (Inbody 770, Biospace, Seoul, Korea), and all participants were assessed in lightweight clothing after they removed their socks, various accessories, and metallic items. The measured variables were body weight, height, body fat mass, fat mass percentage, and free fat mass. BMI was calculated using the following formula: $\text{weight (kg)}/\text{height}^2 (\text{m}^2)$.

2.4 Graded exercise test

The GXT of participants was performed using a treadmill (Intertrack 6025, Taeha, Kyungki-do, Republic of Korea) while they wore an automatic heart rate monitor (S610i, Polar Electro Oy, Kempele, Finland) and an automatic portable respiratory gas analyzer (K4B², COSMED, Rome, Italy). All the participants warmed up by walking at 3.6 km/h for 5 minutes, and subsequently, GXT was measured using the modified Bruce protocol [22]. The exercise load began at a speed of 3.6 km/h, which was increased by 1.2 km/h every 2 minutes without increasing the inclination. The termination criterion for VO_2max was determined by when two or more of the following conditions were met: (1) when oxygen uptake (VO_2) and heart rate (HR) no longer increase despite increasing exercise intensity; (2) when the target HR exceeds 90% of the predicted maximum HR; (3) when the respiratory exchange ratio (RER) is greater than 1.15; and (4) when the participant expresses a desire to discontinue the process.

2.5 Taegeuk Poomsae energy metabolism measurement

To measure the energy metabolism of Taegeuk Poomsae, the participants wore an automatic heart rate monitor (S610i, Polar Electro Oy, Kempele, Finland) and a portable automatic respiratory gas analyzer (K4B², COSMED, Rome, Italy). All the participants rested before the measurement to ensure a stable state, and after stabilization, one of the Taegeuk Poomsae (1–8 Jang) was performed and measured 10 times. After the measurement, the remaining Taegeuk Poomsae were also measured using the same method at a one-week interval. The variables measured by performing Taegeuk Poomsae were VO_2 , carbon dioxide excretion (VCO_2), RER, ventilation per minute (VE), HR, and exercise time. Substrate oxidation was calculated using the formula described by Jeukendrup and Wallis [23].

Carbohydrate (CHO) oxidation (g) = $4.210 \times \text{VCO}_2 - 2.962 \times \text{VO}_2$

Fat oxidation (g) = $1.695 \times \text{VO}_2 - 1.701 \times \text{VCO}_2$

Energy expenditure (EE, kcal) = $4.07 \times \text{CHO} + 9.75 \times \text{FAT}$

2.6 Statistical analysis

All data obtained in the present study were analyzed using SPSS software (version 25.0; IBM Corp., Armonk, NY, USA), and descriptive statistics were calculated for each dependent variable. Data are presented as mean ± standard deviation. The assumption of normality and homoscedasticity was verified using the Shapiro–Wilk test. First, a two-way analysis of variance (ANOVA) with repeated measures was used to elucidate the interaction effects between the Taegeuk Poomsae (1–8 Jang) and the number of repetitions. Second, repeated one-way ANOVA was used to evaluate differences in dependent variables between all the Taegeuk Poomsae and the number of repetitions, and the post-hoc test was performed using the Bonferroni test. A significance level was set at $p < 0.05$.

3. Results

3.1 Physical characteristics of participants

The physical characteristics of the participants are shown in Table 1. There were a total of 30 participants, among which one was eliminated due to personal reasons, and a total of 29 were included in the final result (Fig. 2).

TABLE 1. Baseline characteristics of the subjects.

Variables	Male (n = 29)
Age (years)	19.5 ± 1.2
Height (cm)	172.9 ± 4.9
Weight (kg)	70.8 ± 11.8
BMI	23.7 ± 3.5
Body fat mass (kg)	13.2 ± 7.2
Percentage body fat (%)	17.8 ± 5.6
Free fat mass (kg)	57.6 ± 5.8
HRrest (beat)	75.2 ± 8.2
HRmax (beat)	199.5 ± 10.1
VO ₂ max (mL/kg/min)	50.6 ± 5.0

BMI, body mass index; HRrest, resting heart rate; HRmax, maximal heart rate; VO₂max, maximal oxygen consumption.

