CARDIOVASCULAR AND METABOLIC RESPONSES
TO NONCONTACT KICKBOXING IN FEMALES

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Table of Contents

List of Figures

List of Tables

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ABSTRACT

CARDIOVASCULAR AND METABOLIC RESPONSES

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by Alev Tug Ergun

This study investigated whether noncontact cardio kickboxing can elicit sufficient intensities for the improvement of cardiorespiratory fitness and weight management. Cardiovascular and metabolic responses to a 22 min noncontact kickboxing routine were analyzed in 18 young fit women (mean VO_{2max}= 40.5 ± 5.0 ml O_2/kg/min). Intensity during the kickboxing routine averaged 49 ± 10% of oxygen uptake reserve, which is the lower end of the range recommended by the American College of Sports Medicine. When the 22 minute routine was divided into segments (arms only, legs only, arms plus legs), the legs only and arms plus legs segments elicited higher intensities. Therefore, it was concluded that noncontact kickboxing exercise sessions should be designed to include predominantly leg exercises combined with some arm movements and to avoid exercises that use arms only. Average caloric expenditure was 7 kcal/min. Thus, over 300 kcal would be expended during a 45 minute workout, meeting the recommendation for weight management.

Chapter I – Introduction

Martial arts-based group exercise classes have been listed as one of the five more profitable programs or services offered by fitness facilities (International Health, Racquet and Sportsclub Association [IHRSA], 2001a). It also appears that the majority of group exercise participants have a tendency to prefer classes that are based on martial arts over traditional aerobics and other types of cardio classes. Kickboxing is a high intensity workout that uses a combination of boxing and martial arts movements, which include a variety of punches, kicks, and footwork (IHRSA, 2001b; Kravitz, Greene, Burkett, & Wongsathikun, 2003). "Kickboxing, also referred to as boxing aerobics and cardio kickboxing, is a hybrid of boxing, martial arts, and aerobics that offers an intense cross-training and total-body workout" (American Council on Exercise [ACE], 2001, Introduction section, para. 1). Punching bags, gloves, and boxing equipment are used for a contact kickboxing workout; whereas, noncontact kickboxing is mainly composed of punches and kicks thrown into the air rather than using contact equipment. Traditional aerobics footwork is also incorporated in a typical cardio kickboxing class to increase the cardiovascular benefits of the workout (American Martial Arts and CDT Training Center, 2003). Independent of its contact or noncontact nature, kickboxing is becoming increasingly attractive to the avid group exerciser. For that reason, it is important to evaluate whether it is effective in improving cardiovascular and/or muscular fitness, and in providing benefits of increased caloric expenditure for weight control.

The American College of Sports Medicine [ACSM] (1998) recommends exercise intensities of 40/50-85% of oxygen uptake reserve (VO_2R) or heart rate reserve (HRR), or 60-90% of age-predicted maximum heart rate (HR_{max}) to improve cardiorespiratory fitness. For weight management, ACSM (1998) recommends programs that are conducted at least 3 days per week, at an intensity and duration to expend approximately 250-300 kilocalories (kcal) per exercise session for total body mass and fat mass loss. If the frequency is more than 3 days per week, an energy expenditure of 200 kcal per session is recommended. The Institute of Medicine [IOM] (2002) recommends 60 min of daily moderate physical activity (e.g., walking/jogging at 4-5 mph) to prevent weight gain, in addition to the activities required by a sedentary lifestyle. The physical activity in this recommendation refers to "bodily movement that is produced by the contraction of muscle and that substantially increases energy expenditure" (IOM, 2002, p. 12-1), and is different from exercise that is considered more vigorous and structured, leading to improvements in physical fitness. Since noncontact cardio kickboxing, by definition, is considered to be a type of exercise training rather than a physical activity, this study focused on the ACSM recommendation for weight loss.

