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BLOOD LACTATE, HEART RATE, AND ENERGY EXPENDITURE RESPONSES TO 500 PUNCHES AND 500 KICKS IN ADVANCED AND BEGINNER TAEKWONDO TRAINING

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BLOOD LACTATE, HEART RATE, AND ENERGY EXPENDITURE RESPONSE TO 500 PUNCHES AND 500 KICKS IN ADVANCED AND BEGINNNER TAEKWONDO TRAINING

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ABSTRACT

The purpose of this study was to compare the responses of heart rate, blood lactate, and energy expenditure in beginning and advanced Taekwondo participants. Sixteen males, 8 beginners and 8 advanced, between the ages of 18 and 40 years who studied Taekwondo were included in the study. There were no significant differences at baseline between the two groups with the exception of percent fat, with the beginners having a significantly higher percent fat than the advanced. No statistical group differences were observed after the 500 punches and 500 kicks for all parameters. There were however, significant trial effects for heart rate responses and lactate responses due to testing protocol. There was also no group by trial interaction for heart rate responses and lactate responses. The strongest correlation in the advanced group was between percent change kicking caloric expenditure [PCKKCAL] (r =.98) and percent change punching caloric expenditure [PCPKCAL]. The strongest relationship for beginners was established between percent change punching caloric expenditure [PCPKCAL] (r =.98) and percent change kicking caloric expenditure [PCKKCAL]. Resting values were significantly lower than punching and kicking values for heart rate and lactate responses, but there was no difference between punching and kicking values. There was no difference between the two groups for total caloric expenditure [TOTKCAL] expended following the punching or kicking. In conclusion HR, LA, and TOTKCAL increased similarly for both advanced and beginner taekwondo participants and both punching and kicking resulted in similar responses following completion of each task.

CHAPTER I

INTRODUCTION

Participation in the martial arts has grown rapidly over the past 10 to 15 years. There are an estimated 1.5 million Americans involved in some form of martial arts (16). Karate is one of the most popular forms of martial arts practiced both inside and outside of Japan (11). Taekwondo (TKD) is the most popular form of martial arts in the world, studied in over 140 countries and practiced by a million participants of all ages (20). Martial arts- based aerobic workouts use a combination of techniques from Eastern and Western self-defense styles to elicit cardiovascular responses (7). Women are becoming more involved for both fitness and self-defense purposes. In addition, the portrayal of martial arts in the media has led to the increased involvement of children. Cardio-kickboxing, fitness boxing, and other forms of fighting-style workouts continue to gain popularity in the fitness industry, representing one of the top 5 profit centers in 6.8% of fitness facilities (7).

Taekwondo, the Korean martial art, is characterized by fast, high, and spinning kicks. The name means "the art of kicking and punching". Taekwondo improves flexibility, strength, and balance, increases speed of movement, and increases reaction time (13).

The typical training regime, involving extensive movements of the entire body, raises the pulse rate and oxygen consumption of the heart and lungs over an extended period of time. In addition to traditional martial arts training, many competitive karate practitioners follow a strenuous running and weight training program to increase cardiovascular endurance, lean body mass, strength and power.

It is thought that Taekwondo can contribute to physical fitness, even to the extent that it is supposed to rank with jogging and cross-country skiing relative to cardiorespiratory endurance (13). Only a few investigations have emphasized that martial arts, in general, improves cardiorespiratory endurance and general physical ability. There is still little information on the acute cardiorespiratory responses to martial arts, perhaps because martial arts is thought of more as a method of self-defense than a fitness program, however, telemetered heart rate responses of Taekwondo practice has the potential to raise heart rates sufficiently to increase cardiorespiratory fitness (20).

PURPOSE

The purpose of this study was to compare the responses of heart rate, blood lactate, and energy expenditure following 500 punches and 500 kicks in beginning and advanced Taekwondo participants.

RESEARCH QUESTIONS

1. Is there a differential heart rate response, blood lactate response and energy expenditure between punches and kicks?
2. Will there be a difference in heart rate response, blood lactate response and energy expenditure between Taekwondo beginners and experts?

HYPOTHESES

1. Heart rate, blood lactate, and energy expenditure will reach higher values for kicking than punching because the larger muscle mass will have an increased need of cardiac output, causing an increased stroke volume and heart rate. Energy expenditure will also be increased due to the larger muscle mass. Additionally, the larger muscle mass of the legs will have a greater anaerobic component compared to the smaller muscle mass of the upper body, and therefore a greater lactate production.
2. Higher responses in heart rate, blood lactate, and energy expenditure will be observed in beginners versus the more skilled participants. This is attributed to the beginners' lower skill level, lower efficiency of movement, and less training in the martial arts.

SIGNIFICANCE OF STUDY

With the rise of martial arts popularity within the media, more individuals are becoming interested in the arts ranging from informal training, like cardio-kickboxing at the gym, to formal instruction, like studying in a martial arts school. Many people want to increase lean muscle mass and decrease their body fat through martial arts training, but are uncertain if they will be able to achieve their goals. This study provides information that will help potential participants make a more informed decision regarding the benefits of this type of training. Some of the reported benefits of martial arts are: 1) helps the lungs operate more efficiently by increasing the exchange of oxygen and carbon dioxide within the alveoli; 2) enlarges the blood vessels, making them more pliable and reducing the resistance to blood flow, thus lowering the diastolic blood pressure; 3) increase the blood supply, especially red blood cells supply and hemoglobin; 4) makes the body tissue healthier by supplying it with more oxygen; 5) conditions the heart, providing more reserve for emergencies; and 6) promotes better sleep and waste elimination (10).

This research also adds to the current body of knowledge of martial arts as a form of cardiorespiratory training and provides a way for karate instructors to assess the level of effort made by their students (12).

DELIMITATIONS

1. The inclusion of beginners (orange belts, green belts, blue belts) and advanced (purple belts, brown belts, black belts) practitioners in the study.
2. Martial artists with more than 8 months of experience were included in the study.
3. Men 18- 40years old were included in the study.
4. The inclusion of practitioners who study Taekwondo into the study.
5. Those excluded from the study are those with elbow joint or knee complications.
6. Those excluded from the study are those who have cardiovascular diseases (hypertension, arteriosclerosis, and atherosclerosis).
7. The exclusion of practitioners who have been inactive in martial arts for more than one year.

LIMITATIONS

1. Self-reported data obtained about years active in the martial arts are prone to errors.
2. Palpation of resting heart rate is a limitation of the study.
3. A limitation of the study is that it is a cross-sectional study.

4. There is a difference in the number of recruited subjects with only 8 subjects to each group.
5. Subjects recruited from different martial arts schools.
6. There was no attempt to control or assess the diets of the subjects.
7. Couldn't obtain 1 min averages for VO_2.

ASSUMPTIONS

1. All subjects knew the basic horse stance.
2. All subjects knew the basic fighting stance.
3. All subjects knew the front and reverse basic punches.
4. All subjects knew a front-leg snap kick and rear-leg front snap kick.
5. All subjects understood the testing procedures.
6. All subjects put forth their best effort on performance of the functional tests.

OPERATIONAL DEFINITIONS

1. Tae kwon do– "art of the hand and foot". Subjects who participated in the Korean martial art style.
2. Front-leg snap kick– motion in which the kick is initiated by hip flexion of the front kicking leg. The thigh is horizontal as it moves upward and the knee flexes at about 110°. Once this is reached the knee begins to extend the lower leg. The lower leg extends and the foot strikes the target area. This is performed at the subject's own pace for a count of 500.
3. Rear-leg front snap kick– motion in which the kick is initiated by hip flexion of the rear kicking leg. The thigh is horizontal as it moves upward and the knee flexes at about 110°. Once this is reached the knee begins to extend the lower leg.

The lower leg extends and the foot strikes the target area. This is performed at the subject's own pace for a count of 500.

4. Front Punch– Subject rotates right and left punches with a closed fist at their own pace for a count of 500.
5. Blood Lactate– During exercise, muscle contraction stimulates glycogenolysis in order to use glycogen as a fuel in glycolysis. Lactic acid is a by-product of anaerobic metabolism. If enough oxygen is not available, lactic acid is produced and begins to accumulate in the muscles. When production exceeds removal, lactate is said to accumulate (12). Blood lactate was measured by an Accusport blood lactate analyzer to determine the anaerobic component.
6. Heart Rate– Aerosport KB1-C monitored the individual's heart rate from a Polar heart rate monitor.
7. Energy Expenditure– calories expended during the exercise session. This was measured by indirect calorimetry open-circuit spirometry before and during the session. Energy expenditure was also recorded by the Aerosport KB1-C metabolic analyzer.
8. Aerosport KB1-C- metabolic analyzer used to measure energy expenditure and exercise heart rate in conjunction with a polar heart rate monitor.
9. Beginner- martial artist who is more than 8 months active in the martial arts and classified as either yellow, orange, green, blue, purple belt.
10. Advanced – martial artist who is more than 8 months active in the martial arts and classified as either brown, or black belt.

CHAPTER II

LITERATURE REVIEW

INTRODUCTION

In 1998, the American College of Sports Medicine (ACSM) recommended the following quantity and quality of training to develop and maintain cardiorespiratory fitness and body composition in healthy adults: frequency: 3 to 5 d·wk, intensity: 55/65-90% of HR_{max}, or 40/50-85% of VO_2R or HRR; duration: 20-60 min of continuous aerobic activity that uses large muscle groups and can be maintained continuously (12). Also according to ACSM, the minimal training intensity threshold for improving VO_{2max} is 53-64% of HR_{max}. Selection of a reasonable target heart rate (THR) based on the Karvonen formula indicates training intensities greater than 60 percent of the minimum heart rate reserve is adequate to improve cardiovascular fitness (19).

Karate training involves three types of karate skills: basic techniques - including punching, kicking, blocking and striking; katas - set forms in a pre-established sequence of defensive and offensive techniques and movements; and sparring - opponents strategize to exchange combinations of defensive and offensive karate techniques. Many karate instructors state that one of the primary goals of karate is the development of characteristics such as perseverance, self-restraint, indomitable spirit, all-round character and/or courtesy (3). To attain this goal to a certain extent, many karate instructors occasionally make their students do hundreds of punches and kicks in addition to regular karate training sessions. Karate practices are characterized by short spells of high intensity exercises and interrupted by milder periods such as active standing rest. Karate training itself appears to be anaerobic (5).

HEART RATE RESPONSES

There is only a 9% change in the heart rate during musculoskeletal work, like weight training, while there is a 21% change in the values during cardiorespiratory work phases such as swimming. This greater increase is consistent with the concept of satisfying the oxygen debt that is produced by prolonged exercise (2). As the musculoskeletal work phases are repeated, the depletion of the oxygen that the body stores increases and therefore the cardiorespiratory work phase, heart rate, must increase to satisfy the increased oxygen debt. In a study reported by Imamura et al. (1997) it stated that the mean values of HR, $\%HR_{max}$ and %MHRR between black belt and white belt groups in the performance of 1,000 punches and 1,000 kicks showed no significant difference (3). Kravitz et al. (2003) found that the HR response to different punching rates were capable of meeting and exceeding the ACSM guidelines of 60-90% maximal HR (8). Use of HR and blood pressure data to estimate myocardial oxygen uptake is common in the context of exercise prescription, cardiovascular training and rehabilitation (19). Upper body exercises have been shown to induce greater changes in HR at a given VO_2 than lower body exercises.

Imamura et al. (1998) reported that the highly competitive black belt group in their study had greater karate experience than the novice white belt. This may indicate that experience and time commitment for development of specific motor skills, required in karate, is important (5). Shaw et al. (1982) suggested that more experienced practitioners would perform their routines at a greater intensity, although the authors themselves did not find any significant correlation between experience and exercise heart rate (6). There is also the possibility that practitioners with more experience would have an increased efficiency of movement, thereby resulting in less energy expenditure and a reduced exercise heart rate. Disparities in findings may reflect differences in the fitness levels, karate experience, skill levels and/or rate punching, and kicking of the subjects (3).

A circulatory strain is reflected in measures of heart rate and blood pressure during upper-body exercise at a given power output and oxygen uptake (10). Several attempts have been undertaken to identify possible causes for differences in HR response patterns. Plasma catecholamine responses, parasympathetic receptor blockades, pH or lactate responses were not able to explain the phenomenon of a decrease in HR in young healthy subjects compared to the older healthy subjects (21). The physiological factors that explain the circulatory strain in upper-body exercise have not been adequately determined. Several factors have been proposed, which most notably included a smaller muscle mass, a larger static exercise component, increased peripheral resistance or possibly a smaller venous return due to less muscle pump activity, and an increased neural drive during upper-body exercise (10).

Zehr and Sale (1993) reported lower mean HR_{max} and peak blood lactate for highly skilled karate practitioners (5). Brynteson and Sinning (1973) found that cardiovascular fitness was maintained significantly better by using work loads that stimulated heart rates of 80% of the maximum heart rate in frequent training sessions (three to four times a week) (18). It was found that eight months of such intense karate training might possibly be enough for beginners to elicit similar values to highly competitive karate practitioners.