3.2 Cardiopulmonary function of Taegeuk Poomsae

Regarding the cardiopulmonary function of Taegeuk Poomsae, the interaction effect was significant in all variables (Ventilation per minute; VE, $p < 0.001$, VO₂, $p < 0.001$, VCO₂, $p < 0.001$, RER, $p < 0.001$), and HR ($p < 0.001$). VE ($p < 0.001$), VCO₂ ($p < 0.001$), RER ($p < 0.001$), and HR ($p < 0.001$) were found to be high in the order of the 10th, 5th, and 1st repetitions. VO₂ ($p < 0.001$) was significantly higher on the 5th and 10th repetition than on the 1st repetition. Considering the differences between the Poomsae, VE, VO₂, and VCO₂ were highest in 1st repetition of Taegeuk 6–8 Jang and in 5 and 10 repetitions of Taegeuk 4 and 5 Jang. The RER was highest in 1st repetition of Taegeuk 1 Jang when measuring 1st, and the highest in 5th and 10th repetitions of Taegeuk 8 Jang (Fig. 3).

3.3 Energy metabolism of Taegeuk Poomsae

Interaction effect were significant differences were observed in all variables of energy metabolism (CHO oxidation, $p < 0.001$, fat oxidation, $p < 0.001$, and energy expenditure, $p < 0.001$). Regarding the energy metabolism of Taegeuk Poomsae, significant differences were found in the amount of CHO oxidation ($p < 0.001$) and energy expenditure ($p < 0.001$) among the number of repetitions, with the highest in the order of 10th, 5th, and 1st repetition. Regarding the amount of fat oxidation ($p < 0.001$), Taegeuk 1, 2, 3, 6, and 7 Jang were significantly higher on the 5th and 10th repetition than on the 1st repetition and on the 5th than the 1st repetition of Taegeuk 4, 5, 8 Jang. Excluding Taegeuk 1 Jang, the other Taegeuk Poomsae were high amounts of fat oxidation on the 5th and 10th repetition. Regardless

of the number of repetitions, CHO oxidation was highest in Taegeuk 8 Jang, and energy expenditure was highest in Taegeuk 5–8 Jang than in the other Taegeuk Poomsae. The amount of fat oxidation was higher in one repetition of the other Taegeuk Poomsae than in one repetition of Taegeuk 1 and 2 Jang, and it was similar at the five times. However, the amount of fat oxidation was the lowest at the 10th repetition of Taegeuk 8 Jang (Fig. 4).

3.4 Taegeuk Poomsae exercise intensity and time

In assessing the exercise intensity of Taegeuk Poomsae, interaction effects were observed in percentage maximal HR (%HRmax, $p < 0.001$), and percentage HR reserve (%HRR, $p < 0.001$). %HRmax ($p < 0.001$), and %HRR ($p < 0.001$) were the highest in Taegeuk 4 Jang regardless of the number of repetitions. The %HRmax exercise intensity for each Poomsae was 54%–63% for one repetition, 69%–82% for 5th repetitions, and 72%–87% for 10 repetitions. Regarding the number of repetitions, the %HRmax ($p < 0.001$), and %HRR ($p < 0.001$) were high in the order of 10th, 5th, and 1st repetition. Looking at the difference in the poomsae of exercise time, The time for Taegeuk Poomsae gradually increased from Taegeuk 1 Jang to Taegeuk 8 Jang, regardless of the number of repetitions. The time duration for one repetition was from 0.31 to 0.66 minutes, for five repetitions was from 2.05 to 3.79 minutes, and for 10th repetitions was from 4.22 to 7.70 minutes (Fig. 5).

4. Discussion

In this study, in order to verify the scientific effect of Taekwondo Taegeuk Poomsae, we tried to find out the heart rate, exercise intensity, and energy consumption of Taekwondo Taegeuk Poomsae, and analyze the difference between chapters 1 and 8 according to the number of repetitions.

In this study, the results related to cardiopulmonary function according to the Taegeuk Poomsae was VE ($p < 0.001$), VCO₂ ($p < 0.001$), RER ($p < 0.001$), and HR ($p < 0.001$) were found to be high in the order of the 10th, 5th, and 1st repetitions. VO₂ ($p < 0.001$) was significantly higher on the 5th and 10th repetition than on the 1st repetition. Considering the differences between the Poomsae, VE, VO₂, and VCO₂ were highest in 1st repetition of Taegeuk 6–8 Jang and in 5 and 10 repetitions of Taegeuk 4 and 5 Jang. The RER was highest in 1st repetition of Taegeuk 1 Jang when measuring 1st, and the highest in 5th and 10th repetitions of Taegeuk 8 Jang.