Participants in a noncontact cardio kickboxing class perform a choreographed workout to upbeat music without a contact device or an opponent. Among the studies conducted on the physiological responses to similar exercise modalities, most analyzed martial arts such as karate (Imamura et al., 1997, 1999, 2002; Imamura, Yoshimura, Nishimura, Nishimura, & Sakamoto, 2003; Imamura, Yoshimura, Uchida, Nishimura, & Nakazawa, 1998; Shaw & Deutsch, 1982; Stricevic, Okazaki, Tanner, Mazzarella, & Merola, 1980), taekwondo (Pieter, Taafe, & Heijmans, 1990; Toskovic, Blessing, & Williford, 2002), or similar sports such as boxing (Bellinger, Gibson, Oelofse, Oelofse, &

Lambert, 1997; Guidetti, Musulin, & Baldari, 2002). Although the exercise modalities in most of these studies are similar to a fitness cardio kickboxing class in terms of being noncontact, the movements were not performed with upbeat music.

Kravitz et al. (2003) stated that *contact* fitness boxing programs meet the criteria established by the American College of Sports Medicine (1998) for the intensity of exercise to improve cardiorespiratory fitness. Shaw and Deutsch (1982) and Imamura et al. (1997) showed that the cardiovascular training effect of a karate kata performance depended on the pace. It has also been reported that the use of particular techniques during karate workouts could be effective in eliciting a cardiorespiratory training effect. Imamura et al. (1999) reported that techniques that included body movements in various stances as opposed to stationary, as well as sparring techniques with or without an opponent, could elicit cardiovascular improvements. Disparities between findings were said to be a possible result of the differences in karate experience, fitness level, skill level, and/or rate of punching or kicking (Imamura et al., 1997, 2002). In addition, Pieter et al. (1990) concluded that the duration and frequency of the workouts; the extent of joint engagement of legs and arms in the exercise; interval-mode of the workout; and experience, skill, and fitness level of the participants play an integrative role in determining whether the workout elicits a training effect. There have been no studies analyzing whether *noncontact* cardio kickboxing meets the criteria that ACSM (1998) set forth for the intensity of exercise to improve cardiovascular fitness. There is also no research pertaining to the effect of *fitness level* and/or *training status* on meeting the ACSM criteria during a noncontact cardio kickboxing workout. Toskovic et al. (2002)

examined the effect of experience and gender on cardiovascular and metabolic responses with dynamic taekwondo exercise, but did not evaluate training status and/or experience alone.

Purpose of the Study

The present study addressed the question of whether noncontact fitness kickboxing is effective in eliciting intensities recommended by ACSM to improve cardiovascular fitness and produce effective caloric expenditure for weight loss. A secondary focus was to evaluate whether current training status or fitness level affects the physiological responses to a noncontact kickboxing workout.

Most of the martial arts and boxing studies used male participants (Bellinger et al., 1997; Guidetti et al., 2002; Imamura et al., 1997, 1998, 1999; Pieter et al., 1990; Stricevic et al., 1980). There are only a few studies examining female martial arts performers (Imamura et al., 2002, 2003). Because it appears that the majority of the cardio kickboxing class participants are females, it is important to study females to determine whether noncontact kickboxing is an effective workout for weight management and improvement of cardiovascular fitness. For that reason, the physiological responses of females to a noncontact kickboxing routine were examined in the present study.

Therefore, this study investigated whether noncontact cardio kickboxing elicits intensities recommended by ACSM (1998) for the improvement of cardiovascular fitness, and whether energy expenditure during this exercise mode is sufficient to promote weight loss and fat reduction in women. The effect of current fitness level (both cardiorespiratory and muscular strength) on the extent that the person can exercise at an intensity recommended by ACSM (1998) to improve cardiorespiratory fitness during a noncontact cardio kickboxing class was a secondary focus of the present study.

It was hypothesized that noncontact cardio kickboxing is an activity that allows a person to exercise at an intensity recommended by ACSM (1998) to improve cardiorespiratory fitness and promote weight loss over time. It was also hypothesized that current fitness level may affect an individual's ability to exercise at intensities that are recommended by ACSM to improve cardiovascular fitness during noncontact cardio kickboxing.

The results of the study provide information regarding whether noncontact cardio kickboxing is another mode of exercise that can be used to improve cardiorespiratory fitness and promote weight loss. This information will guide the fitness expert when designing a noncontact cardio kickboxing program to promote both cardiovascular training and weight management, thus assuring targeted and well-designed fitness programs.

