

Effects of Basic Karate Exercises on Maximal Oxygen Uptake in Sedentary Collegiate Women

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The primary purpose of this study was to investigate the chronic effects of practicing 30 min of basic karate exercises (BKEs) for 10 weeks on maximal oxygen uptake ($\dot{V}O_2\text{max}$) in sedentary collegiate women who had no previous karate experience. The secondary purpose of this study was to investigate physiological responses and intensities of BKEs to examine the intensity of exercise. Nine women practiced 30 min of BKEs, 4 days-week⁻¹, for 10 weeks. The six other women acted as controls. The 30 min of BKEs consisted of 9 min of stationary basics in a parallel stance (S-Basics I), 12 min of stationary basics in a front stance (S-Basics II), and 9 min of movement basics in the front stance (M-Basics). For S-Basics I, the mean percent of maximum $\dot{V}O_2$ reserve (% $\dot{V}O_2R$) was much lower than the accepted threshold, while the mean percent of maximum heart rate reserve (%HRR) was slightly lower than the accepted threshold for increasing $\dot{V}O_2\text{max}$, i.e., 40% of $\dot{V}O_2R$ or HRR. For S-Basics II, the mean % $\dot{V}O_2R$ was marginal, while the mean %HRR was above the accepted threshold for increasing $\dot{V}O_2\text{max}$. The mean % $\dot{V}O_2R$ and %HRR for M-Basics were above the threshold for increasing $\dot{V}O_2\text{max}$. $\dot{V}O_2\text{max}$ in both l·min⁻¹ and ml·kg⁻¹·min⁻¹ in the experimental group significantly increased at the end of the

10 weeks of training (from 1.80 ± 0.30 to 2.00 ± 0.34 l·min⁻¹ and 32.3 ± 4.1 to 36.0 ± 4.4 ml·kg⁻¹·min⁻¹, respectively), while neither value changed significantly in the control group. In conclusion, 30 min of BKEs can reach the minimal threshold level to increase cardiovascular fitness and can improve cardiovascular fitness in sedentary women.

Key words—karate, maximal oxygen uptake, heart rate, body composition

INTRODUCTION

In 2006, the Ministry of Health, Labour and Welfare of Japan published the “Exercise and Physical Activity Reference for Health Promotion 2006: Physical Activity, Exercise, and Physical Fitness” (Exercise Guide 2006). In the Exercise Guide 2006, the goal of physical fitness in terms of maximal oxygen uptake ($\dot{V}O_2\text{max}$) was set at 33 ml·kg⁻¹·min⁻¹ for young women, ranging from 20 to 29 years of age.¹⁾ In a recent study²⁾ at our laboratory, we reported that the goal of $\dot{V}O_2\text{max}$ in ml·kg⁻¹·min⁻¹ set in the Exercise Guide 2006 was valid.

Karate training involves basic techniques, kata and sparring. Basic techniques such as punching, kicking, blocking, and striking are practiced either in the stationary position (S-Basics) or with body movements in various formal stances (M-Basics). The S-Basics and M-Basics are very formal and systematic and combined with kata, which are set forms of pre-established sequences of defensive and offensive techniques and movements.

Karate training in general and karate kata have been claimed to contribute to increasing cardiovascular fitness by some karate masters.^{3,4)} In addition, some studies suggested that M-Basics^{5,6)} or kata⁷⁻¹⁰⁾ could be used as an effective means for training cardiovascular fitness in karate practitioners. However, as far as the authors are aware, the chronic effects of karate exercises on $\dot{V}O_2\text{max}$ have never been investigated.

The primary purpose of this study was to investigate the chronic effects of practicing 30 min of basic karate exercises (BKEs) for 10 weeks on $\dot{V}O_2\text{max}$ in sedentary collegiate women who had no previous karate experience. The secondary purpose of this study was to investigate physiological responses and intensities of BKEs to examine the

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intensity of exercise.

MATERIALS AND METHODS

Subjects — We recruited collegiate women who had been sedentary for at least one year at one university. Fifteen women participated in this study. Among the subjects, 9 women practiced 30 min of BKEs, 4 days·week⁻¹, for 10 weeks. The six other women acted as controls. Prior to the study, there were no significant differences in the mean age (21.1 ± 0.9 and 20.2 ± 0.4 yrs, respectively) and body height (160.0 ± 5.1 and 157.1 ± 2.5 cm, respectively) between the experimental and control groups. Both groups were asked to maintain their regular diet and general physical activity throughout the experimental period. The study protocol was approved by the ethics committee of the university. Informed consent was obtained from each participant.