Taekwondo Poomsae is divided into Taegeuk 1 to 8 Jang, depending on the complexity and difficulty of the movement and the number of movements, and its difficulty increases as the level of movement increases [2, 24]. Similar to a preceding study, our study found an increase in cardiopulmonary function (VE, VO₂, VCO₂) after one repetition of Taekwondo Poomsae [2, 24]. In contrast, cardiopulmonary function was the highest in Taegeuk 4 and 5 Jang on the 5th and 10th repetitions, and it was similar except for Taegeuk 1 and 2 Jang. Heart rate and exercise intensity were sim-

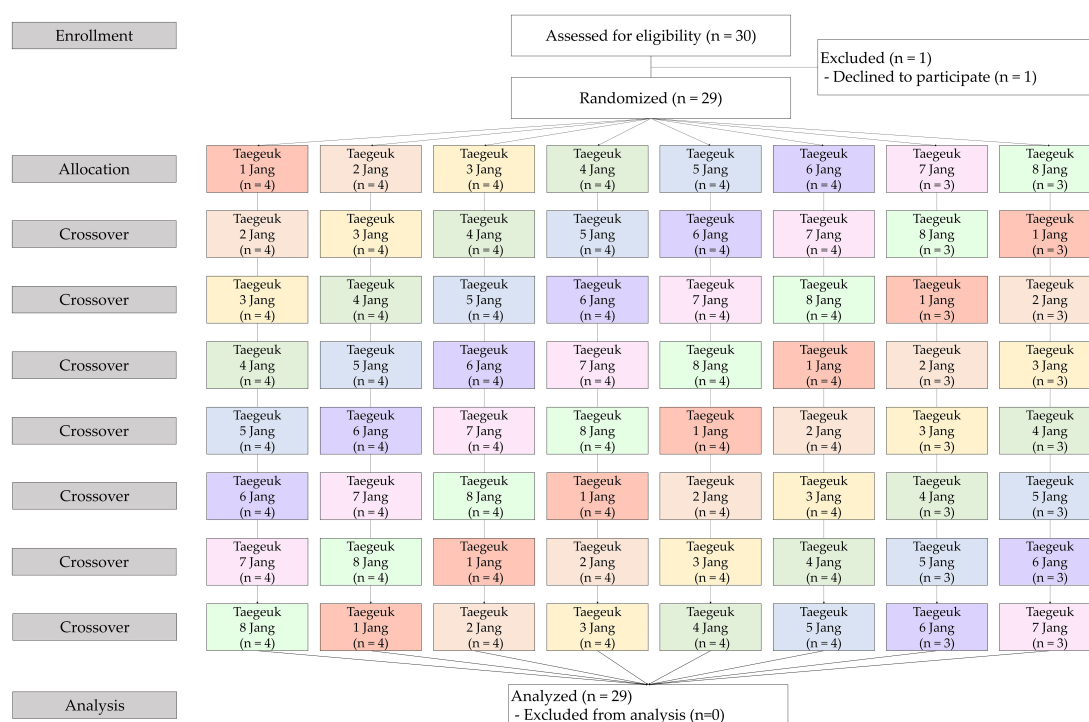


FIG. 2. Consolidated Standards of Reporting Trials (CONSORT) flow diagram.

ilar to oxygen consumption, but not related to repetition measurement. A previous study have reported that increase in oxygen consumption is proportional to the heart rate, but in a martial arts environment such as Taekwondo, the relationship between heart rate and oxygen consumption should be approached with caution [25]. It has been reported that in intermittent exercise environments such as martial arts, the heart rate can be overestimated than that of oxygen intake [26, 27]. Taekwondo mainly uses movement of the legs and the arms, but emotional factors and thermal stress can affect the heart rate during Taekwondo exercise [28, 29]. Nevertheless, some studies have shown similar tendencies towards oxygen intake and heart rate, and this study also showed a similar tendency towards oxygen intake and heart rate [30, 31]. The increase in heart rate is believed to be due to increased breathing rate and the demand for more nutrients and oxygen by the large active muscles recruited when performing from Taegeuk 4 to 8 Jang.