Delimitations

The study focused on the physiological responses in females when other confounding variables, such as the routine and technique of the exercise, skill and experience level of the participant, and music tempo remained constant. Kickboxing style was limited to *noncontact*, and skill and experience level of the participants was limited to *moderate*. Moderate skill and experience level was defined as having participated in a contact or noncontact fitness kickboxing class for 10 hours. Music tempo was set at *135 beats per minute* (bpm) as recommended by the Aerobics and Fitness Association of America [AFAA] (2001). The duration of the noncontact kickboxing routine was *22 min,* which is at the low end of the range that is recommended by ACSM (1998) for developing and maintaining cardiorespiratory fitness in the healthy adult.

Limitations

Since participants' aerobic capacity (VO_{2max}) was measured by maximal exercise testing, only individuals that were categorized as *low risk* according to ACSM guidelines (2000) were recruited for this study. Another limitation was having no control over participants' training background. There may not have been consistency in the type of activity and/or sport in which the participants had trained. This may limit the generalizability of the results to a specific population.

Participants performed the kickboxing routine alone in a laboratory while following videotaped instructions rather than with a group of people while an instructor taught the routines in a class setting. This may have adversely affected their motivation, thereby altering the physiological responses to the exercise. Participants also indicated that they felt restricted in their moves since they were wearing a face mask that was connected to the metabolic cart via wires. The length of the wires limited the available space in which they could move. They deliberately limited the range of motion of their punches and kicks in an effort to stay away from the wires. This may have reduced the exercise intensity, consequently reducing the validity of the study.

Assumptions

The study was designed to measure cardiovascular and metabolic responses of women who had moderate skill in kickboxing. Therefore, it was assumed that the participants declared their kickboxing experience correctly. It was also assumed that the participants learned and executed the kickboxing routine easily with few or no problems. Resting oxygen consumption was assumed to be 3.5 ml/kg/min.

Definitions

1RM: "The heaviest weight that can be lifted only once using good form" (ACSM, 2000, p. 81).

1RM test: The gold standard of dynamic muscle strength testing (ACSM, 2000).

Aerobic capacity (VO_{2max}): "VO_{2max}, or aerobic capacity, is accepted as the single best measure of cardiorespiratory fitness" (P.Plato, personal communication, 2001). It is defined as "the product of the maximal cardiac output (L/min) and arterial-venous oxygen difference (mL O_2 / L)" (ACSM, 2000, p. 68). It is also defined as "the region in which oxygen consumption plateaus or increases only slightly with additional increases in exercise intensity" (McArdle, Katch, & Katch, 2001, p. 162).

Aerobic (cardiorespiratory or cardiovascular) fitness: "The ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods" (ACSM, 2000, p. 68).

Heian 1 Kata: One of the 50 contemporary kata forms, which is used in special forms of interval training (Stricevic et al., 1980).

Karate: "An offensive and defensive art form that contains both hand strikes and kicking techniques. It includes a variety of blocks and powerful blows" (Matsuda, 2003, para.5).

Karate Kata: Predetermined sequences of techniques and movements, which are performed slowly and in prescribed stances and directions (Imamura et al., 1999).

Martial arts: "Basically, a martial art is a skill or skill set relating to human conflict, particularly physical. (Martial = war, art = skill)" (Rogers, 2003, para.1)

MET (Metabolic Equivalent): "The amount of oxygen required per minute under resting, sitting conditions. It is approximately 3.5 mL of oxygen consumed per kilogram of body weight per minute." (Foss & Keteyian, 1998, p. 603).

Muscular strength: The maximal force a muscle or muscle group can generate at a given velocity (ACSM, 2000).

Open circuit spirometry: The open circuit spirometry method is utilized to measure VO_{2max} and, in this procedure, the individual breathes in room air and expires into a gas collection system while volume of air and the fractions of oxygen (O_2) and carbon dioxide (CO_2) in the expired air are measured. A metabolic cart with a computer interface calculates the O_2 consumption and CO_2 production rates, VO_2 and VCO_2 respectively (ACSM, 2000).