Procedure — 3–7 days before the experiment, and after 10 weeks of training, body weight, height, $\dot{V}O_2$ max, and body composition were measured, and energy intake was assessed. Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. Each participant performed an incremental test to volitional exhaustion on a Woodway treadmill (Tokyo, Japan) using a modified Bruce Protocol, which consisted of 3-min work stages, starting at 1.7 mph and 0% incline, after which the treadmill speed and incline were increased according to the protocol of Bruce *et al.*¹¹⁾ The test was conducted in air-conditioned facilities with a temperature set at 22°C. Ventilatory measurements were made continuously by standard open-circuit calorimetry using a Metabolic Cart (Sensormedics Vmax, Yorba Linda, CA, U.S.A.) with 20-sec sampling intervals. The system was calibrated against a known mixture of gases before each experiment. $\dot{V}O_2$ max was based on the following criteria: a plateau in $\dot{V}O_2$ with an increase in work rate; a respiratory exchange ratio (RER) of greater than 1.0. The electrocardiogram (ECG), using a bipolar CM5 lead configuration, was monitored via radio telemetry (Fukuda Denshi, Tokyo, Japan). Exercise heart rate (HR) was recorded for 10 sec during the final minute of each stage. Shortly after 5 μ l of blood lactate sample was drawn from an earlobe, it was analyzed with the Lactate Pro Analyzer (Akray, Tokyo, Japan). The Lactate Pro is supplied with a Check Strip to confirm that the

analyzer is operating correctly and a Calibration Strip that provides a non-quantitative indication of instrument accuracy. The reported correlations between the Lactate Pro and the ABL 700 Series Acid-Base analyzer, YSI 2300, and Accusport were $r = 0.98$, $r = 0.99$, and $r = 0.97$, respectively.¹²⁾ Body composition was measured with air-displacement plethysmography methods (Bod Pod; Life Measurement Instruments, Concord, CA, U.S.A.).¹³⁾ In brief, the 5-min test consists of measuring the subject's weight using an electronic scale, and the subject's volume, which is determined by sitting inside the Bod Pod chamber. From these 2 measurements, the subject's body composition is calculated. The reported correlation between the Bod Pod and hydrostatic weighing was $r = 0.88$.¹⁴⁾ All subjects were interviewed by experienced dietitians using a food frequency questionnaire (FFQ), which is based on 29 food groups and 10 types of cooking, for estimating the energy and nutrient intakes of each subject during the past 1–2 months.¹⁵⁾ From the FFQ, the mean daily energy intake was calculated according to the Tables of Japanese Foodstuff Composition.¹⁶⁾

BKEs — The 30 min of BKEs consisted of 9 min of stationary basics in a parallel stance (feet apart at shoulder width, S-Basics I), 12 min of stationary basics in a front stance (feet widely apart in front and behind; deeply bending the front knee and keeping the back knee straight, S-Basics II), and 9 min of movement basics in the front stance (M-Basics). The participants stretched for 10 min before and after the 30 min of BKEs, and 5 min of active standing rests were taken between S-Basics I and S-Basics II and between S-Basics II and M-Basics. For each type of exercise, a few seconds of active standing rest was taken between executing each technique.

The series of S-Basics I consisted of a middle punch with alternating arms, 2 punch combinations (right upper and left middle punches followed by left upper and right middle punches), and 3 punch combinations (right upper, left middle, and right upper punches followed by left upper, right middle, and left upper punches). Each exercise was performed 10 times lightly and 20 times at full speed. Each leg was swung straight up as high as possible 20 times continuously and was swung to the side as high as possible 20 times continuously. Middle front kick and roundhouse kick were performed 10 times lightly and 20 times at full speed with alternating legs.

The series of S-Basics II consisted of middle

punch with alternating arms, 2 punch combinations, middle front kick, and roundhouse kick. These exercises were performed with the left foot front 10 times lightly and 20 times at full speed, and then the feet were switched and the same exercises were repeated.

The series of M-Basics consisted of lunge middle punch, reverse middle punch, front kick, and roundhouse kick performed 30 times with alternating arms or legs at full speed.

This program was similar to the typical karate training session used at some civic karate schools in Japan.