According to the energy metabolism of Taekwondo Taegeukpum Bird, there was a significant difference in CHO oxidation and energy consumption according to the number of repetitions, and it was the highest in the order of 10th, 5th, and 1st repetitions. Regardless of the number of repetitions, CHO oxidation was the highest in the Taegeuk chapter 8, and fat oxidation was the lowest in the Taegeuk 8 and 10 Jang.

Energy metabolism was calculated as the amount of oxygen used during physical activity or metabolic activity in proportion to the oxygen consumption. The contraction and relaxation of skeletal muscles during exercise require the use of energy [32]. The energy source used in this study was oxygen, and it required that breathing, circulation, nerves,

and muscles work together organically [33]. In this study, the energy consumption of each Taekwondo Poomsae was 1.03–3.50 kcal when measured on the 1st repetition, 18.97–39.74 kcal when measured on the 5th repetition, and 40.81–80.19 kcal when measured on the 10th repetition. Based on these results, the energy consumption per minute for 1 time measurement was 3.32–5.30 kcal/min. As reported in the study by Jung *et al.* [18], the average energy consumption of Taekwondo Poomsae was reported as 3.05–6.43 kcal/min, which is consistent with that reported in this study. Previous studies have reported the average energy consumption of walking as 3.5 ± 0.58 kcal/min, of stair climbing as 6.57 ± 1.31 kcal/min [34], of brisk walking as 4.73–6.68 kcal/min [35], of golf as 3.3–8.15 kcal/min [36], and of Pilates as 3.2 ± 0.6 kcal/min [37], which are consistent with the findings in this study. However, when Taekwondo Poomsae is measured when the repetitions are more than 5, the energy consumption per minute is 9.25–10.49 kcal/min, indicating that the relative exercise intensity of continuous Taekwondo Poomsae is increased.

The repeated performance of Taekwondo Poomsae requires the consumption of more calories than that required by light badminton, volleyball, and sports dance, and shows similar calorie consumption to soccer, swimming (40 minutes), cycling (20 km/h), and running (10 km/h) [38]. It can be observed that the effect of physical activity and exercise as measured by the energy consumption can be achieved even with one-repetition of Taekwondo Poomsae, but more energy consumption is required with 5 or more repetitions of Taekwondo Poomsae. Chung *et al.* [17] found that the speed and number of kicks involved in Taekwondo Poomsae can increase energy consumption. However, the fast speed