Sparring: Free-form combination of defensive and offensive basic techniques. It is done while freely moving against an opponent (Imamura et al., 1999).

Taekwondo: "Tae Kwon Do Karate is a native Korean art that is comprised of 90% kicking" (Matsuda, 2003, para. 9).

VO$_{2max}$ test: “A test that determines VO$_{2max}$, using a variety of exercises that activate the body’s large muscle groups, provided the intensity and duration of effort are sufficient to maximize aerobic energy transfer” (McArdle et al., 2001, p. 233).

Operational Definitions

Moderate skill and experience: Individuals who have participated in a contact or noncontact fitness kickboxing class for 10 hours were considered to have moderate skill. Fitness instructors, particularly kickboxing instructors, were not accepted because this study analyzed the benefits of noncontact kickboxing for the population taking kickboxing classes, not teaching them.

22 min noncontact kickboxing routine: A combination of basic punches, kicks, and aerobic moves, which was designed into a very simple choreography. It was noncontact in nature and lasted 22 min.

Summary

The present study was descriptive in nature, and analyzed the acute cardiorespiratory and metabolic (caloric expenditure) responses of females to a noncontact kickboxing routine. The primary focus was to evaluate whether this activity required sufficient intensity to improve aerobic fitness and promote weight loss. The secondary focus was to evaluate whether fitness level of the participant affected the intensity of exercise during a noncontact kickboxing workout.

Chapter II – Review of Literature

In recent years, kickboxing has emerged as a blend of martial arts, boxing, and aerobics (ACE, 2001). Since it is a relatively new fitness activity, there are only a few studies on kickboxing. Martial arts and boxing play important roles in forming this exercise style. There are a number of studies on martial arts as well as boxing, and they serve as valuable resources to understand kickboxing dynamics.

Martial Arts and Boxing

Excluding other types of martial arts such as kung fu, wu-shu, kempo, aikido, judo, and jujitsu, this review focused on karate, taekwondo, and boxing because the literature is mostly confined to these three activities. Karate is one of the most popular martial arts in the world (Imamura et al., 1997, 1998, 1999, 2002). Taekwondo has also become a popular form of martial arts in the United States, and has gradually changed into a modern, Olympic sport with a worldwide population (Toskovic et al., 2002). There has been a move from full contact boxing toward a form of training that eliminates any body contact due to concerns about injuries associated with full contact boxing (Bellinger et al., 1997).

Karate training involves three basic karate skills: basic techniques, kata, and sparring. Basic techniques that consist of punching, kicking, striking, and blocking are practiced either in a stationary position or with body movements in different stances (Imamura et al., 1997, 1998, 1999, 2002; Shaw & Deutsch, 1982; Stricevic et al., 1980). Thus, karate training can be performed either in a contact or a noncontact manner, depending on the skill being practiced.

Imamura et al. (1998) compared VO_{2max}, body composition, and strength of 7 competitive male karate practitioners with 9 less experienced or novice karate practitioners. All participants were practitioners of basics, kata, and sparring in karate. They reported significantly higher mean values for age, lean body mass, 1RM, and maximal minute ventilation in competitive karate practitioners, and no difference in VO_{2max}, percent body fat, lactate, and maximal heart rate between the two groups. It was concluded that both novice and highly competitive karate practitioners are within the range of nonendurance athletes in aerobic capacity, and their percent body fat is lower than the average college-age population.

Guidetti et al. (2002) examined the relationship between boxing competition performance and physical fitness, muscular strength, and anthropometric measures. They concluded that a high anaerobic threshold, good aerobic power, and hand-grip strength are three contributing factors to boxing performance.

Both of these studies were descriptive in nature and attempted to delineate the physiological characteristics of practitioners involved in a particular sport or activity. Because kickboxing includes both boxing and martial arts attributes, it is interesting to see that a karate practitioner can be categorized as a nonendurance athlete aerobically, while a boxer's performance is dependent on both high aerobic and anaerobic power. In order to understand this phenomenon clearly, the studies that specifically analyzed the cardiovascular and metabolic responses to martial arts and boxing will be the next topic of this review.