The HR_{max} method should be adapted so that it more accurately reflects the relationship between HR and power output (21). When using exercise HR alone, one assumes that the VO_2-HR relationship is similar for rhythmic and sustained large muscle mass activity (19). One point, taken into consideration when discussing the disparities between the differences in HR_{max} among highly skilled karate practitioners and novice practitioners in the Imamura et al. (1998) study results, is the quantity of karate training (5). The Francescato et al. (1995) study found that mean HR_{max} values measured by the bicycle ergometer were lower than those measured on the treadmill. The subjects involved in the Francescato et al. (1995) study had practiced karate for the past one to three years and trained at least twice a week for 2 hours.

ENERGY EXPENDITURE

The estimated caloric consumption for a vigorous martial arts work out is about 600 calories per hour, one of the highest for any sports activity (14). Since the expenditure of about 3,500 calories results in the weight loss of one pound, it can be seen that a weekly training schedule of only six hours will result in weight loss of one pound per week (14). Regular physical activity (PA), fitness and exercise are critically important for the health and well being of people of all ages (7).

Energy expenditure can be broken down into separate components: resting energy expenditure, the thermic effect of food, and energy expended due to physical activity (20). The most popular method of measurement of REE in the clinical setting is by indirect calorimetry using a metabolic cart. Indirect calorimetry is the measurement of energy expenditure by the measurement of the volume of oxygen consumption and carbon dioxide produced. Imamura et al. (2002) also hypothesized that practitioners with greater experience would have an increased efficiency of movement, thereby resulting in less energy expenditure (12). ACSM suggested exercising at least 3d·wk, of at least a sufficient intensity and duration to expend approximately 250 to 300 kcal per exercise session as a threshold level for total body mass and fat mass loss. It is also stated that an expenditure of 200 kcal per session has also been shown to be useful in weight reduction if the exercise frequency is at least 4d·wk (12). Kravitz et al. (2003) found a significant increase in caloric expenditure between punching tempos which is caused by the rise in RER throughout the trials (8).

BLOOD LACTATE RESPONSES

Blood lactate concentration became established as a measure of exercise intensity during incremental and constant-workload exercise (17). It has also been reported that the blood lactate threshold may be a more significant physiological anchor point for the perception of effort on the basis that fitness status and gender were not seen to influence RPE at this index of exercise intensity (18). A study by Hetzler et al. (1991) suggested that blood lactate-anchored RPE could be used effectively for exercise prescription regardless of whether lactate threshold (LT) or a fixed blood lactate concentration was employed (18). Imamura et al. (1997) found that there was no significant difference between the black belt and white belt groups in blood lactate responses immediately after performing 1,000 punches (3). They also found no significant difference between the two groups in RPE for 1,000 punches. Nishibita et al. (1993) reported that in subjects of average fitness the measurement of the LT was less reproducible compared with the measurement of fixed blood lactate concentrations (18).

Since the exercises performed were continuous and blood lactate samples were taken immediately after performing 15 minutes of punching and 17 minutes of kicking, the modest elevation in blood lactate may possibly be the result of the blood lactate produced by a active muscle group taken up and utilized by an inactive muscle, which could result in missing the peak blood lactate levels during each exercise (3). It is assumed that maximal lactate steady state can be used to detect the highest workload that can be maintained over time without continual blood lactate accumulation (17).

Beneke et al. (2003) found that differences in maximal lactate steady states (MLSS) between different exercise modalities seem to be caused by differences in the mass of the primarily engaged muscle. MLSS is determined by the power output (load) per unit mass of working muscle (1).

CHAPTER III

METHODS

SUBJECTS

Sixteen male subjects between the ages of 18 and 40 years were recruited for this study. They were recruited from martial art schools in the greater Oklahoma City area. Subjects included in the study were those with at least eight months of martial arts experience. The study included subjects who studied Taekwondo; 8 Beginners (orange, yellow, green, blue, purple belts) and 8 advanced (brown and black belts) martial artists.

Subjects were excluded for the following reasons; (1) children, (2) elbow joint and/or knee complications, (3) those with cardiovascular diseases (hypertension, arteriosclerosis, and atherosclerosis), (4) those who had been inactive in the martial arts for a year, and (5) women.

MEASUREMENTS

All testing was conducted at the University of Oklahoma Human Performance Laboratory, Norman Campus. Subjects completed the following tests.

1. **Anthropometry.** Subjects arrived at the University of Oklahoma Human Performance Lab and had their weight and height measured. Subjects removed their shoes and total body weight was measured using an Accu-Weigh Bench Beam Scale. The subjects wore only light fitting clothes, recording a measurement in pounds to the nearest hundredth (also converted to kilograms). Height was measured using a stadiometer.
2. **Percent of Body fat.** Percent body fat was obtained by the BOD POD. It was important that minimal clothing was worn, such as a swimsuit or speedo

swimming trunks, the subjects also wore a swim cap to compress the hair on the head. Measurement of body volume involved 3 steps. First, a standard 2-point calibration process: first with the chamber empty to establish baseline and then with a calibration cylinder to establish range (50 secs) (2). The subjects were weighed using the scale attached to the BOD POD system. Then the subject's age, sex, and height were all entered into the computer system. Each subject then entered the BOD POD and sat in a comfortable standardized position in which the back was straight and not touching the back wall of the machine, feet slightly apart and hands placed in a relaxed manner in the subject's lap. Next, the subject's volume in the chamber was measured. This measurement data is termed "raw" and not corrected for thoracic gas volume (V_{TG}) and surface area artifact (SAA) (2). In the third step, V_{TG} was measured. It was done using a procedure similar to that used in standard pulmonary plethysmography, often called panting (2). The procedure began with the subject breathing room air quietly through a disposable tube and antimicrobial filter while wearing a nose clip. After a few normal tidal breaths, a shutter valve in the airway closes (2). During the occlusion, the subject made 3 gentle quick puffs. An entire test, with printed results was completed within just 5 minutes without discomfort.

3. **Heart Rate.** Resting heart rate was obtained through palpation of the radial artery for 15 secs. Exercise heart rate was measured using the Aerosport KB1-C in conjunction with a Polar Monitor. The telemetric monitor was moistened with water and strapped across the subject's chest, just below the nipple line. It fit snug

but not tight. The KB1-C then began to register the subject's heart rate. Heart rate was recorded every 20 seconds.

4. **Blood Lactate.** Blood lactate was obtained through a finger prick. The analyzer was calibrated first by turning the Accusport analyzer "on". Next a code strip was slid into the bottom of the analyzer and quickly removed. A code number matching the lactate strips showed on the screen. To calibrate the analyzer, a blank strip was slid into the bottom of the analyzer. After two beeps, the top of the lid was lifted exposing the test strip. One drop of calibration solution 1 was placed on the test strip and the lid was closed. The analyzer read the strip and displayed the number on the screen. If the number matched the solution 1 reading on the bottle it was calibrated. The lid was then lifted and the strip was removed. Next solution 2 was used to calibrate the analyzer using the same procedure as before. The following guidelines were used; 1) the top of the lancelet was removed and a new, sterile needle was placed inside a lancelet. The cover was then removed from the needle tip and the top was placed back onto the lancelet, 2) a blank lactate strip was slid into the bottom slot of the Accusport blood lactate analyzer. Once two beeps sounded it meant that the lactate analyzer was ready to be used. The lid on the lactate analyzer was now opened, 3) the subject's hands were warmed if they were cold and blood was squeezed from the top of the arm down to the fingertips. The fingertip was cleaned with a sterile alcohol pad and air-dried. Then the lancelet was pressed on the side of the finger, 4) the button on top of the lancelet was pressed and punched a hole in the side of the finger. The blood was then squeezed to the tip of the finger to get a drop of blood onto the lactate

strip, 5) the lid on the lactate analyzer was then closed. The lactate analyzer read the strip and gave a reading which was recorded. This was a process that was also performed at the beginning for a resting lactate (La), and at the end of each activity for an exercise lactate.

5. **Energy Expenditure.** Energy expenditure was obtained through the use of indirect calorimetry. It was measured using Aerosport KBI-C Metabolic Analyzer. The Aerosport analyzer flow was calibrated first by attaching the analyzer to a 5mL cylinder. Following the instructions on the screen, the process was started by pressing the "flow" button and then by entering the flow amount (5mL) into the analyzer, then the test began. The cylinder was pumped 3 times. Once the test was successful, the screen returned to the home page. The gas analyzers were then calibrated. First the oxygen concentration and carbon dioxide concentration were entered and the analyzer zeroed on room air temperature. The analyzer was then attached to a calibrated gas cylinder where the bag was flushed 3 times and then filled with gas. The "start" button was pressed and the test began calibrating the gases. If the values were within the entered amounts then the test was a success. The analyzer again zeroed on room air temperature. The subject's age, sex, height and weight were entered into the analyzer. A mask was then placed on the subject's face with the analyzer attached to the other end of the breathing tube. The subject rested in a sitting position for 5 min, with their arms to their side, their legs together and remaining still. At the beginning of the test, the subject inhaled and exhaled, and the analyzer recorded their calories (kcal). Data was recorded throughout the exercise: 5 minutes between the exercises, 5

minutes pre-exercise, and 5 minutes post-exercise. Total caloric expenditure was measured from the beginning of the resting period to 5 minutes post --exercise session.

TESTING PROCEDURES

1. **Kicks**. Subjects got into a martial arts fighting stance. In this stance, their feet were under their shoulders, knees slightly bent, and their front foot was facing forward; while their back foot was turned parallel to the front foot. The tester counted one to fifty while the kicks were performed. The subjects were allowed to rest ten seconds before continuing with the next 50 kicks. This was repeated until the subject reached 500 kicks. Blood lactate was recorded before, after, and 5 minutes after the activity. Heart rate was recorded every twenty seconds. The final record was taken at the end of the 500 kicks. Energy expenditure was recorded every twenty seconds, before, and after the activity. After recording post-activity blood lactate, the subjects prepared themselves for the recording data when they punched.
2. **Punches**. Subjects got into a martial arts horse stance, which their legs were much wider than their shoulders. Their feet were facing forward and knees pointing outward. One hand was chambered to the side and the other forward. The tester counted one to 100 while the punches were performed. This was repeated until the subject reached 500 punches. Blood lactate was recorded before, after, and 5 minutes after the activity. Heart rate was recorded every twenty seconds. The final record was taken at the end of the 500 punches. Energy expenditure was recorded every twenty seconds, before, and after the activity.

TIMELINE FOR DATA COLLECTION

The subjects randomly alternated the order of punches and kicks. A total of 6 beginners were randomized to punch first, while 2 beginner subjects kicked first. 3 advanced subjects punched first and 5 subjects kicked first. The study was a one time data collection.

- Subject arrived; obtained ht/wt (0-5min)
- BOD POD (5-20min)
- Resting blood lactate data were collection through finger pricks (20-30min)
- Resting heart rate and resting energy expenditure was collected using the Aerosport KB1-C (30-35min)
- 500 kicks or punches (35-55min)
- Post-exercise heart rate, lactate, and energy expenditure recorded (55min - 1hr)
- 500 punches or kicks (1hr -1hr 20min)
- Post-exercise heart rate, lactate, and energy expenditure recorded (1hr 20min-1hr 25min)
- Total time ~1 hr 30 min

STATISTICAL ANALYSES.

Descriptive statistics were run on all variables and reported as means ± standard error of the mean (SE) as well as percent change [(final measure- initial measure)/ initial measure x 100]. Statistical analyses were performed on SPSS® version 10.0 for Windows™. Descriptive statistics were used to look at the entire sample and split by advanced and beginners. A repeated measures analysis of variance (ANOVA) was conducted to compare whether differences in punches and kicks existed between the two levels of experience (beginners vs. advanced). A comparison of the percent change was assessed using a one-way ANOVA. An independent t-test was used to compare the advanced vs. beginners for baseline values. A repeated measures analysis of covariance (ANCOVA) was used to control for percentage of body fat. To determine the relationships between the variables within each group, Pearson Correlation Coefficients were used. Statistical significance was set at an alpha level of $p < 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to examine the effects of 500 punches and 500 kicks on blood lactate, heart rate, and energy expenditure between advanced and beginner taekwondo training. All blood lactate was measured on the Accusport lactate analyzer, while all heart rate and energy expenditure was measured using the KB1-C metabolic analyzer at the University of Oklahoma Human Performance Lab. The results of this study are presented as follows: 1) subject characteristics and 2) exercise responses.

SUBJECT CHARACTERISTICS

Sixteen (16) male subjects, all between the ages of 18 and 40 years, participated in the study. All of the participating subjects were assigned to one of two training groups; beginners (rank= 2, N=8, 0 orange, 2 yellow, 3 green, 2 blue, 1 purple) and advanced (rank=1, N=8, 8 black belts).

Baseline data were analyzed to ensure no differences existed between training groups before the testing sessions began. An independent t-test was used to compare the groups for resting values. At baseline only percent fat was different between beginners and the advance groups with beginners having significantly higher percent fat (13.4% vs. 23.4%). Height (cm), weight (kg), percent fat (% fat), resting lactate (RLA), resting heart rate (RHR), and calories expended (kcal) were similar between the two groups ($p > 0.05$). Table 1 presents the resting values for the individual groups.