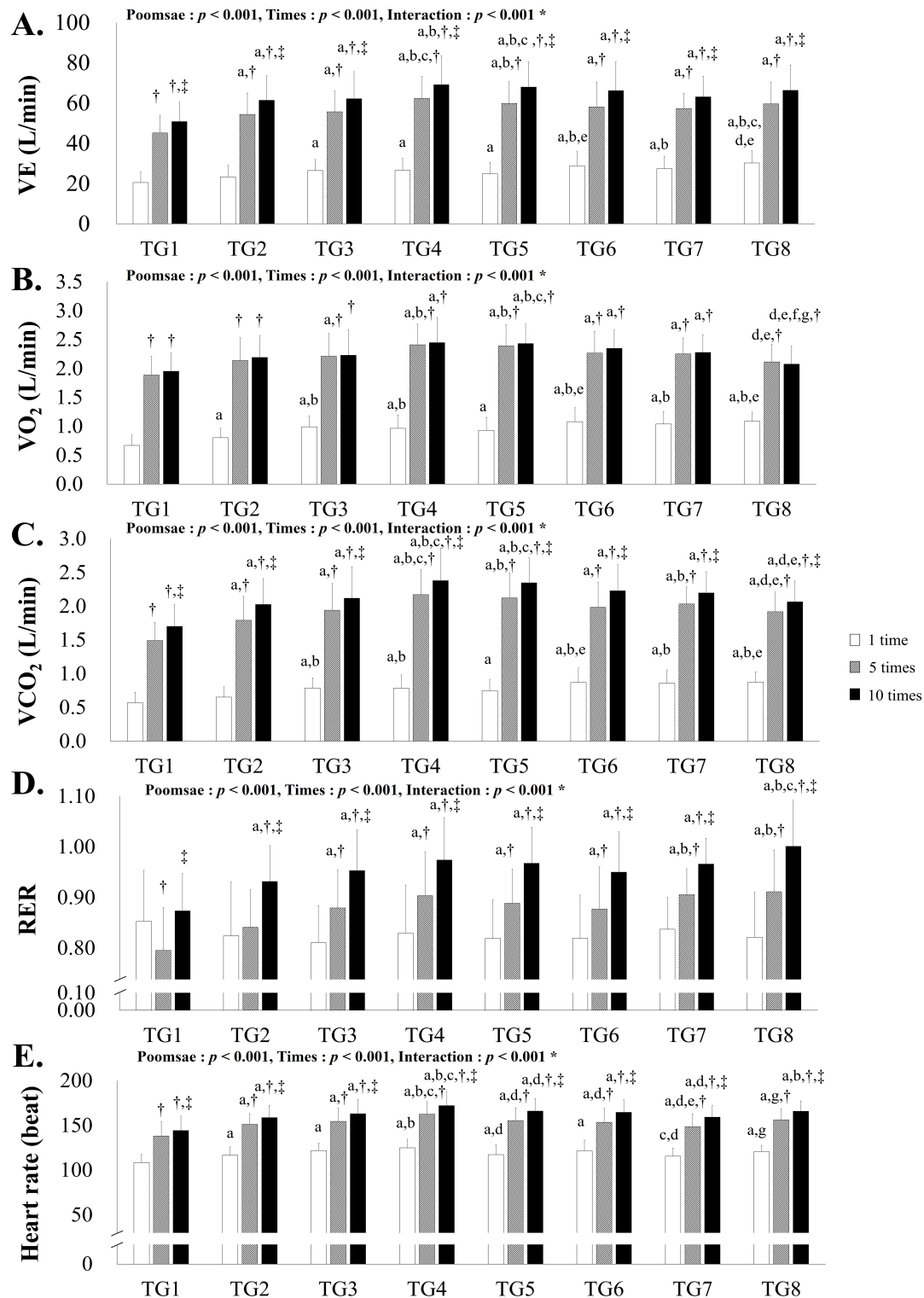


FIG. 3. Cardiopulmonary function of Taekwondo Taeguek Poomsae (mean $\pm$ standard deviation). (A) change in VE, (B) change in VO₂, (C) change in VCO₂, (D) change in RER, (E) change in HR are shown. TG, Taeguek; VE, minute ventilation; VO₂, oxygen uptake; VCO₂, carbon dioxide excretion; RER, respiratory exchange ratio; HR, heart rate. a: $p < 0.05$ vs. TG1, b: $p < 0.05$ vs. TG2, c: $p < 0.05$ vs. TG3, d: $p < 0.05$ vs. TG4, e: $p < 0.05$ vs. TG5, f: $p < 0.05$ vs. TG6, g: $p < 0.05$ vs. TG7. †: $p < 0.05$ vs. 1st repetition, ‡: $p < 0.05$ vs. 5th repetition.

and several kicks involved in Taekwondo Poomsae does not seem to affect energy metabolism because Taekwondo Poomsae is performed once, over a short duration. Taekwondo Poomsae is a combination of isometric exercises of the lower extremities and isotonic exercise of the upper extremities.

Repetitive performance demonstrates the characteristics of energy consumption according to differences in the exercise execution time of the upper and lower extremities.

The main energy used by the body during exercise is from carbohydrates, fats, and proteins, and oxidation of carbohy-