Cardiorespiratory and Metabolic Responses to Martial Arts and Boxing

Karate is the most studied martial art in the literature. Studies by Funakoshi; Iiyama; Zehr and Sale (as cited in Imamura et al., 1998) showed that karate training improves general physical fitness and/or cardiovascular fitness. On the other hand, there are studies that showed that karate training does not improve cardiorespiratory fitness and/or body composition (Imamura et al., 1999, 2002; Shaw & Deutsch, 1982). While karate skills (basics, kata, sparring) may be performed with both contact and noncontact styles, generally only the noncontact form of taekwondo and boxing are practiced. Consequently, the physiological responses might vary depending on whether the activity is contact in nature. In this section, martial arts and boxing studies that reported a potential to improve cardiorespiratory fitness and/or body composition, and those that reported intensities that did not elicit a cardiorespiratory training effect are reviewed. The possible causes of the disparities between studies and the need for future research are also discussed.

Performances that elicited fitness improvements. Stricevic et al. (1980) analyzed the heart rate (HR) responses to typical karate-interval training in 50 experienced, male karate athletes and showed that heian 1 kata performed as interval training produced exercise heart rates that were greater than 80% of the age-predicted HR_{max}. Thus, this form of karate training has the potential to improve cardiovascular fitness with frequent training sessions.

Imamura et al. (1997) compared the HR and blood lactate responses of 6 male, highly skilled, black belt practitioners with 8 male, novice, white belt practitioners during the performance of 1000 punches and 1000 kicks. Heart rates ranged between 53-58% of HR_{max} during 1000 punches and 66-70% of HR_{max} during 1000 kicks. Although the heart rate responses during 1000 punches were significantly lower than those during 1000 kicks, these responses were still moderate in intensity. There were no significant differences in blood lactate, HR, and $\%HR_{max}$ between experienced and novice practitioners. Although the intensity was sufficient to elicit cardiovascular training effects, the results were lower than found by Sugiyama et al. (as cited in Imamura et al., 1997) for 12 male karate players who practiced various punching and kicking techniques for 3 min. The authors stated that the disparities in findings might reflect differences in karate experience, fitness level, skill level, and rate of punching or kicking. The same protocol of 1000 punches and kicks was used in a different study on 6 female black belt practitioners (Imamura et al., 2003). The VO_2, HR, and blood lactate responses during the punches and kicks were found to be moderate. The mean $\%HR_{max}$ and $\%VO_{2max}$ were 57% and 17% for 1000 punches, and 83% and 41% for 1000 kicks, respectively. While the $\%HR_{max}$ response in females was comparable to that of males during 1000 punches, it was higher (83%) in women for 1000 kicks. This might be explained by the smaller muscle mass of women and lower VO_{2max} values.

Bellinger et al. (1997) studied contact boxing using a punching bag, focus pads, and gloves in 8 relatively experienced males. They quantified the energy expenditure of a 1 hr boxing session and compared the results with the energy expenditure of a more traditional recreational activity such as running. They found that the energy expended during the boxing session was equivalent to running at 9.2 km/hr on a treadmill (approximately 11 METS).

Cardiorespiratory responses of two basic taekwondo forms and two series of combinations were compared by Pieter et al. (1990). Beginner forms (one with only arm techniques and one with both arm and leg techniques) and technique combinations (one with only kicks and one with kicks and punches) were compared to determine which would elicit higher exercise heart rates. Exercise HR for combinations was higher than for forms. The authors concluded that taekwondo, and especially kicking exercises with or without punches, has the potential to contribute to cardiorespiratory fitness. They suggested future research should investigate more complex forms, the effect of using more arm techniques, modifying rest and work intervals, and using participants with different levels of experience.