TABLE 1. SUBJECT CHARACTERISTICS

	Beginners	Advanced
Sample size (N)	**8**	**8**
Age (yrs)	**27 ± 2.7**	**25 ± 2**
Experience (yrs)	**1 ± 0.2**	**8.7 ± 2.6**
Ht. (cm)	**175.6 ± 3.2**	**176.6 ± 2.5**
Wt. (kg)	**84.0 ± 8.3**	**79.6 ± 4.5**
%fat	**23.4± 3.8***	**13.4 ± 1.3***
Rest La (mmol/L)	**1.6 ± 0.24**	**2.6 ± 0.39**
RHR (bpm)	**74 ± 5.2**	**75 ± 4.3**
Rkcal (per·min	**5.8 ± 2.8**	**6.5 ± 3.1**

Values are means ± SE **$*p < 0.05$**

EXERCISE RESPONSES

Table 2 shows the Mean ± SE for each variable of interest and both groups. There were no statistical differences ($p > 0.05$) between the two groups after the 500 punches in HR, percent change of heart rate (PCHR), punching lactate (PLA), percent change of lactate (PCLA), punching caloric expenditure (PKCAL), and percent change of caloric expenditure (PCPKCAL).

Table 3 shows the Mean ± SE for each variable of interest and both groups. There were no statistical differences ($p > 0.05$) between the two groups after the 500 kicks in HR, percent change of heart rate (PCHR), kicking lactate (KLA), percent change of lactate (PCLA), kicking caloric expenditure (KKCAL), and percent change of caloric expenditure (PCKKCAL).

TABLE 2. PARAMETERS OF INTEREST FOR ADVANCED VS. BEGINNERS FOLLOWING 500 PUNCHES

	Beginners	Advanced
PHR (bpm)	146 ± 6.4	148 ± 4.1
PCPHR (%)	103.1 ± 11.2	99.0 ± 9.2
PLA (mmol/L)	9.0 ± 1.3	7.6 ± .8
PCPLA (%)	556.0 ± 158.0	244.2 ± 62.5
PKCAL (per·min)	7.2 ± 1.5	9.1 ± 3.1
PCPKCAL (%)	269.0 ± 97.3	182.7 ± 59.0

Values are Means ± SE

PHR-punching heart rate, PCPHR-percent change punching heart rate, PLA- punching lactate, PCPLA-percent change punching lactate, PKCAL- punching caloric expenditure, PCPKCAL-percent change punching caloric expenditure

TABLE 3. PARAMETERS OF INTEREST FOR ADVANCED VS. BEGINNERS FOLLOWING 500 KICKS

	Beginners	Advanced
KHR (bpm)	161 ± 3.6	151 ± 10.2
PCKHR (%)	124.6 ± 11.6	104.0 ± 16.8
KLA (mmol/L)	8.8 ± 1.4	7.1 ± 1.1
PCKLA (%)	512.8 ± 146.5	234.0 ± 63.3
KKCAL (per·min)	8.3 ± 1.5	9.6 ± 2.2
PCKKCAL (%)	332.8 ± 127.9	228.1 ± 67.7

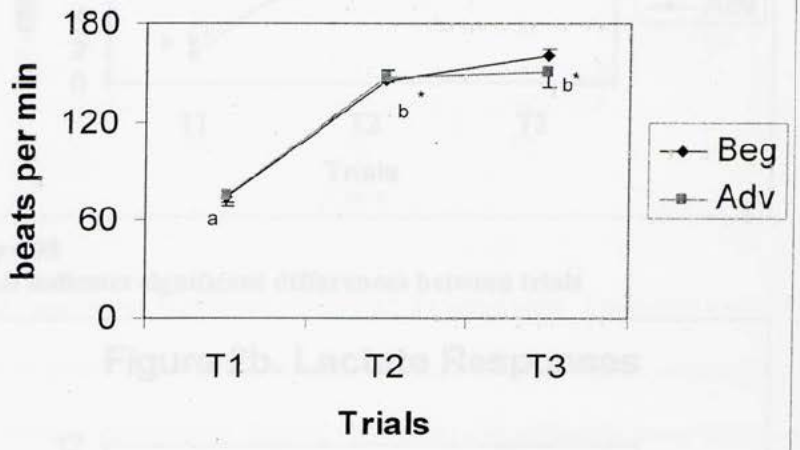
Values are means ± SE

KHR-kicking heart rate, PCKHR- percent change kicking heart rate, KLA- kicking lactate, PCKLA-percent change kicking lactate, KKCAL-kicking caloric expenditure, PCKKCAL-percent change kicking caloric expenditure

All variables for the study were measured at rest, during the exercise, and post-exercise. A general linear model of repeated measures was used to determine if there was a significant difference between the trials ($p < 0.05$). Each subject was measured across trials and by their ranks assessing group interactions. The tests of between subjects' effects were also analyzed in order to assess differences between groups.

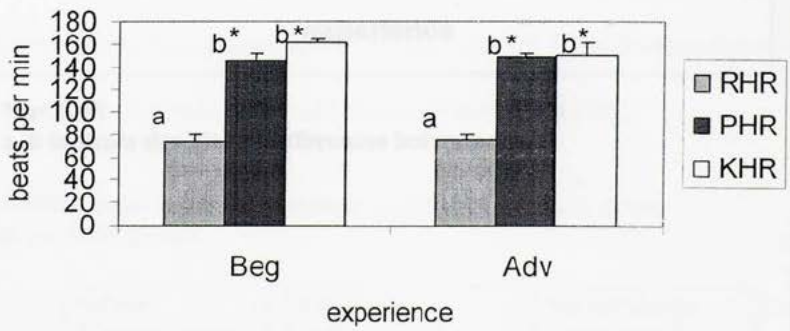
A significant trial effect was observed for heart rate (Figure 1a and 1b) and lactate (Figure 2a and 2b) in response to the testing protocol ($p < 0.05$); however, no difference was determined between the groups ($p = .454$). No group by trial interaction was observed (p=.285). Caloric expenditure (Figure 3) showed no significance for the trial main effect, group main effect (p=.685), or group by interaction (p=.900).

Figure 1a. Trial Effect of Heart Rate Responses



***p<0.05**
a,b indicate significant differences between trials

Figure 1b. Heart Rate Responses



***p<.05**
a,b indicates significant differences between trials

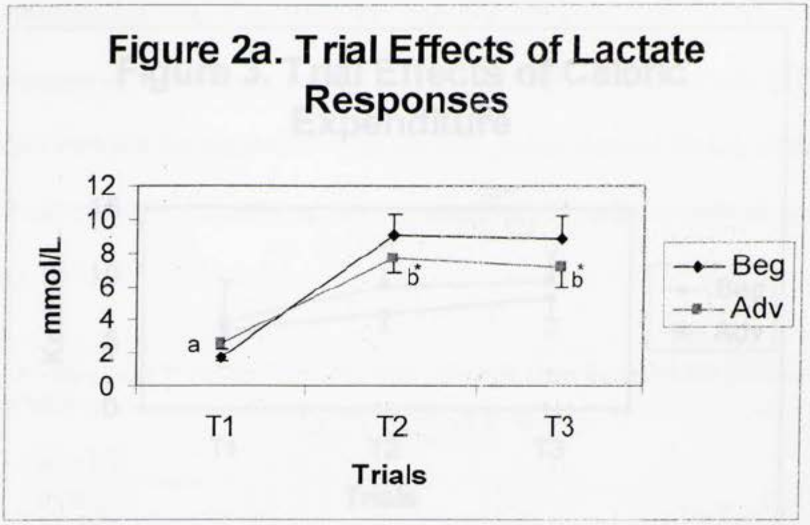


Figure 2a. Trial Effects of Lactate Responses

$*p<.05$

a,b indicates significant differences between trials

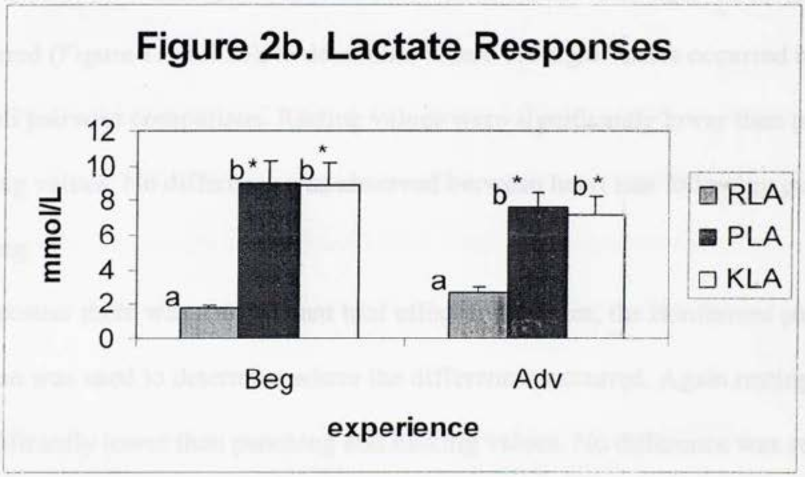
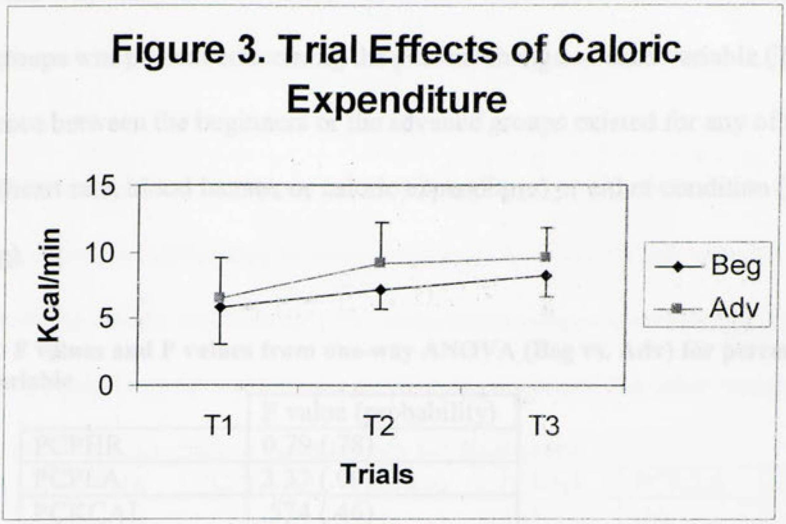


Figure 2b. Lactate Responses

$* p< 0.05$

a, b indicate significant differences between trials



Since there was a significant trial effect for heart rates, a post-hoc analysis was administered (Figure 1a and 1b), to determine where the significance occurred by using a Bonferroni pairwise comparison. Resting values were significantly lower than punching and kicking values. No difference was observed between heart rate following punching and kicking.

Because there was a significant trial effect for lactates, the Bonferroni pairwise comparison was used to determine where the differences occurred. Again resting values were significantly lower than punching and kicking values. No difference was seen between lactate following punching and kicking (Figure 2a and 2b).

Table 4. Probability from repeated measures analysis of variance across trials for both groups

	Group F value (prob)	Trial F value (prob)	Trial by Group F value (prob)
HR	.11 (.746)	175.6 (.000)*	.98 (.388)
LA	.593 (.454)	32.2 (.000)*	1.3 (.285)
KCAL	.17 (.682)	2.3 (.115)	.11 (.900)

***p< 0.05**

A one-way analysis of variance was used to determine if a statistical difference between groups was present concerning the percent change of each variable (Table 5). No difference between the beginners or the advance groups existed for any of the variables (heart rate, blood lactate, or caloric expenditure) or either condition (punching vs. kicking).

TABLE 5. F values and P values from one-way ANOVA (Beg vs. Adv) for percent change for each variable

	F value (probability)
PCPHR	0.79 (.78)
PCPLA	3.37 (.09)
PCKCAL	.574 (.46)
PCKHR	1.02 (.33)
PCKLA	3.05 (.10)
PCKKCAL	.524 (.48)

Based on the fact that there was a significant difference between beginners and advanced for percent fat at the baseline assessment, a repeated measures ANCOVA was used. Controlling for percent fat (Table 6) there was no change from the original repeated measures ANOVA results with only HR and LA demonstrating a significant trial effect.

Table 6. F value and (p values) from the repeated measures ANCOVA

	Trial F value(prob)	Group F value (prob)	Trial by group F value (prob)
HR	23.39 (.00)*	.01 (.91)	1.71 (.20)
LA	8.22 (.00)*	.53 (.47)	1.82 (.182)
KCAL	1.21 (.316)	.82 (.38)	.05 (.95)

*** $p < 0.05$**

Pearson Correlation Coefficients were calculated to determine if significant relationships existed between the variables within each group. The analysis indicated that among the advanced subjects, the strongest correlation was between percent change kicking caloric expenditure (.98) and percent change punching caloric expenditure.

The strongest relationship between beginners was established between percent change punching caloric expenditure (.98) and percent change kicking caloric expenditure. Table 8a and b indicate the relationships between the other variables.