Training Intensities — At the fifth week and at the end of the training period, training intensities of the 30 min of BKEs were measured. The test was conducted in air-conditioned facilities with a temperature set at 22°C. The participants changed into their karate uniforms after ECG surface electrodes were taped and sat quietly for 30 min. At the end of this resting period, $\dot{V}O_2$, HR, and blood lactate were measured. Analyses for O_2 and CO_2 were performed on the system as described above. A face mask was removed after resting measurements were taken. Participants were allowed to stretch for 10 min, after which they wore the face mask again and performed 30 min of BKEs as described above. During the performance of S-Basics I and II by the participants, one assistant held the Metabolic Cart, and another one held the hose leading from the two-way valve to the mixing box at the analyzer. During the performance of M-Basics by the participants, one assistant pushed the Metabolic Cart, and another one held the hose. Prior to the study, they practiced pushing the Metabolic Cart as fast as possible so that the participants could perform the M-Basics with minimal disturbance. Because participants moved straight back and forth (no side steps) during M-Basics, this was accomplished easily. Blood lactate samples were analyzed with the Lactate Pro Analyzer as described above. Blood lactate samples were taken in the sitting position in a chair at the end of the resting period. During exercise, blood lactate samples were taken in the standing position immediately after the performance of each exercise. The ECG as described above was monitored via radio telemetry (Fukuda Denshi, Tokyo, Japan). The participants' HR was recorded for 10 sec at the end of the 30-min sitting rest and every minute thereafter. The percent of maximum HR ($\%HR_{max}$) and $\%\dot{V}O_{2max}$ were calculated by dividing exercise HR by HR_{max} and

exercise $\dot{V}O_2$ by $\dot{V}O_{2max}$ obtained from maximal treadmill exercise. Maximum HR reserve (HRR) and maximum $\dot{V}O_2$ reserve ($\dot{V}O_{2R}$) were calculated from the difference between resting and maximum HR and resting and maximum $\dot{V}O_2$, respectively. Perceived exertion using Borg's scale¹⁷⁾ was obtained immediately after the performance of each exercise. The energy expenditure (EE) in kJ was calculated from $\dot{V}O_2$ and respiratory exchange ratio (R) according to the following formula: $EE = \dot{V}O_2 \cdot (15.480 + 5.550 \cdot R)$.¹⁸⁾

Statistical Analysis — Descriptive statistics include means and S.D. Data before and after the experimental period were analyzed by paired Mann-Whitney U test. Data between the experimental and control groups were analyzed by non-paired Mann-Whitney U test. A *p* value of less than 0.05 was considered to be statistically significant.

RESULTS

Physiological responses and training intensities of the 30 min of BKEs measured at the 5th week of the training period are shown in Table 1. For S-Basics I, the mean $\%\dot{V}O_{2R}$ was much lower than the accepted threshold, while the mean $\%HRR$ was slightly lower than the accepted threshold for increasing $\dot{V}O_{2max}$. For S-Basics II, the mean $\%\dot{V}O_{2R}$ was marginal, while the mean $\%HRR$ was above the accepted threshold for increasing $\dot{V}O_{2max}$. The mean $\%\dot{V}O_{2R}$ and $\%HRR$ for M-Basics were above the threshold for increasing $\dot{V}O_{2max}$. Although all subjects (9 women) in the experimental group participated in the measurement of acute responses of BKEs at the fifth week of the training period, only 5 women participated at the end of the training period because of the busy schedule of the subjects' academic studies. However, the results obtained at the fifth week and at the end were very similar (data not shown).

Maximal values obtained by a treadmill test, body composition, and energy intake before and after 10 weeks of training are shown in Table 2. $\dot{V}O_{2max}$ in both $l \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in the experimental group significantly increased at the end of the 10 weeks of training, while neither value changed significantly in the control group. The body composition and energy intake did not change significantly in either group.