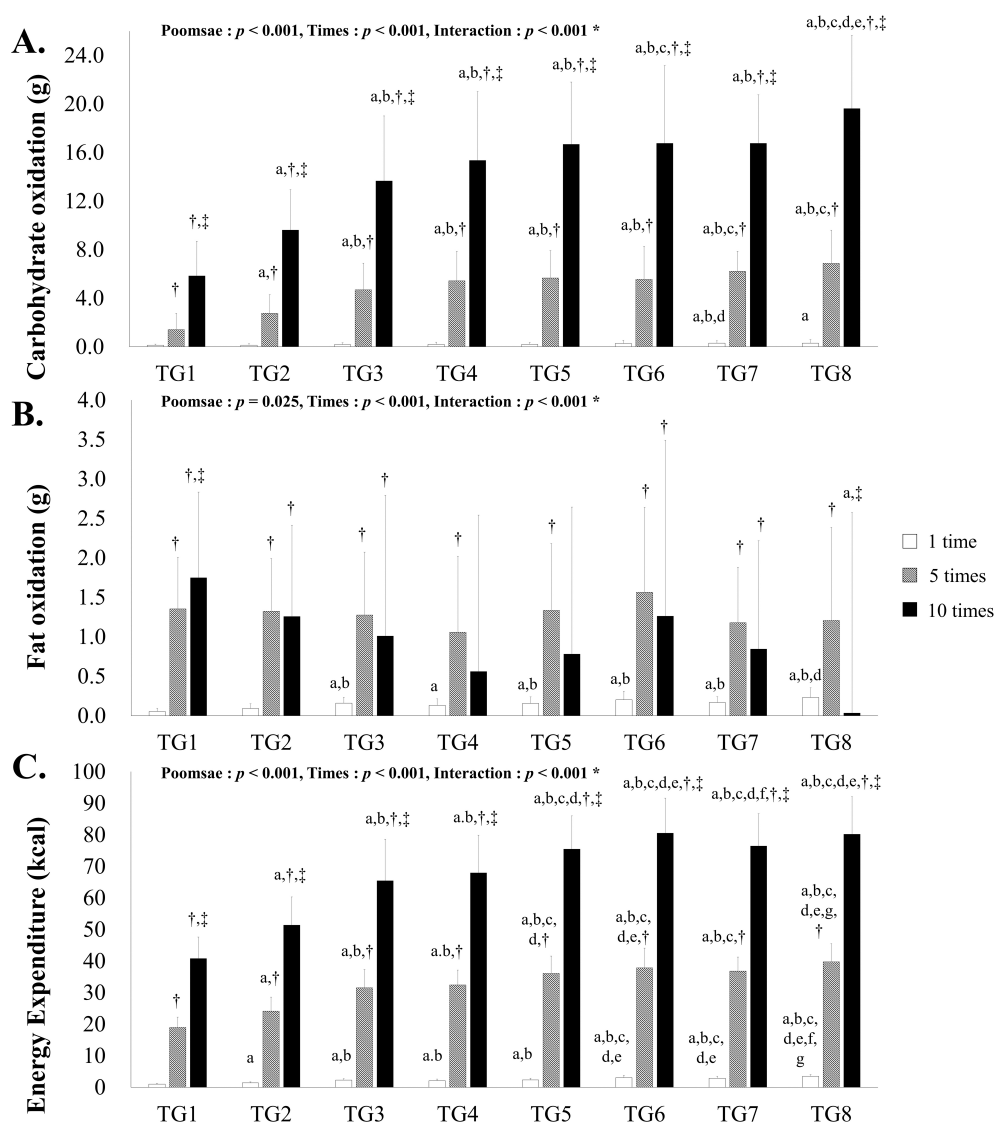


FIG. 4. Energy metabolism of Taekwondo Taegeuk Poomsae (mean $\pm$ standard deviation). (A) change in CHO oxidation, (B) change in fat oxidation, (C) change in EE are shown. TG, Taegeuk; CHO, carbohydrate; EE, energy expenditure. a: $p < 0.05$ vs. TG1, b: $p < 0.05$ vs. TG2, c: $p < 0.05$ vs. TG3, d: $p < 0.05$ vs. TG4, e: $p < 0.05$ vs. TG5, f: $p < 0.05$ vs. TG6, g: $p < 0.05$ vs. TG7. †: $p < 0.05$ vs. 1st repetition, ‡: $p < 0.05$ vs. 5th repetition.

drates gradually increases with increased kinetic intensity, fat oxidation increases with low and moderate intensity, and fat oxidation decreases with moderate and vigorous intensity exercises [23, 39]. In this study, the exercise intensity of one repetition of Taekwondo Poomsae was 54% to 63% HRmax, of 5 repetitions was 69% to 82%, of 10 repetitions was 72% to 87%. The American College of Sports Medicine (ACSM) [11] reported that moderate intensity exercise was 65%–75% of HRmax and high intensity was 76%–96% of HRmax. In this study, one repetition of Taegeuk Poomsae corresponded to low intensity, five repetitions corresponded to moderate-vigorous intensity, and ten repetitions corresponded to vigorous intensity exercises. As shown in Fig. 3, if Taekwondo Poomsae is repeated five times, it is considered to correspond to moderate-vigorous intensity exercises, considering that it requires higher fat oxidation than carbohydrates. In addition, if the carbohydrate ratio is extremely high with 10