Table 7a. Pearson Correlation Coefficients for Beginners

	PCPHR	PCPKCAL	PCPLA	PCKHR	PCKLA	PCKKCAL
PCPHR		-.01	.18	.83*	.34	-.17
PCPKCAL			.06	.13	-.01	.98**
PCPLA				.11	.89**	-.02
PCKHR					.25	.02
PCKLA						-.13

Strong: ≥ .8, Moderate: ≥.5, Weak: ≤ .3
***p ≤ .05, **p ≤ .01**

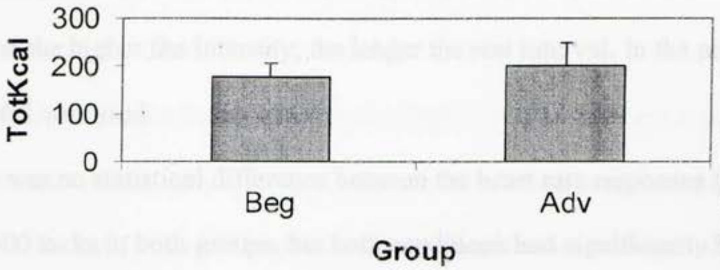
Table 7b. Pearson Correlation Coefficients for Advanced

	PCPHR	PCPKCAL	PCPLA	PCKHR	PCKLA	PCKKCAL
PCPHR		.58	-.37	.68	-.56	.63
PCPKCAL			-.43	.53	-.38	.98**
PCPLA				.11	.67	-.42
PCKHR					-.28	.59
PCKLA						-.30

Strong: ≥ .8, Moderate: ≥.5, Weak: ≤ .3
****p ≤ .01**

A one way ANOVA was performed to compare the total amount of calories expended between both groups (Figure 4). The total time for each group from the beginning resting period to the ending resting period was: beginner group ~32 minutes vs. advanced group ~30 minutes. No significant difference was found (p= .663) between the groups (advanced 201.49 ± 46.69 vs. beginners 176.62 ± 30.55).

Figure 4. Total Caloric Expenditure Responses



DISCUSSION

The purpose of this study was to compare heart rate responses, blood lactate responses, and energy expenditure of beginning and advanced taekwondo training to 500 punches and 500 kicks. There were a total of 16 subjects (8 advanced and 8 beginners) used in this study. The Imamura et al. (1997) study had fewer subjects (14 subjects- 8 advanced and 6 beginners) but still achieved a statistical power of 0.85. Both studies found that, compared to beginners, the advanced taekwondo subjects had a significantly less amount of percent fat. The results of the current study were similar to the results of the Imamura et al. (1997) study when the variables of heart rate responses and lactate responses between the advanced and beginners karate practitioners were compared. Both studies found no difference between punches and kicks whether it was 500 (as in the current study) or 1,000 (Imamura et al.) repetitions.

HEART RATE RESPONSES

The training intensity of performing the punches and kicks were examined by instructing the subjects to punch for a count of 100 and resting for five seconds between sets. Performing the kicks, the subjects were instructed to kick with a maximum kicking speed up to waist height for a count of 50 then rested for 10 seconds. The punches lasted on average for 10 minutes while the kicks lasted 12 minutes. The heart rate was recorded for each subject every 20 seconds. Pieter et al. (1990) used a work-rest ratio of 1:2, which is dependent on the higher the intensity, the longer the rest interval. In the present study a work-ratio of 6:1 was used.

There was no statistical difference between the heart rate responses to the 500 punches and 500 kicks in both groups, but both conditions had significantly higher heart rates than resting values. For example, the results of the Imamura et al. (1997) study found a mean heart rate response of 102.5 ± 14.8 beats•min for the advanced following 1,000 punches, and 116.1 ±17.9 beats•min for beginners following 1,000 punches (2). The current study found a heart rate response of 147.63 ± 4.07 beats•min for the advanced following 500 punches, and 146.13 ± 6.38 beats•min for the beginners following 500 punches. There was no significant difference between heart rate responses for both groups in the two studies. The differentiation in mean heart rate responses in both studies to punches could be due to the differences in the counts used between the studies. For instance, in the Imamura et al. (1997) study he quoted that "each subject counted one to 10, while the other subject punched or kicked with the count. After the last subject finished counting one to 10, the first subject started to count again." In the present study the participants punched at their own count of 100 focusing on power and speed. The different heart rate responses could also be a result of additional rest periods between sets. Because each participant in the Imamura et al. (1997) study used a different person to count, one subject may reach the count of 10 before another allowing more rest. The present study allowed a 5 second rest period between sets; which did not allow enough recovery time for the heart rate to decrease. Another reason could be that Imamura et al. (1997) averaged the fifth and the fifteenth minute of punches and the seventeenth minute of the kicks then presented the results as the mean heart rates for both groups.

Other disparities between the two studies could be that karate experience and skill level of the subjects, with skill level being due to the conditioning of the students. Conditioning of the students could be that each martial arts school focuses either more on karate techniques or taekwondo techniques. Pieter et al (1990) found karate practitioners utilize more arm techniques in their training, which would put more strain on the subjects during kicking conditions, where taekwondo athletes perform more leg techniques, placing more strain on them during punching conditions. Taekwondo athletes are closer to meeting at least 50% of the total muscle mass to improve aerobic endurance.

BLOOD LACTATE RESPONSES

Blood lactate levels increase with prolonged, high-intensity exercise. During anaerobic glycolysis, $NADH^+$ production exceeds the cell's capacity for shuttling its H^+ ions down the respiratory chain because of insufficient oxygen at the tissue level. The excess hydrogen electrons combined with pyruvate forms lactate. Once lactate forms in the muscles, it diffuses rapidly into the interstitial space and into the blood for buffering and removal from the site.

In the current study, blood lactate was measured before the exercise and immediately after each exercise. There were no statistical differences between beginners and advanced, but there were statistical differences between the trials. The beginners however, had higher mean values for exercising lactate levels (beginners: resting lactate

(RLA) = 1.67 ± .24 mmol/L, punching lactate (PLA) = 8.99 ±1.28 mmol/L, kicking lactate (KLA) = 8.78 ± 1.39 mmol/L; advanced: resting lactate (RLA) = 2.55 ±.39, punching lactate (PLA) = 7.59 ± .83 mmol/L, kicking lactate (KLA) = 7.11 ± 1.09 mmol/L). For healthy, untrained persons, blood lactate begins to accumulate and rise in an exponential fashion at about 55% of their maximal capacity for aerobic metabolism (15). One reason for this difference is that lactate clearance is higher in trained individuals than it is in untrained individuals due to an enhanced blood flow to the liver; which aids in lactate removal (21). The enhanced uptake of lactate by active and inactive muscles means that there is a change in the rate of lactate clearance. This explains the decreased concentration of lactate in muscle and in blood at the same relative workload. Another reason could be that the advanced individuals have increased levels of glycogen and glycolytic enzymes. They also retain improved motivation and "pain" tolerance to fatiguing exercise (15).

Comparing the Imamura et al. (1997) study to the present study, the Imamura et al. (1997) study found lower values for lactic acid accumulation following the exercise periods. The possible discrepancy here could be due to the longer rest periods. Imamura et al. (1997) mentioned in their study that immediately after the exercise the moderate elevation in blood lactate may be the result of blood lactate produced by an active muscle group taken up and utilized by inactive muscles. This could result in missing the peak blood lactate levels during each exercise.

ENERGY EXPENDITURE RESPONSES

ACSM suggests exercising at least 3d•wk for at least 20 min and with sufficient intensity to expend approximately 300 kcal per session as a threshold for decreasing total body mass and increasing fat-free mass. In the current study the total caloric expenditure for the entire session among the advanced (201.49 ± 46.69 kcal) was higher than the values for the beginners (176.62 ± 30.55 kcal).

McArdle et al. (2001) used a five-level classification system based on energy (kcal) required by untrained men performing different physical activities (10). When comparing calories to the McArdle et al. (2001) table, both beginners and advanced subjects of the current study expended between seven and nine kcal•min which was classified as a moderate to heavy level of exercise.

Movement economy also played an important role in the amount of calories expended during the exercises. It is stated that an individual with greater movement economy expends less calories. In this case both groups expended the same amount of calories.

The results of the current study show no statistical difference, but the threshold for energy expenditure, according to ACSM, was nearly reached by both groups for the total time periods in approximately 30 minutes (advanced = 201.5 ± 46.7 kcal vs. beginners = 176.6 ± 30.6 kcal). Both groups were efficient enough to increase their heart rate and were able to expend more calories during the exercise periods.

CHAPTER V
CONCLUSIONS

The purpose of this study was to compare the responses of heart rate, blood lactate, and energy expenditure in beginning and advanced Taekwondo participants to 500 punches and 500 kicks.

RESEARCH QUESTIONS:

1. Is there a differential heart rate response, blood lactate response and energy expenditure between punches and kicks?

   There was no statistical difference between heart rate response, blood lactate response and energy expenditure following 500 punches and 500 kicks.

2. Will there be a difference in heart rate response, blood lactate response and energy expenditure between Taekwondo beginners and experts?

   There was no difference in heart rate response, blood lactate response and energy expenditure between Taekwondo beginners and experts following 500 punches and 500 kicks.

CONCLUSIONS:

HYPOTHESIS

1. Heart rate, blood lactate, and energy expenditure will all reach higher values for kicking than punching because the larger muscle mass will have an increased need of cardiac output, causing an increased stroke volume. Energy expenditure will also be increased due to the larger muscle mass. Because fast-twitch fibers predominately make up the quadriceps, ATP-CP will only last a few seconds

causing a quick build up of blood lactate making the participants exhausted quickly.

The study revealed that there was no difference in heart rate, blood lactate, and energy expenditure between punches and kicks. As mentioned earlier in the study this differentiation could be due to training conditions. Since there are many forms of Taekwondo, one martial arts school may focus more on punching techniques than kicking, while another school may have deeper roots in kicking techniques over punching techniques. For instance a subject who practices more punching techniques may be placed under more stress while performing kicking techniques and vice versa, while some schools practice punching and kicking evenly during a class session. These findings are causes why the first hypothesis is rejected, stating that heart rate, blood lactate, and energy expenditure will reach higher values in kicking than punching.

HYPOTHESIS

2. Higher responses in heart rate, blood lactate, and energy expenditure will be observed in beginners versus the more skilled participants. This is attributed to their skill level, efficiency, and training in the martial arts.

The current study found that there was no statistical difference in heart rate, blood lactate, and energy expenditure between the two groups. There is no difference because of the initial conditioning of the beginners and the continuing work-out habits of the advanced subjects. For example, a subject who has been physically active before initially attending martial arts may have the same results as an advanced subject. Or an advanced subject who is fairly active or not active can have the same results as a beginner who is not active in any other activities. After the first eight months beginners become as efficient as the advanced in basic techniques such as punching and kicking. Because of these reasoning's, we rejected the second hypothesis stating that the variables will be higher values in beginners than those seen in the advanced.

RECOMMENDATIONS FOR FUTURE RESEARCH

One of the major problems in this study was monitoring the subject's VO_2 per minute using the Aerosport KB1-C. This device uses a calibrated flow reader on the end attachment. Here the flow was set at either "low", "med", or "high". The "low" reading was used at rest. The "medium" reading was used for settings at moderate levels of exercise. The "high" reading level was set for those levels at maximum intensity. The major issue here was finding the current settings for the exercise intensity. Since all levels of intensity were used in this study, interchanging the flow meter would have required changing the flow meter throughout the exercise giving incorrect data readings. Using a device such as the one used in the Zehr et al. (1993) would allow better measurement of VO_2 values. Measuring energy expenditure using a Medgem after the exercise periods would also provide better results for the amount of calories expended in those periods.

SIGNIFICANCE

By the end of the study, all participants had learned their predicted resting metabolic rate, percent fat, and their resting heart rate response to kicking and punching. Every participant learned how in shape their bodies were for martial arts and also learned ways to improve their training sessions. The study does prove that martial arts kicks increase the subject's heart rate above the ACSM threshold for increasing cardiovascular performance. It has also shown that the kicks meet the ACSM threshold for caloric expenditure in an exercise session. Generally speaking, taking a 45 minute cardio-kickboxing class at a neighborhood fitness center or using a Tae-Bo tape will increase cardiovascular fitness, lactate threshold, and energy expenditure enough to also increase lean muscle mass.

CHAPTER VI
MANUSCRIPT

Blood lactate, heart rate, and energy expenditure responses to 500 punches and 500 kicks in advanced and beginner taekwondo training

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Blood lactate, heart rate, and energy expenditure responses to 500 punches and 500 kicks in advanced and beginner taekwondo training

ABSTRACT

The purpose of this study is to compare the responses of heart rate, blood lactate, and energy expenditure in beginning and advanced Taekwondo participants. Sixteen males, 8 beginners and 8 advanced, subjects between the ages of 18 and 40 years who studied Taekwondo were included. Baseline data showed no significance for both groups with the exception of percent fat, with the beginners significantly fatter. No difference was observed between groups after the 500 punches and 500 kicks in all parameters. A significant trial effect existed for heart rate (HR) and lactate (LA) in response to testing protocol. There was also no group by trial interaction. Since resting values were significantly lower than exercise values, there were no differences between the conditions. No difference between the two groups for total calories (TOTKCAL) expended following all conditions. HR, LA, and TOTKCAL increased similarly for both groups and following completion of each condition.