Table 1. Physiological Responses and Training Intensities of BKEs

Parameters	S-Basics I		S-Basics II		M-Basics	
HR (beats·min ⁻¹)	109.8 ± 8.7		128.9 ± 14.9*		133.0 ± 16.4*	
%HRmax (%)	60.5 ± 3.6		70.9 ± 6.6*		73.1 ± 7.4*	
HRR (%)	37.4 ± 6.8		53.8 ± 10.9*		57.4 ± 12.1*	
$\dot{V}O_2$ (ml·min ⁻¹)	658.6 ± 188.5		883.8 ± 299.6*		1064.6 ± 187.9*	
% $\dot{V}O_2$ max (%)	33.3 ± 8.7		44.4 ± 13.8*		53.8 ± 8.5**	
$\dot{V}O_2R$ (%)	26.7 ± 9.7		38.9 ± 15.2*		49.2 ± 9.3**	
METs	3.8 ± 1.3		5.1 ± 2.1		6.1 ± 1.7**	
LA (mmol·l ⁻¹)	2.5 ± 0.7		3.8 ± 1.4*		2.2 ± 0.9**	
RPE	11.6 ± 0.7		14.3 ± 1.5*		13.9 ± 1.6*	
EE (kJ)	103.8 ± 20.1		192.1 ± 32.5*		153.4 ± 33.1*	
EE (kcal)	27.0 ± 4.4		36.6 ± 5.7*		42.9 ± 6.0*	

LA = lactic acid, RPE= ratings of perceived exertion. * $p < 0.05$ compared with S-Basics I, ** $p < 0.05$ compared with S-Basics II.

Table 2. Maximal Values Obtained by a Treadmill Test, Body Composition, and Energy Intake before and after 10 Weeks of Training Period

Parameters	Experimental Group				Control Group	
	Pre-training		After 10 weeks		Pre-training	After 10 weeks
Weight (kg)	56.1 ± 8.5		55.7 ± 7.9		55.2 ± 5.7	54.0 ± 5.2
%Fat (%)	28.4 ± 7.1		27.0 ± 7.0		25.3 ± 6.9	23.7 ± 6.2
$\dot{V}O_2$ max (ml·kg ⁻¹ ·min ⁻¹)	32.3 ± 4.1		36.0 ± 4.4*		33.2 ± 4.1	34.4 ± 6.9
$\dot{V}O_2$ max (l·min ⁻¹)	1.8 ± 0.3		2.0 ± 0.3*		1.8 ± 0.4	1.9 ± 0.5
Peak LA (mmol·l ⁻¹)	6.7 ± 1.9		6.3 ± 1.4		6.6 ± 2.1	6.0 ± 1.6
HRmax (beats·min ⁻¹)	180.1 ± 7.3		180.9 ± 7.4		182.2 ± 10.5	184.5 ± 8.8
Energy intake (kcal)	1710 ± 330		1690 ± 140		1590 ± 150	1650 ± 290

* $p < 0.05$ compared with pre-training.

DISCUSSION

Several limitations of our study need to be mentioned. First, we used sedentary subjects because many karate practitioners cross-train by undertaking strenuous running and weight training programs to increase endurance, muscle development and power, so it is difficult to conclude that karate exercises *per se* can be used as an effective means for training cardiovascular fitness. Thus, to examine karate exercises *per se*, it seems better to use sedentary beginners who have no karate experience. Second, we used women because most karate studies have used male practitioners,^{6-10, 19, 20} although many women engage in karate training.²¹ We may have obtained different results if we used men because women practiced BKEs at lower intensities than men.^{5, 6} Thus, future studies need to investigate chronic effects of various karate exercises in men. Third, we investigated the effects of 30 min of BKEs on $\dot{V}O_2$ max, not on body composition, because karate beginners need to spend at least a

few months acquiring basic techniques prior to learn kata and/or sparring, and the studies investigating intensities of karate exercises examined whether or not karate exercises can be used as an effective means for increasing $\dot{V}O_2$ max.^{6-10, 19, 20} Thus, future studies should include kata and/or sparring to investigate longer duration and higher intensities of karate exercises to examine the effects of these exercises on body composition. Fourth, although all subjects (9 women) in the experimental group participated in the measurement of acute responses of BKEs at the fifth week of the training period, only 5 women participated at the end of the training period because of the busy schedule of the subjects' academic studies. However, the results obtained at the fifth week and at the end were very similar. Even with these limitations taken into consideration, it was worthwhile to conduct this study because karate is one of the most popular martial arts practiced both inside and outside of Japan, and as far as the authors are aware, this is the first study to show that BKEs can improve $\dot{V}O_2$ max in sedentary women.