repetitions of Taekwondo Poomsae, it is judged as a vigorous intensity exercise. ACSM [11] recommends 30–60 minutes of moderate-intensity exercise for at least 5 days a week to maximize the effect of exercise, and 20–60 minutes of vigorous-intensity exercise for at least 3 days a week. It is also recommended that moderate-intensity and vigorous-intensity exercises should be combined. Based on the results shown in this study, repeating Taekwondo Poomsae five times is also effective, but repeating Taekwondo Poomsae over a long duration is effective against consuming energy, given that the energy consumption is high when measured repeatedly for 10 times.

In most cases, medium-high intensity aerobic exercise is highly recommended for weight loss and health promotion [11, 40]. Regarding the effect of the type of exercise on the body, long-term light exercise reduces body fat and blood lipids, short-term intensity exercise improves cardiovascu-

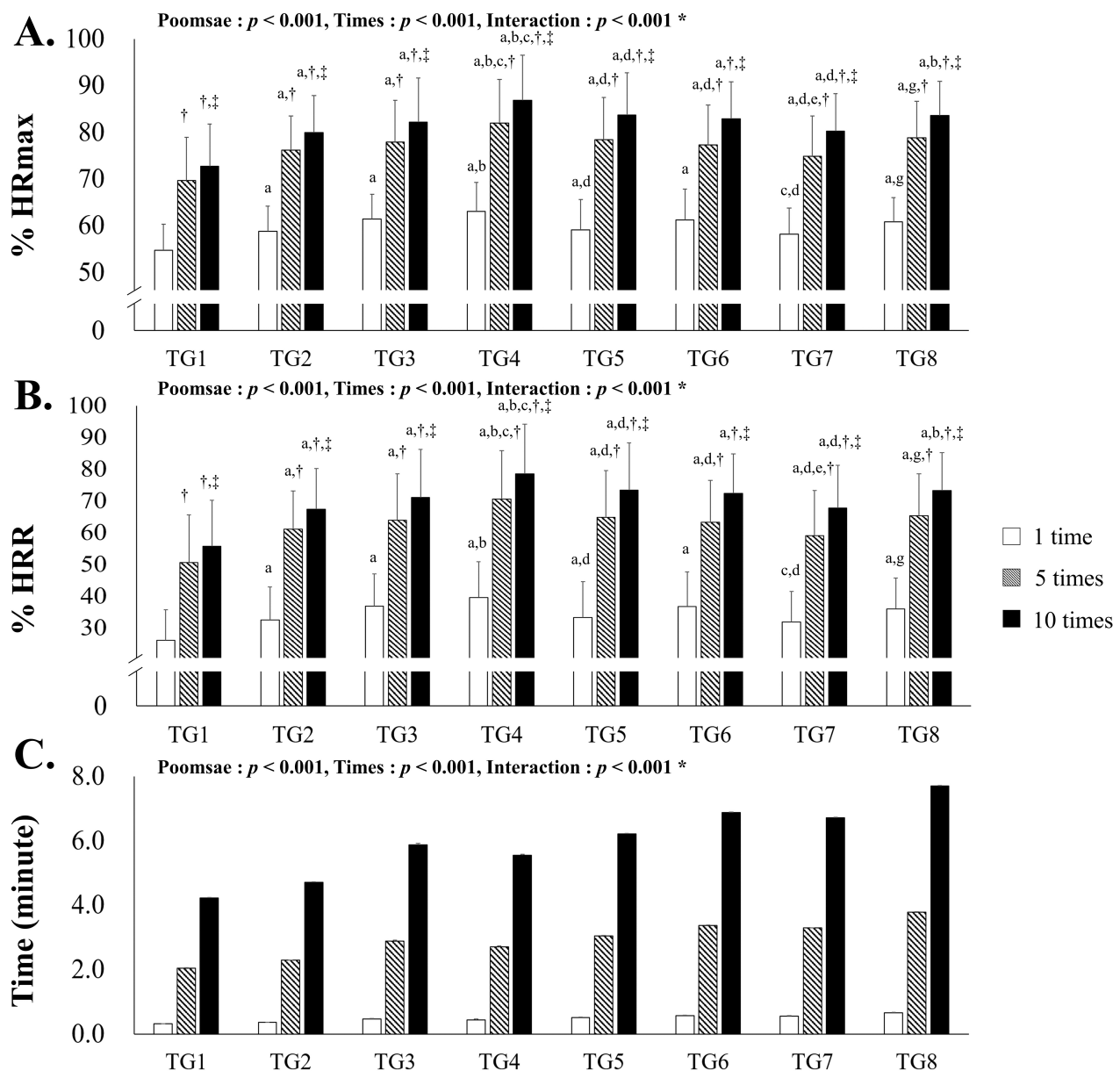


FIG. 5. Taekwondo Taegeuk Poomsae intensity and time (mean $\pm$ standard deviation). (A) change in %HRmax, (B) change in %HRR, (C) change in time are shown. TG, Taegeuk; %HRmax, percentage maximal heart rate; %HRR, percentage heart rate reserve. a: $p < 0.05$ vs. TG1, b: $p < 0.05$ vs. TG2, c: $p < 0.05$ vs. TG3, d: $p < 0.05$ vs. TG4, e: $p < 0.05$ vs. TG5, f: $p < 0.05$ vs. TG6, g: $p < 0.05$ vs. TG7. †: $p < 0.05$ vs. 1st repetition, ‡: $p < 0.05$ vs. 5th repetition.

lar function, moderate-intensity sustained exercise decreases heart rate and blood pressure, increases blood volume and thyroid hormone, and decreases blood catecholamines [40–44]. If various programs for Taekwondo Poomsae are developed, its popularity regarding its role in health promotion can increase. To increase energy consumption using Taekwondo Poomsae, Taegeuk 5–8 Jang can be performed as a vigorous intensity exercise, and it is considered to be good to configure the program by adding 5 and 10 repetitions. In addition, if an individual wishes to perform a low intensity exercise over a long duration, Taegeuk 1 to 4 Jang with a break between repetitions. This study has several limitations as