Key words: front-leg front snap kick, rear-leg front snap kick, front punch and reverse punch

INTRODUCTION

Participation in martial arts has grown rapidly over the past 10 to 15 years. There are an estimated 1.5 million Americans involved in some form of martial arts (1). Karate is one of the most popular forms of martial arts practiced both inside and outside of Japan (3). Taekwondo (TKD) is the most popular form of martial arts in the world, studied in over 140 countries and practiced by a million participants of all ages (2). Martial arts-based aerobic workouts use a combination of techniques from Eastern and Western self-defense styles to elicit cardiovascular responses (7). Women are becoming more involved for fitness and self-defense purposes. The portrayal of martial arts in the media has led to the increased involvement of children. Cardio-kickboxing, fitness boxing, and other forms of fighting-style workouts continue to gain popularity in the fitness industry, representing one of the top 5 profit centers in 6.8% of fitness facilities (7).

The typical training regime, involving extensive movements of the entire body, raises the pulse rate and oxygen consumption of the heart and lungs over an extended period. In addition to traditional martial arts training, many competitive karate practitioners follow a strenuous running and weight training program to increase cardiovascular endurance, lean body mass, strength and power.

It is thought that Taekwondo has contributed to physical fitness, even to the extent that it is supposed to rank with jogging and cross-country skiing relative to cardiorespiratory endurance (9). Only a few investigations have emphasized that martial arts, in general, improve cardiorespiratory endurance and general physical ability.

There is still little information on the acute cardiorespiratory responses to martial arts, perhaps because martial art is thought of more as a method of self-defense than a fitness program. Telemetered heart rate responses of Taekwondo practice have the potential to raise heart rates sufficiently to increase cardiorespiratory fitness (2). The purpose of this study is to compare the responses of heart rate, blood lactate, and energy expenditure in beginning and advanced Taekwondo participants.

METHODS

Sixteen male subjects between the ages of 18 and 40 years were recruited for this study. They were recruited from area martial art schools in the greater Oklahoma City area. Subjects included in the study were those with eight months of martial arts experience. The study included subjects who studied Taekwondo; 8 Beginners (orange/yellow, green, blue belts) and 8 advanced (purple, brown, and black belts) martial artists.

Patients were excluded for the following reasons; (1) white belt practitioners, (2) children, (3) have elbow joint and knee complications, (4) those with cardiovascular diseases (hypertension, arteriosclerosis, and atherosclerosis), and (5) those who have been inactive in the martial arts for a year, and (6) women.

MEASUREMENTS

1. **Anthropometry.** Subjects arrived at the University of Oklahoma Human Performance Lab and had their weight, height and body mass index measured. Subjects removed their shoes and total body weight was measured using an Accu-Weigh Bench Beam Scale. The subjects wore only light fitting clothes,

recording a measurement in pounds to the nearest hundredth (also converted to kilograms). Height was measured using a stadiometer.

2. **Percent of Body fat.** Percent body fat was obtained by the BOD POD. It was important that minimal clothing was worn, such as a swimsuit or speedo swimming trunks, the subjects also wore a swim cap to compress the hair on the head. First the subjects were weighed using the scale attached to the BOD POD system. Then the subject's age, sex, and height were all entered into the computer system. The subject then entered the BOD POD and sat in a comfortable standardized position in which the back is straight and not touching the back wall of the machine, feet slightly apart and hands placed in a relaxed manner in the subject's lap. Measurement of body volume involves 3 steps. First, a standard 2-point calibration process: first with the chamber empty to establish baseline and then with a calibration cylinder to establish range (50 secs) (2). Next the subject's volume in the chamber was measured. This measurement data was termed "raw" and not corrected for thoracic gas volume (V_{TG}) and surface area artifact (SAA) (2). In the third step V_{TG} was measured. It was done using a procedure similar to that used in standard pulmonary plethysmography, often called panting (2). The procedure began with the subject breathing room air quietly through a disposable tube and antimicrobial filter while wearing a nose clip. After a few normal tidal breaths, a shutter valve in the airway closes (2). During the occlusion the subject made 3 gentle quick puffs. An entire test, with printed results, was completed within just 5 minutes without discomfort.

3. **Resting Heart Rate.** Heart rate was obtained through measurements from a Polar Monitor. The telemetric monitor was moistened with water and strapped across the subject's chest, just below the nipple line. It fit snug but not tight. The KB1-C then began to register the subject's heart rate. Heart rate was recorded every 20 seconds.
4. **Blood Lactate.** Blood lactate was obtained through a finger prick. The analyzer was calibrated first by turning the Accusport analyzer "on". Next a code strip was slid into the bottom of the analyzer and quickly removed. A code number matching the lactate strips showed on the screen. To calibrate the analyzer a blank strip was slid into the bottom of the analyzer. After two beeps, the top of the lid was lifted exposing the test strip. One drop of calibration solution 1 was placed on the test strip and the lid was closed. The analyzer read the strip and displayed the number on the screen. If the number matched the solution 1 reading on the bottle it was calibrated. The lid was then lifted and the strip was removed. Next solution 2 was used to calibrate the analyzer using the same procedure as before. The following guidelines were used; 1) the top of the lancelet was removed and a new, sterile needle was placed inside a lancelet. The cover was then removed from the needle tip and the top was placed back onto the lancelet, 2) a blank lactate strip was slid into the bottom slot of the Accusport blood lactate analyzer. Once two beeps sounded, it meant that the lactate analyzer was ready for use. The lid on the lactate analyzer was now opened, 3) the subject's hands were warmed if they were cold and blood was squeezed from the top of the arm down

to the fingertips. The fingertip was cleaned with a sterile alcohol pad and air-dried. Now the lancelet was pressed on the side of the finger, 4) the button on top of the lancelet was then pressed and punched a hole in the side of the finger. The blood was then again squeezed to the tip to get a drop of blood onto the lactate strip, 5) the lid on the lactate analyzer was now closed. The lactate analyzer read the strip and gave a reading which was recorded. This was a process that was performed at the beginning for a resting lactate (La), and at the end of each activity for an exercise lactate.

5. **Energy Expenditure.** Energy expenditure was obtained through the use of indirect calorimetry. It was measured using Aerosport KBI-C Metabolic Analyzer. The Aerosport analyzer flow was calibrated first by attaching the analyzer to a 5mL cylinder. Following the instructions on the screen, the process was started by pressing; the "flow" button, and then by entering the flow amount (15mL) into the analyzer, then the test began. The cylinder was then pumped 3 times. Once the test was successful the screen returned to the home page. The gas was then calibrated. First the oxygen concentration and carbon dioxide concentration were entered and the analyzer zeroed on room air temperature. The analyzer was then attached to a calibrated gas cylinder where the bag was flushed 3 times and then filled with gas. The "start" button was pressed and the test began calibrating the gases. If the values were within the entered amounts then the test was a success. The analyzer then again zeroed on room air temperature. The subject's age, sex, height and weight were entered into the analyzer. A mask was then placed on the subject's face with the analyzer attached to the other end of the

breathing tube. The subject rested in a sitting position for 5 min, with their arms to their side, legs together and remaining still. At the beginning of the test the subject inhaled and then exhaled and the analyzer recorded calories (kcal). Data was recorded throughout the exercise: 5 minutes between the exercises, and 5 minutes post-exercise.

TESTING PROCEDURES

1. **Kicks**. Subjects got into a martial arts fighting stance. In this stance, their feet were under their shoulders, knees slightly bent and front foot facing forward while their back foot was turned parallel to the front foot. The tester counted one to fifty while the kicks were performed. The subjects were allowed to rest ten seconds before continuing with the next 50 kicks. This was repeated until the subject reached 500 kicks. Blood lactate was recorded before, after, and 5 minutes after the activity. Heart rate was recorded every twenty seconds. The final record was taken at the end of the 500 kicks. Energy expenditure was recorded every twenty seconds, before, and after the activity. After recording a post-activity blood lactate, the subjects then prepared themselves for recording data for punching.
2. **Punches**. Subjects got into a martial arts horse stance, which their legs were much wider than their shoulders. Their feet were facing forward and knees pointing outward. One hand was chambered to the side and the other forward. The tester counted one to 100 while the punches were performed. This was repeated until the subject reached 500 punches. Blood lactate was recorded before, after, and 5

minutes after the activity. Heart rate was recorded every twenty seconds. The final record was taken at the end of the 500 punches. Energy expenditure was recorded every twenty seconds, before, and after the activity.

STATISTICAL ANALYSES

Descriptive statistics were run on all variables and reported as means ± standard error of the mean (SE) as well as percent change [(final measure- initial measure)/ initial measure x 100]. Statistical analyses were performed on SPSS® version 10.0 for Windows™. Descriptive statistics were used to look at the entire sample and split by advanced and beginners. A repeated measures analysis of variance (ANOVA) was conducted to compare whether differences in punches and kicks existed between the two levels of experience (beginners vs. advanced). A comparison of the percent of change and experience was assessed by using a one-way ANOVA. An independent t-test was used to compare the experience levels. A repeated measures analysis of covariance (ANCOVA) was used to control for percentage of body fat. To determine the relationships between the variables within each group, Pearson Correlation Coefficients was used. Statistical significance was set at an alpha level of $p < 0.05$.

RESULTS

Sixteen (16) male subjects, all between the ages of 18 and 40 years, participated in the study. All of the participating subjects were assigned to one of two training groups; beginners (rank= 2, N=8, 0 orange, 2 yellow, 3 green, 2 blue, 1 purple) and advanced (rank=1, N=8, 8 black belts).

Baseline data were analyzed to ensure no differences existed between training groups before the testing sessions began. An independent t-test was used to compare the groups for resting values. At baseline only percent fat was different between beginners and the advance groups with beginners having significantly higher percent fat (13.4% vs. 23.4%). Height (cm), weight (kg), percent fat (% fat), resting lactate (RLA), resting heart rate (RHR), and calories expended (kcal) were similar between the two groups ($p > 0.05$). Table 1 presents the resting values for the individual groups.

TABLE 1. SUBJECT CHARACTERISTICS

	Beginners	Advanced
Sample size (N)	**8**	**8**
Age (yrs)	**27 ± 2.7**	**25 ± 2**
Experience (yrs)	**1 ± 0.2**	**8.7 ± 2.6**
Ht. (cm)	**175.6 ± 3.2**	**176.6 ± 2.5**
Wt. (kg)	**84.0 ± 8.3**	**79.6 ± 4.5**
%fat	**23.4± 3.8***	**13.4 ± 1.3***
Rest La (mmol/L)	**1.6 ± 0.24**	**2.6 ± 0.39**
RHR (bpm)	**74 ± 5.2**	**75 ± 4.3**
Rkcal (per·min	**5.8 ± 2.8**	**6.5 ± 3.1**

Values are means ± SE **$*p < 0.05$**

EXERCISE RESPONSES

Table 2 shows the Mean ± SE for each variable of interest and both groups. There were no statistical differences ($p > 0.05$) between the two groups after the 500 punches in HR, percent change of heart rate (PCHR), punching lactate (PLA), percent change of lactate (PCLA), punching caloric expenditure (PKCAL), and percent change of caloric expenditure (PCPKCAL).

Table 3 shows the Mean ± SE for each variable of interest and both groups. There were no statistical differences ($p > 0.05$) between the two groups after the 500 kicks in HR, percent change of heart rate (PCHR), kicking lactate (KLA), percent change of lactate (PCLA), kicking caloric expenditure (KKCAL), and percent change of caloric expenditure (PCKKCAL).