Although, the intensity of M-Basics was higher than that of S-Basics II, the mean blood lactate in M-Basics was lower than that in S-Basics II. This could be due, at least in part, to the fact that these exercises were practiced continuously, and blood lactate samples were taken immediately after performing M-Basics or S-Basics II. Blood lactate produced by an active muscle group is taken up and utilized by an inactive muscle, which could result in missing the peak blood lactate levels during M-Basics.²²⁾

The mean values of $\dot{V}O_2\text{max}$ in both experimental and control groups (32.3 ± 4.1 and $33.2 \pm 4.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, respectively) prior to the study were close to the value ($33 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) set for young women in the Exercise Guide 2006.¹⁾ However, they were lower than the value ($36.4 \pm 5.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) reported for the general population of a similar age as determined by the Laboratory of Physical Education, Tokyo Metropolitan University.²³⁾

According to the American College of Sports Medicine (ACSM),²⁴⁾ the minimal intensity threshold for improving $\dot{V}O_2\text{max}$ is approximately 40% of $\dot{V}O_2R$ or HRR. Regarding the intensity of S-Basics I, the mean % $\dot{V}O_2R$ ($26.7 \pm 9.7\%$) and %HRR ($37.4 \pm 6.8\%$) were lower than the accepted threshold for increasing $\dot{V}O_2\text{max}$. Regarding training intensity of S-Basics II, the mean % $\dot{V}O_2R$ ($38.9 \pm 15.2\%$) was marginal, while the mean %HRR ($53.8 \pm 10.9\%$) was above the accepted threshold for increasing $\dot{V}O_2\text{max}$. However, they were higher than the mean % $\dot{V}O_2R$ and %HRR for stationary basics reported in our previous study⁵⁾ using women of similar age. These disparities could be due to the greater mean experience of the participants (4.5 ± 1.7 yrs) in our previous study as opposed to the 5 or 10 weeks of experience when the training intensities were measured in the present study. It could be hypothesized that practitioners with a greater mean experience would have an increased efficiency of movement, thereby resulting in less energy expenditure.

Regarding intensity of M-Basics, the mean % $\dot{V}O_2R$ ($49.2 \pm 9.3\%$) and %HRR ($57.4 \pm 12.1\%$) were above the accepted threshold for increasing $\dot{V}O_2\text{max}$ and were similar to the results obtained in our previous study.⁵⁾

In the Exercise Guide 2006, “active physical activity” is defined as that with an intensity of 3 metabolic equivalents (METs) or more, and physical activity with less than 3 METs is not included in the definition of this term.¹⁾ The mean

MET intensities of S-Basics I, S-Basics II, and M-Basics (3.8 ± 1.3 , 5.1 ± 2.1 , and 6.1 ± 1.7 , respectively) were above this goal.

ACSM²⁴⁾ recommended the following quantity and quality of training to develop and maintain cardiovascular fitness in healthy adults: frequency: 3–5 days·week⁻¹; intensity: 40/50–85% of $\dot{V}O_2R$ or HRR; duration: 20–60 min of continuous aerobic activity; and mode: any rhythmical and aerobic activity that uses large muscle groups and can be maintained continuously. The frequency (4 days·week⁻¹) and duration of the 30 min of BKEs satisfied the quantity and quality of training to develop and maintain cardiovascular fitness recommended by ACSM.²⁴⁾ $\dot{V}O_2\text{max}$ in both l·min⁻¹ and $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in the experimental group significantly increased at the end of 10 weeks of training, while neither value changed significantly in the control group. Thus, we consider that 30 min of BKEs can increase cardiovascular fitness in sedentary women.

In summary, for S-Basics I, the mean % $\dot{V}O_2R$ was much lower than the accepted threshold, while the mean %HRR was slightly lower than the accepted threshold for increasing $\dot{V}O_2\text{max}$. For S-Basics II, the mean % $\dot{V}O_2R$ was marginal, while the mean %HRR was above the accepted threshold for increasing $\dot{V}O_2\text{max}$. The mean % $\dot{V}O_2R$ and %HRR for M-Basics were above the threshold for increasing $\dot{V}O_2\text{max}$. $\dot{V}O_2\text{max}$ in both l·min⁻¹ and $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in the experimental group significantly increased at the end of 10 weeks of training, while neither value changed significantly in the control group. The results of the present study indicate that 30 min of BKEs can reach the minimal threshold level to increase cardiovascular fitness and can improve cardiovascular fitness in sedentary women. However, the total EE might be too low for total body mass and fat weight loss.

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