follows. The subjects of this study are young and skilled in Taekwondo Taegeuk Poomsae, and there is a limit of applying the same results from the general public who has never experienced Taegeuk Poomsae. In addition, the variables that significantly affect energy metabolism was controlled as much as possible, but the psychological factors of the subjects were not sufficiently considered on the same day. Taekwondo proficiency can be different from unskilled in many ways, and it is difficult to identify and properly control disturbing factors. In this study, documented attempts were made throughout the design and performance of this study to evaluate and report evidence of an objective manner, and we tried our best to post all insignificant results, whether the results are positive or negative.

5. Conclusions

The results of this study suggest that as the number of repetitions of Taekwondo Poomsae increased, the cardiopulmonary function, exercise intensity, and energy metabolism increased. In particular, cardiopulmonary function and exercise intensity were similar in all Taeguk Poomsae except for Taeguk Poomsae 1 Jang, but the energy consumption was higher in Taeguk 5–8 Jang than in Taeguk 1–4 Jang. Based on these results, if Taekwondo Taeguk Poomsae is repeatedly conducted for the general public, it can probably be recommended as a positive exercise program to increase energy consumption. In the future, it can be used not only for the development of various programs of Taekwondo Poomsae, but also as an effective exercise program for people with physical activity restrictions due to COVID-19.

Abbreviations

VE, ventilation per minute; VO_2 , oxygen uptake; VCO_2 , carbon dioxide excretion; HR, heart rate; RER, respiratory exchange ratio; CHO, Carbohydrate; EE, energy expenditure; VO_{2max} , maximum oxygen intake; GXT, graded maximal exercise test.

Author contributions

SSN conceived and designed this study; SSN, JDL, SHC, JBP, HYP, JWK, HWM, and WSJ performed the experiments and measurements; SSN and WSJ conducted the data analysis; WSJ, HWM, and SSN wrote the original draft preparation; WSJ, HWM, and SSN discussed the results and concluded. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

This study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the local ethics committee of Eulji University (EUIRB2019-80). Informed consent was obtained from all the subjects involved in the study.

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Conflict of interest

The authors declare no conflict of interest.

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