TABLE 2. PARAMETERS OF INTEREST FOR ADVANCED VS. BEGINNERS FOLLOWING 500 PUNCHES

	Beginners	Advanced
PHR (bpm)	146 ± 6.4	148 ± 4.1
PCPHR (%)	103.1 ± 11.2	99.0 ± 9.2
PLA (mmol/L)	9.0 ± 1.3	7.6 ± .8
PCPLA (%)	556.0 ± 158.0	244.2 ± 62.5
PKCAL (per·min)	7.2 ± 1.5	9.1 ± 3.1
PCPKCAL (%)	269.0 ± 97.3	182.7 ± 59.0

Values are Means ± SE
PHR-punching heart rate, PCPHR-percent change punching heart rate, PLA- punching lactate, PCPLA-percent change punching lactate, PKCAL- punching caloric expenditure, PCPKCAL-percent change punching caloric expenditure

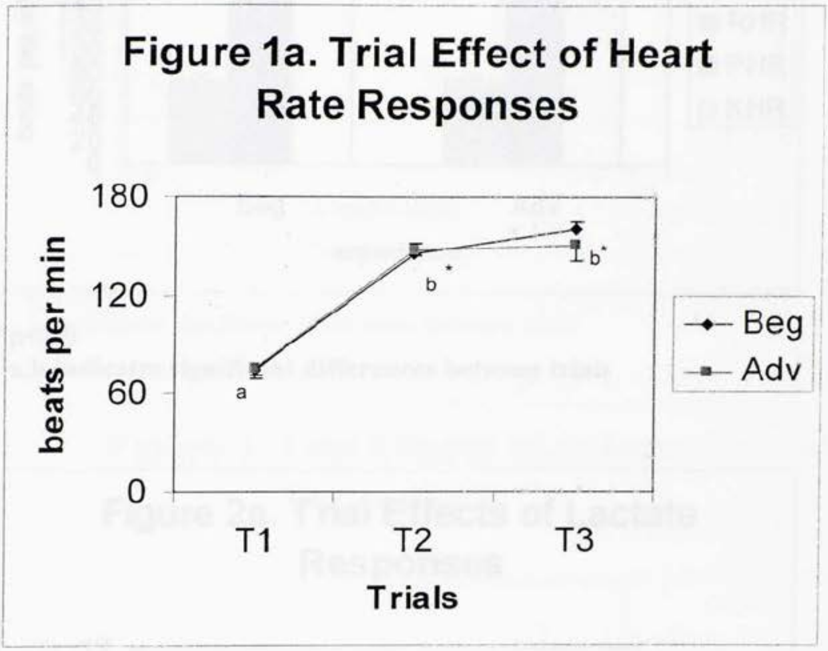
TABLE 3. PARAMETERS OF INTEREST FOR ADVANCED VS. BEGINNERS FOLLOWING 500 KICKS

	Beginners	Advanced
KHR (bpm)	161 ± 3.6	151 ± 10.2
PCKHR (%)	124.6 ± 11.6	104.0 ± 16.8
KLA (mmol/L)	8.8 ± 1.4	7.1 ± 1.1
PCKLA (%)	512.8 ± 146.5	234.0 ± 63.3
KKCAL (per·min)	8.3 ± 1.5	9.6 ± 2.2
PCKKCAL (%)	332.8 ± 127.9	228.1 ± 67.7

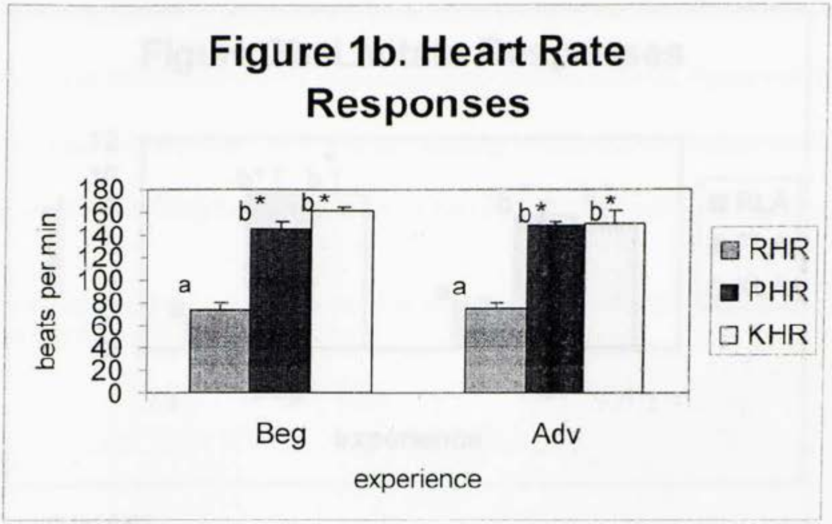
Values are means ± SE
KHR-kicking heart rate, PCKHR- percent change kicking heart rate, KLA- kicking lactate, PCKLA-percent change kicking lactate, KKCAL-kicking caloric expenditure, PCKKCAL-percent change kicking caloric expenditure

All variables for the study were measured at rest, during the exercise, and post-exercise. A general linear model of repeated measures was used to determine if there was a significant difference between the trials ($p < 0.05$). Each subject was measured across trials and by their ranks assessing group interactions. The tests of between subjects' effects were also analyzed in order to assess differences between groups.

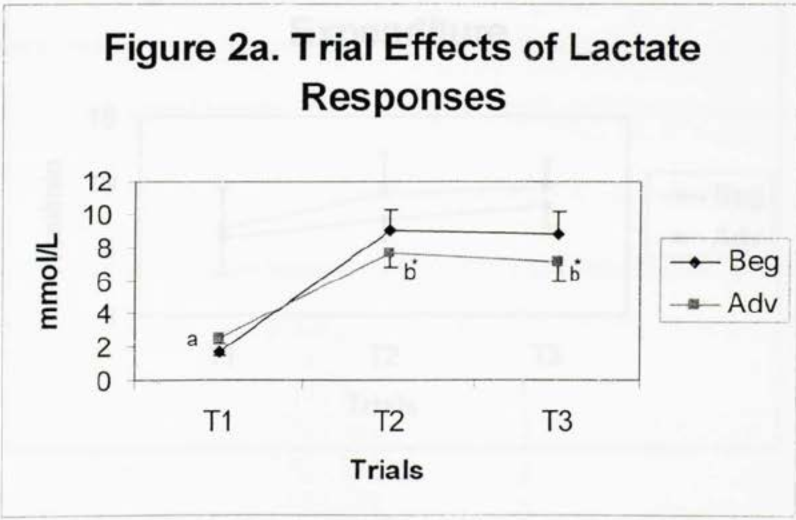
A significant trial effect was observed for heart rate (Figure 1a and 1b) and lactate (Figure 2a and 2b) in response to the testing protocol ($p < 0.05$); however, no difference was determined between the groups ($p = .454$). No group by trial interaction was observed (p=.285). Caloric expenditure (Figure 3) showed no significance for the trial main effect, group main effect (p=.685), or group by interaction (p=.900).



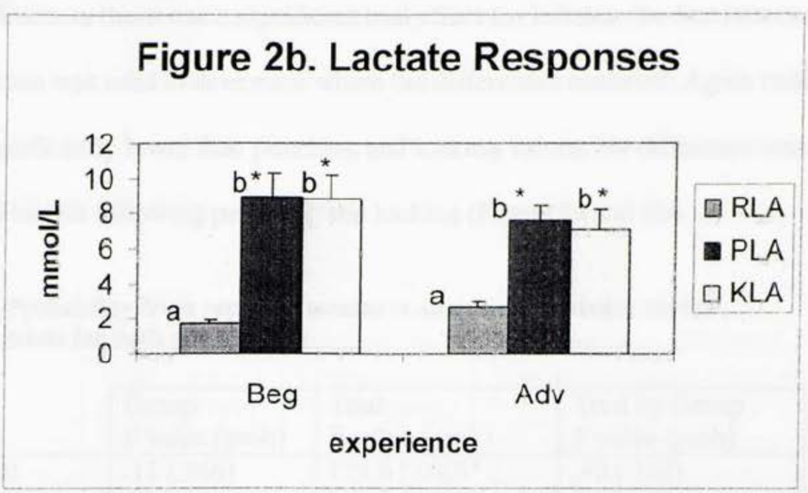
$^*p<0.05$
a,b indicate significant differences between trials



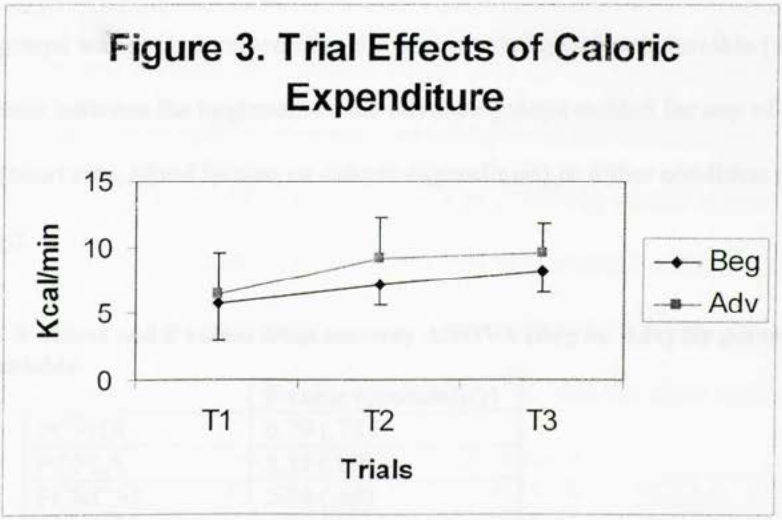
*p<.05
a,b indicates significant differences between trials



*p<.05
a,b indicates significant differences between trials



* p< 0.05
a, b indicate significant differences between trials



Since there was a significant trial effect for heart rates, a post-hoc analysis was administered (Figure 1a and 1b), to determine where the significance occurred by using a Bonferroni pairwise comparison. Resting values were significantly lower than punching and kicking values. No difference was observed between heart rate following punching and kicking.

Because there was a significant trial effect for lactates, the Bonferroni pairwise comparison was used to determine where the differences occurred. Again resting values were significantly lower than punching and kicking values. No difference was seen between lactate following punching and kicking (Figure 2a and 2b).

Table 4. Probability from repeated measures analysis of variance across trials for both groups

	Group F value (prob)	Trial F value (prob)	Trial by Group F value (prob)
HR	.11 (.746)	175.6 (.000)*	.98 (.388)
LA	.593 (.454)	32.2 (.000)*	1.3 (.285)
KCAL	.17 (.682)	2.3 (.115)	.11 (.900)

*$p < 0.05$

A one-way analysis of variance was used to determine if a statistical difference between groups was present concerning the percent change of each variable (Table 5). No difference between the beginners or the advance groups existed for any of the variables (heart rate, blood lactate, or caloric expenditure) or either condition (punching vs. kicking).

TABLE 5. F values and P values from one-way ANOVA (Beg vs. Adv) for percent change for each variable

	F value (probability)
PCPHR	0.79 (.78)
PCPLA	3.37 (.09)
PCKCAL	.574 (.46)
PCKHR	1.02 (.33)
PCKLA	3.05 (.10)
PCKKCAL	.524 (.48)

Based on the fact that there was a significant difference between beginners and advanced for percent fat at the baseline assessment, a repeated measures ANCOVA was used. Controlling for percent fat (Table 6) there was no change from the original repeated measures ANOVA results with only HR and LA demonstrating a significant trial effect.

Table 6. F value and (p values) from the repeated measures ANCOVA

	Trial F value(prob)	Group F value (prob)	Trial by group F value (prob)
HR	23.39 (.00)*	.01 (.91)	1.71 (.20)
LA	8.22 (.00)*	.53 (.47)	1.82 (.182)
KCAL	1.21 (.316)	.82 (.38)	.05 (.95)

*** p< 0.05**

Pearson Correlation Coefficients were calculated to determine if significant relationships existed between the variables within each group. The analysis indicated that among the advanced subjects, the strongest correlation was between percent change kicking caloric expenditure (.98) and percent change punching caloric expenditure.

The strongest relationship between beginners was established between percent change punching caloric expenditure (.98) and percent change kicking caloric expenditure. Table 8a and b indicate the relationships between the other variables.

Table 7a. Pearson Correlation Coefficients for Beginners

	PCPHR	PCPKCAL	PCPLA	PCKHR	PCKLA	PCKKCAL
PCPHR		-.01	.18	.83*	.34	-.17
PCPKCAL			.06	.13	-.01	.98**
PCPLA				.11	.89**	-.02
PCKHR					.25	.02
PCKLA						-.13

Strong: ≥ .8, Moderate: ≥.5, Weak: ≤ .3
***p ≤ .05, **p ≤ .01**

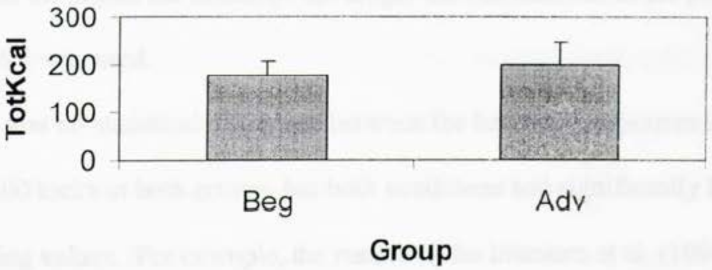
Table 7b. Pearson Correlation Coefficients for Advanced

	PCPHR	PCPKCAL	PCPLA	PCKHR	PCKLA	PCKKCAL
PCPHR		.58	-.37	.68	-.56	.63
PCPKCAL			-.43	.53	-.38	.98**
PCPLA				.11	.67	-.42
PCKHR					-.28	.59
PCKLA						-.30

Strong: ≥ .8, Moderate: ≥.5, Weak: ≤ .3
$^{**}p \leq .01$

A one way ANOVA was performed to compare the total amount of calories expended between both groups (Figure 4). The total time for each group from the beginning resting period to the ending resting period was: beginner group ~32 minutes vs. advanced group ~30 minutes. No significant difference was found (p= .663) between the groups (advanced 201.49 ± 46.69 vs. beginners 176.62 ± 30.55).

Figure 4. Total Caloric Expenditure Responses



DISCUSSION

The purpose of this study was to compare heart rate responses, blood lactate responses, and energy expenditure of beginning and advanced taekwondo training to 500 punches and 500 kicks. There were a total of 16 subjects (8 advanced and 8 beginners) used in this study. The Imamura et al. (1997) study had fewer subjects (14 subjects- 8 advanced and 6 beginners) but still achieved a statistical power of 0.85. Both studies found that, compared to beginners, the advanced taekwondo subjects had a significantly less amount of percent fat. The results of the current study were similar to the results of the Imamura et al. (1997) study when the variables of heart rate responses and lactate responses between the advanced and beginners karate practitioners were compared. Both studies found no difference between punches and kicks whether it was 500 (as in the current study) or 1,000 (Imamura et al.) repetitions.

The training intensity of performing the punches and kicks were examined by instructing the subjects to punch for a count of 100 and resting for five seconds between sets. Performing the kicks, the subjects were instructed to kick with a maximum kicking speed up to waist height for a count of 50 then rested for 10 seconds. The punches lasted on average for 10 minutes while the kicks lasted 12 minutes. The heart rate was recorded for each subject every 20 seconds. Pieter et al. (1990) used a work-rest ratio of 1:2, which is dependent on the higher the intensity, the longer the rest interval. In the present study a work-ratio of 6:1 was used.

There was no statistical difference between the heart rate responses to the 500 punches and 500 kicks in both groups, but both conditions had significantly higher heart rates than resting values. For example, the results of the Imamura et al. (1997) study found a mean heart rate response of 102.5 ± 14.8 beats•min for the advanced following 1,000 punches, and 116.1 ±17.9 beats•min for beginners following 1,000 punches (2). The current study found a heart rate response of 147.63 ± 4.07 beats•min for the advanced following 500 punches, and 146.13 ± 6.38 beats•min for the beginners following 500 punches. There was no significant difference between heart rate responses for both groups in the two studies. The differentiation in mean heart rate responses in both studies to punches could be due to the differences in the counts used between the studies. For instance, in the Imamura et al. (1997) study he quoted that "each subject counted one to 10, while the other subject punched or kicked with the count. After the last subject finished counting one to 10, the first subject started to count again." In the present study the participants punched at their own count of 100 focusing on power and speed. The different heart rate responses could also be a result of additional rest periods between sets. Because each participant in the Imamura et al. (1997) study used a different person to count, one subject may reach the count of 10 before another allowing more rest. The present study allowed a 5 second rest period between sets; which did not allow enough recovery time for the heart rate to decrease. Another reason could be that Imamura et al. (1997) averaged the fifth and the fifteenth minute of punches and the seventeenth minute of the kicks then presented the results as the mean heart rates for both groups.

Other disparities between the two studies could be that karate experience and skill level of the subjects, with skill level being due to the conditioning of the students. Conditioning of the students could be that each martial arts school focuses either more on karate techniques or taekwondo techniques. Pieter et al. (1990) found karate practitioners utilize more arm techniques in their training, which would put more strain on the subjects during kicking conditions, where taekwondo athletes perform more leg techniques, placing more strain on them during punching conditions. Taekwondo athletes are closer to meeting at least 50% of the total muscle mass to improve aerobic endurance.

Blood lactate levels increase with prolonged, high-intensity exercise. During anaerobic glycolysis, $NADH^+$ production exceeds the cell's capacity for shuttling its H^+ ions down the respiratory chain because of insufficient oxygen at the tissue level. The excess hydrogen electrons combined with pyruvate forms lactate. Once lactate forms in the muscles, it diffuses rapidly into the interstitial space and into the blood for buffering and removal from the site.

In the current study, blood lactate was measured before the exercise and immediately after each exercise. There were no statistical differences between beginners and advanced, but there were statistical differences between the trials. The beginners however, had higher mean values for exercising lactate levels (beginners: resting lactate (RLA) = 1.67 ± .24 mmol/L, punching lactate (PLA) = 8.99 ±1.28 mmol/L, kicking lactate (KLA) = 8.78 ± 1.39 mmol/L; advanced: resting lactate (RLA) = 2.55 ±.39, punching lactate (PLA) = 7.59 ± .83 mmol/L, kicking lactate (KLA) = 7.11 ± 1.09 mmol/L). For healthy, untrained persons, blood lactate begins to accumulate and rise in an exponential fashion at about 55% of their maximal capacity for aerobic metabolism (15). One reason for this difference is that lactate clearance is higher in trained individuals than it is in untrained individuals due to an enhanced blood flow to the liver; which aids in lactate removal (21). The enhanced uptake of lactate by active and inactive muscles means that there is a change in the rate of lactate clearance. This explains the decreased concentration of lactate in muscle and in blood at the same relative workload. Another reason could be that the advanced individuals have increased levels of glycogen and glycolytic enzymes. They also retain improved motivation and "pain" tolerance to fatiguing exercise (15).

Comparing the Imamura et al. (1997) study to the present study, the Imamura et al. (1997) study found lower values for lactic acid accumulation following the exercise periods. The possible discrepancy here could be due to the longer rest periods. Imamura et al. (1997) mentioned in their study that immediately after the exercise the moderate elevation in blood lactate may be the result of blood lactate produced by an active muscle group taken up and utilized by inactive muscles. This could result in missing the peak blood lactate levels during each exercise.

ACSM suggests exercising at least 3d•wk for at least 20 min and with sufficient intensity to expend approximately 300 kcal per session as a threshold for decreasing total body mass and increasing fat-free mass. In the current study the total caloric expenditure for the entire session among the advanced (201.49 ± 46.69 kcal) was higher than the values for the beginners (176.62 ± 30.55 kcal).

McArdle et al. (2001) used a five-level classification system based on energy (kcal) required by untrained men performing different physical activities (10). When comparing calories to the McArdle et al. (2001) table, both beginners and advanced subjects of the current study expended between seven and nine kcal•min which was classified as a moderate to heavy level of exercise.

Movement economy also played an important role in the amount of calories expended during the exercises. It is stated that an individual with greater movement economy expends less calories. In this case both groups expended the same amount of calories.

The results of the current study show no statistical difference, but the threshold for energy expenditure, according to ACSM, was nearly reached by both groups for the total time periods in approximately 30 minutes (advanced = 201.5 ± 46.7 kcal vs. beginners = 176.6 ± 30.6 kcal). Both groups were efficient enough to increase their heart rate and were able to expend more calories during the exercise periods.

PRACTICAL APPLICATIONS

By the end of the study, all participants had learned their predicted resting metabolic rate, percent fat, and their resting heart rate response to kicking and punching. Every participant learned how in shape their bodies were for martial arts and also learned ways to improve their training sessions. The study does prove that martial arts kicks increase the subject's heart rate above the ACSM threshold for increasing cardiovascular performance. It has shown that the kicks meet the ACSM threshold for caloric expenditure in an exercise session. Generally speaking, a 45 minute cardio-kickboxing class at a neighborhood fitness center or exercising to a Tae-Bo tape will increase cardiovascular fitness, lactate threshold, and energy expenditure enough to also increase lean muscle mass.

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APPENDICIES

INFORMED CONSENT FORM FOR RESEARCH BEING CONDUCTED UNDER THE

AUSPICES OF THE UNIVERSITY OF OKLAHOMA-NORMAN CAMPUS

TITLE OF PROJECT: Blood Lactate, Heart Rate, and Energy Expenditure Response of 500 Punches and 500 Kicks in Taekwondo Training.

PRINCIPAL INVESTIGATOR: Dr. Michael Bemben, Professor, Department of Health and Exercise Science, University of Oklahoma

CO-PRINCIPAL INVESTIGATOR: Shaun Steen, M.S. Candidate, Department of Health and Exercise Science, University of Oklahoma

INTRODUCTION:

I, ______________________, agree to participate as a volunteer in a study concerning blood lactate, heart rate, and energy expenditure response of 500 punches and 500 kicks in taekwondo training. This study will be conducted at the University of Oklahoma, under the supervision of Dr. Michael Bemben. The purpose of this study is to compare heart rate responses, blood lactate responses, and energy expenditure of beginning and taekwondo experts following 500 punches and 500 kicks.

DESCRIPTION OF THE STUDY:

A. Testing

The participants will have their weight, height and percent of body fat measured. The subjects will be randomly assigned to perform the 500 kicks or 500 punches first. Heart rate will be recorded every minute, while testing of blood lactate will occur, before the 500 kicks or 500 punches and after, then 10 minutes after the session. Energy expenditure will be recorded during the exercise, after, and 10 minutes after the exercise. The entire testing will take 2 hours to complete.

RISKS AND BENEFITS:

A. Risks

There is a risk of possible muscle strains, soreness and fatigue, which may be associated with improper punching or kicking techniques.

B. Benefits

This study will benefit the science of martial arts by contributing to the body of knowledge that states whether or not if martial arts increases lean body mass or increases cardiovascular fitness.

INJURY COMPENSATION:

In case of injury or illness resulting from this study, emergency medical treatment is available. However, you or your insurance company may be expected to pay the usual charge for this treatment. No funds have been set aside by the University of Oklahoma Norman Campus, to compensate you in the event of injury. The University of Oklahoma has not made provisions for monetary compensation in the event of injury resulting from the research. In the event of such injury, treatment is provided, but is not provided, but is not provided free of charge.

CONDITIONS OF PARTICIPATION:

Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. Furthermore, you may discontinue participation at any time without penalty or loss of benefits to which you are entitled.

CONFIDENTIALITY:

Confidentiality will be maintained by coding all information with individual identification numbers as described above. The master list will be kept in a locked file cabinet in the PI's (Michael Bemben) office. Only qualified research personnel and University of Oklahoma Institutional Review Board (IRB) will have access to database containing study information. All study data that entered into statistical analyses and publication reports will refer to group mean data. No individual or group other than the research team will be given information, unless specifically requested by you. All subject-related materials and data will be held confidential and will stored in the PI's records for a period not less than 5 years. After this time, all subject-related materials and data will be shredded.

CONTACTS FOR QUESTIONS ABOUT THE STUDY:

Participants may contact Dr. Michael Bemben, Professor, Department of Health and Sport Sciences, University of Oklahoma, (405) 325-2717 or Shaun Steen, M.S. Candidate, Department of Health And Exercise Science, University of Oklahoma, (405) 325-5211 with questions about the study.

For inquires about the rights as a research participant, contact the University of Oklahoma-Norman Campus Institutional Review Board (OU-IRB) at 405/325-8110 or irb@ou.edu.

PARTICIPANT ASSURANCE:

I have read and understand the terms and conditions of this study and I hereby agree to participate in the above-described research study. I understand my participation is voluntary and that I may withdraw at any time without penalty.

Signature of Participant	Date
Printed Name of Participant	Research Signature

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 1994)

PAR – Q & YOU

(A Questionnaire for People Aged 15 to 69)

egular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more :tive is very safe for most people. However, some people should check with their doctor before they start becoming much more ıysically active.

you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 9 years of age, and you are not used to being very active, check with your doctor.

ommon sense is your best guide when you answer these questions. Please read the questions carefully and answer each one onestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of <u>any other reason</u> why you should no do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want - as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

'you answered NO honestly to all PAR-Q questions, you can be reasonably ure that you can:

- start becoming much more physically active - being slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: if your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether or not you should change your physical activity plan.

<u>nformed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and f in doubt after completing this questionnaire, consult your doctor prior to physical activity.

You are encouraged to copy the PAR-Q but only if you use the entire form

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________

SIGNATURE OF PARENT ______________________________ WITNESS ______________________

or GUARDIAN (for participants under the age of majority)

continued on other side...

Karate Data Sheet

Name: [redacted]

ID# 16

Age: 20 Belt Ranking: 2nd Dan

Experience Years: 15years

0:00

Baseline

Ht: 176 cm 69in Wt: 169 lbs 76.76kg

%BF: 28.3

RLa[]: 1.0mmol RHR: 68bpm 17/4

500 Punches

20.00min

Time: 24:13 VO_{2max}: 2.13

ExHR: 92 La[]: 10.5mmol

Kcal: 10.2 RQ:

5:00min

500 Kicks

Time: 1500 VO_{2max}: 2.19

23/4 ExHR: ~~[illegible]~~ 115 La[]: 12.2mmol

Kcal: 10.6 ~~RQ~~

BOD POD

BODY COMPOSITION ANALYSIS

Univ. of Oklahoma
Body Composition Lab
(325-5211)

Name	: -.	Date	: Mar 26 2004
Age	: 23	Height	: 72 ins (183 cms)
Gender	: M	Model	: Siri 1961
Technician	: Shaun	Density	: 1.062 kg/l

Percent Fat	: 16.2 %	Fat Weight	: 25.2 lbs
Percent Lean	: 83.8 %	Lean Weight	: 130.7 lbs
		Total Weight	: 155.9 lbs

Body Fat

Your Percent Body Fat is currently 16.2 percent. Generally, health professionals recommend that women should not exceed 30 percent fat for optimal health, and men not exceed 20 percent.

Lean Body Weight

Your Lean Body Weight is currently 130.7 lbs. The largest component of your Lean Body Weight is muscle. The more muscle you have, the higher your metabolism (the number of calories you burn in a day).

Metabolism

Your resting metabolism is related to your lean body weight. This is the mimimum number of calories you burn in a 24 hour period with no additional activity. Physical activity will increase your metabolism beyond the resting level.

How To Change Your Body Composition

The most effective way to improve (or maintain) healthy body composition is to combine appropriate exercise with good nutrition. Two types of exercise can be helpful: 1) aerobic exercise to burn fat, and 2) resistance exercise to increase muscle mass. Consult with a knowledgeable health professional for advice on designing a program. Congratulations on taking the first step with a body composition evaluation!

AeroSport KB1-C
Metabolic Analyzer

I.D. NUMBER 15 WEIGHT kg 66.7 Starting Temp Deg C 20 BP 731 mm/Hg
HEIGHT cm 180.3 AGE 29 Years MALE

PREDICTED VALUES B.S.A. 1.850 m2 B.M.I. 20.52 B.M.R. 38.06
R.M.R. 1690 Kcal/24hr MaxVO2 2.66 MaxHR 191

Time	VO2	O2/Kg	Kcl/m	METS	VEb	HR	RQ	%FAT	%CHO	GrFat	GrCHO
:20	.17	2.5	.80	.7	11.5	81	.06	100	0	.08	.21
:40	.39	5.8	1.83	1.7	13.9	96	.41	100	0	.19	.48
1:00	.56	8.4	2.62	2.4	15.1	96	.68	100	0	.28	.69
1:20	.52	7.8	2.49	2.2	13.1	102	.79	70	30	.19	.17
1:40	.62	9.3	3.01	2.7	14.8	111	.84	53	47	.17	.33
2:00	.56	8.4	2.73	2.4	14.0	117	.86	46	54	.14	.35
2:20	.56	8.4	2.68	2.4	14.3	108	.79	70	30	.20	.18
2:40	.42	6.3	2.01	1.8	10.1	96	.79	70	30	.15	.14
3:00	.50	7.5	2.41	2.1	11.9	114	.82	60	40	.16	.23
3:20	.62	9.3	2.95	2.7	14.3	117	.77	77	23	.25	.16
3:40	.79	11.8	3.76	3.4	17.3	105	.77	77	23	.31	.20
4:00	.64	9.6	3.08	2.7	14.5	111	.81	63	37	.21	.26
4:20	.60	9.0	2.88	2.6	13.6	99	.80	67	33	.21	.22
4:40	.71	10.6	3.44	3.0	17.4	105	.83	56	44	.21	.35
5:00	.63	9.4	3.03	2.7	15.8	117	.81	63	37	.21	.26
5:20	.90	13.5	4.39	3.9	22.2	99	.86	46	54	.22	.56
5:40	.70	10.5	3.39	3.0	17.9	117	.83	56	44	.21	.35
6:00	.87	13.0	4.18	3.7	21.2	135	.80	67	33	.30	.32
6:20	1.36	20.4	6.61	5.8	32.7	147	.85	49	51	.36	.79
6:40	1.57	23.5	7.58	6.7	38.0	162	.82	60	40	.49	.71
7:00	1.79	26.8	8.59	7.7	41.1	159	.80	67	33	.62	.66
7:20	2.32	34.8	11.31	9.9	51.1	174	.86	46	54	.57	1.44
7:40	2.10	31.5	10.24	9.0	49.6	159	.86	46	54	.52	1.30
8:00	2.28	34.2	11.23	9.8	57.5	165	.90	32	68	.41	1.80
8:20	2.33	34.9	11.53	10.0	61.3	171	.92	26	74	.33	2.04
8:40	2.11	31.6	10.42	9.0	54.4	165	.91	29	71	.34	1.76
9:00	2.50	37.5	12.43	10.7	65.6	180	.94	19	81	.27	2.41
9:20	2.37	35.5	11.64	10.1	63.9	174	.89	36	64	.46	1.78
9:40	2.05	30.7	10.04	8.8	56.7	180	.88	39	61	.44	1.45
10:00	2.56	38.4	12.54	11.0	67.9	165	.88	39	61	.55	1.80
10:20	2.69	40.3	13.21	11.5	74.0	168	.89	36	64	.52	2.01
10:40	2.10	31.5	10.21	9.0	59.1	162	.85	49	51	.55	1.22
11:00	2.78	41.7	13.52	11.9	74.8	186	.85	49	51	.73	1.61
11:20	2.53	37.9	12.30	10.8	73.1	174	.85	49	51	.67	1.46
11:40	2.19	32.8	10.60	9.4	62.3	177	.83	56	44	.65	1.09
12:00	2.67	40.0	12.95	11.4	71.2	171	.84	53	47	.75	1.43
12:20	2.51	37.6	12.11	10.7	70.0	177	.82	60	40	.79	1.14
12:40	2.49	37.3	11.98	10.7	67.8	177	.81	63	37	.82	1.03
13:00	2.79	41.8	13.53	11.9	80.5	165	.84	53	47	.78	1.50
13:20	2.39	35.8	11.53	10.2	72.1	183	.82	60	40	.75	1.09
13:40	1.87	28.0	8.98	8.0	56.3	156	.80	67	33	.65	.69
14:00	3.13	46.9	15.06	13.4	86.3	165	.81	63	37	1.03	1.29

I.D. NUMBER 15

Time	VO2	O2/Kg	Kcl/m	METS	VEb	HR	RQ	%FAT	%CHO	GrFat	GrCHO
14:20	2.32	34.8	11.17	9.9	71.2	180	.81	63	37	.77	.96
14:40	2.74	41.1	13.05	11.7	78.4	177	.77	77	23	1.09	.69
15:00	2.91	43.6	13.86	12.5	83.3	174	.77	77	23	1.15	.73
15:20	2.08	31.2	9.91	8.9	61.2	183	.77	77	23	.82	.52
15:40	1.77	26.5	8.41	7.6	49.6	165	.76	81	19	.73	.37
16:00	1.59	23.8	7.59	6.8	46.7	168	.78	74	26	.60	.46
16:20	1.28	19.2	6.15	5.5	38.2	150	.80	67	33	.44	.47
16:40	1.10	16.5	5.31	4.7	33.3	144	.82	60	40	.34	.50
17:00	1.09	16.3	5.29	4.7	35.1	129	.84	53	47	.31	.59
17:20	.69	10.3	3.35	2.9	23.7	129	.84	53	47	.19	.37
17:40	.92	13.8	4.47	3.9	30.5	129	.85	49	51	.24	.53
18:00	.83	12.4	4.08	3.5	27.8	135	.89	36	64	.16	.62
18:20	.93	13.9	4.54	4.0	29.9	120	.87	42	58	.21	.62
18:40	.79	11.8	3.84	3.4	26.5	123	.85	49	51	.21	.46
19:00	.62	9.3	2.99	2.7	21.2	117	.82	60	40	.19	.28
19:20	.56	8.4	2.69	2.4	18.0	114	.80	67	33	.19	.21
19:40	.70	10.5	3.37	3.0	21.7	108	.81	63	37	.23	.29
20:00	.67	10.0	3.25	2.9	20.9	114	.84	53	47	.19	.36
20:20	.73	10.9	3.55	3.1	23.5	117	.85	49	51	.19	.42
20:40	.93	13.9	4.50	4.0	29.8	129	.83	56	44	.28	.46
21:00	.99	14.8	4.79	4.2	32.7	150	.83	56	44	.29	.49
21:20	1.91	28.6	9.31	8.2	51.6	174	.86	46	54	.47	1.19
21:40	2.48	37.2	11.75	10.6	68.7	183	.75	84	16	1.06	.42
22:00	2.79	41.8	13.29	11.9	75.5	174	.77	77	23	1.10	.70
22:20	2.45	36.7	11.70	10.5	73.8	168	.78	74	26	.93	.71
22:40	2.79	41.8	13.43	11.9	80.4	183	.81	63	37	.92	1.15
23:00	2.53	37.9	12.15	10.8	78.1	177	.80	67	33	.88	.94
23:20	2.51	37.6	12.02	10.7	76.2	177	.79	70	30	.91	.83
23:40	2.88	43.2	13.75	12.3	83.8	186	.78	74	26	1.09	.84
24:00	2.58	38.7	12.32	11.1	74.2	174	.78	74	26	.98	.75
24:20	2.22	33.3	10.52	9.5	65.8	159	.75	84	16	.95	.38
24:40	1.93	28.9	9.15	8.3	57.0	171	.75	84	16	.83	.33
25:00	1.40	21.0	6.65	6.0	42.9	156	.76	81	19	.58	.30
25:20	1.24	18.6	5.94	5.3	38.4	141	.79	70	30	.45	.41
25:40	1.08	16.2	5.19	4.6	34.1	138	.80	67	33	.37	.40
26:00	.99	14.8	4.76	4.2	31.4	132	.81	63	37	.33	.41
26:20	1.05	15.7	5.07	4.5	34.2	126	.82	60	40	.33	.48
26:40	.81	12.1	3.92	3.5	26.5	126	.83	56	44	.24	.40
27:00	.88	13.2	4.26	3.8	29.7	126	.83	56	44	.26	.44
27:20	.78	11.7	3.75	3.3	25.4	123	.81	63	37	.26	.32
27:40	.80	12.0	3.87	3.4	26.1	117	.83	56	44	.24	.40
28:00	.86	12.9	4.16	3.7	27.8	114	.83	56	44	.26	.43
28:20	.70	10.5	3.40	3.0	22.7	123	.84	53	47	.20	.38
28:40	.75	11.2	3.63	3.2	23.9	114	.83	56	44	.22	.37
29:00	.72	10.8	3.44	3.1	22.5	117	.78	74	26	.27	.21

```
TOTAL CALORIES  =    211.59
TOTAL GRAMS FAT =  13.55
TOTAL GRAMS CHO =  20.83
PEAK VO2 = 3.13 and is 118 % PREDICTED
PEAK  HR =  186 and is  97 % PREDICTED
```

Subject	BeltRank	Age(yrs)	Exp(yrs)	Ht.(in)	Wt.(kg)	%BF	RLa(mmol)	RHR(bpm)
1	B	34	1	65.67	82.36	38.5	2	80
2	A	21	6	73.6	100	13.7	2.9	76
3	A	22	13	69.8	93.2	15.1	1.7	80
4	B	24	1	62.5	48.42	11.7	1.1	72
5	A	22	1.5	67	63.81	8.7	0.9	84
6	B	24	.75	70	76.78	14.1	3.6	64
7	B	35	.83	69	78.62	15.8	1.3	68
8	B	23	.75	72	70.72	16.2	2.4	64
9	A	27	8	65	82.24	15	4.4	64
10	A	20	1	70.5	101.32	23.5	1.9	68
11	A	36	24	67.9	83.54	17.3	2	72
12	B	20	2	72	66.9	7.7	1.1	76
13	B	18	.67	73.8	127	33.6	3	104
14	B	39	.75	70.5	90.18	28.3	1.9	52
15	A	29	6	71	66.86	7	2.5	99
16	A	20	15	69	76.76	28.3	1	68

RKcl/m	PExHR	%changeHR	PLa(mmol)	%changeLa	PKcl/m	%changeKcl/m
0.611	165	106.3	6.8	240	5.53	805.1
2.96	154	102.6	5.3	82.8	3.67	24
1.96	161	101.3	8.4	394.1	6.21	216.8
1.2	147	104.2	17	1445.5	3.54	195
16.41	145	72.6	6.5	622.2	5.01	-69.5
1.11	137	114.1	10.2	183.3	5.04	354
2.44	149	119.1	9.2	607.7	10.02	310.7
1.43	157	145.3	6.4	166.7	6.67	366.4
1.67	133	107.8	11.8	168.2	6.7	301.2
1.94	136	100	5.2	173.7	3.92	102.1
23.89	135	87.5	5.2	160	30.16	26.2
0.64	117	53.9	7	536.4	3.39	429.7
17.36	170	63.4	8.2	173.3	5.01	-71.1
19.86	129	148.1	8	321.1	14.68	26.1
2.65	159	60.6	6.9	176	9.07	242.3
2.49	156	129.4	10.5	950	11.3	353.8

KExHR	K%changeHR	KLa(mmol)	K%changeLa
180	125	7.5	275
143	88.2	9.1	213.8
158	97.5	10.2	500
158	119.4	14.2	1190.1
183	117.9	4.7	422.2
140	118.8	7.2	100
155	127.9	4.4	238.5
174	171.9	5.2	116.7
161	151.6	3.9	11.4
157	130.9	4.3	126.3
89	23.6	4.4	120
162	113.2	5.2	372.7
167	60.6	10.3	243.3
145	178.8	12.1	536.8
161	62.6	12.2	388
164	141.2	12.2	1120

KKcl/m	K%changeKcl/m	TotKcal
6.89	1027.7	145.02
5.76	94.6	73.06
7.59	287.2	285.58
3.96	230	95.69
7.34	-55.3	129.63
5.35	382	125.89
12.12	369.7	228.51
8.3	480	136.28
7.25	334.1	162.73
4.7	142.3	84
24.36	1.96	487.46
4.87	660.9	93.93
7.14	-58.9	221.75
16.08	-19	328.49
10.6	300	211.29
10.2	309.6	215.59