Toskovic et al. (2002) studied both male and female taekwondo practitioners with different experience levels to determine whether a single bout of dynamic taekwondo exercise favorably affected the cardiovascular system by initiating adaptations sufficient for improving and maintaining cardiovascular fitness. They also examined whether dynamic taekwondo exercise elicited sufficient energy expenditure for promoting total body mass and fat loss. The mean intensity ranged from 68 to 72% of VO_{2max} and 88 to 92% of HR_{max}. Heart rates elicited during dynamic taekwondo exercise were high for a given percentage of VO_{2max}. This suggested that using heart rate as an intensity measure for taekwondo may result in overestimation of exercise intensity. The energy expenditure was found to be lower in females because they have a smaller body mass compared to males. The data demonstrated that dynamic taekwondo may require substantially higher energy expenditure compared to other modes of exercise such as karate, tennis, and aerobic dance. The energy expenditure during dynamic taekwondo was found to be comparable to that of judo, boxing, and running at 11.3 km/h (7 mph). "High energy expenditure with this form of exercise may be the reflection of the large amount of muscle mass used during exercise, superimposition of a strenuous arm exercise on leg exercise, continuous high-intensity performance, and the nature of the taekwondo movements by themselves or combined with dynamic exercise" (Toskovic et al., p. 284). The authors concluded that practicing taekwondo could elicit intensities sufficient to meet ACSM recommendations for improving aerobic fitness and promoting total body mass and fat weight loss. They suggested that extensive taekwondo skill was not necessary to induce beneficial cardiovascular adaptations.

When karate practice was performed as interval training, Stricevic et al. (1980) showed heart rates that were greater than 80% of the age-predicted $HR_{max,}$ indicating a potential to improve cardiovascular fitness with frequent training sessions. In addition to HR responses, $\%VO_{2max}$ values during a karate practice were also found to be effective in improving cardiorespiratory fitness (Imamura et al., 1997). A 1 hr boxing training session burned calories that were equivalent to running at 9.2 km/hr (Bellinger et al., 1997). Heart rate responses during taekwondo training consisting of kicking exercises with or without punches demonstrated a potential to contribute to cardiorespiratory fitness (Pieter et al., 1990). When VO_2 responses were also analyzed to identify any cardiorespiratory training effect during a taekwondo practice, Toskovic et al. (2002)

pointed out that $\%VO_{2max}$ is a better indicator of exercise intensity than $\%HR_{max}$ because arm movements and isometric muscle contractions during dynamic taekwondo exercise result in heart rates that are high for a given percentage of VO_{2max}. In summary, karate and taekwondo training programs may elicit cardiovascular training effects, and 1hr of boxing training requires a caloric expenditure equivalent to running 9 km/hr.

Performances that did not elicit fitness improvements. Shaw and Deutsch (1982) investigated the VO_2 and HR relationship in 9 male and 1 female experienced karate practitioners during intermittent and continuous karate kata. They found that the performance of kata was not of sufficient intensity to elicit target heart rates except when kata was performed 15 times continuously in 30 sec, which resulted in at least 50% of VO_{2max}. They also found a higher HR response for a given percentage of VO_{2max} than would be expected for aerobic activity. This suggests that upper body movements, such as punches and blocks, during kata are the cause of the elevation of exercise HR due to isometric muscular contractions. Therefore, it was concluded that use of HR to assess the exercise intensity in activities that include arm movements and isometric contractions might result in overestimation of the intensity.

The same research design was used in two separate studies to analyze HR, VO_2, blood lactate, energy expenditure, and postexercise oxygen consumption responses before, during, and after karate training. One of the two studies was conducted on 7 males (Imamura et al., 1999) and the other was conducted on 6 female black belt karate practitioners (Imamura et al., 2002) in order to determine whether each exercise and an entire karate training session could elicit cardiorespiratory and body composition improvements. Four types of contact and noncontact karate skills were analyzed. In males, $\%VO_{2max}$ and $\%HR_{max}$ values for basic techniques without movements were found to be below the accepted threshold. Percent VO_{2max} and $\%HR_{max}$ were above the threshold for basic techniques with movements, and sparring techniques with or without an opponent. For the entire 70 min practice, the mean value for $\%VO_{2max}$ was 47%, indicating an intensity at the lower end of the range recommended by ACSM, and the mean value for $\%HR_{max}$ was 73%, indicating intensities slightly above the threshold. In females, neither of the techniques nor the entire training session created training intensities that were above the threshold for improving cardiorespiratory fitness. The intensities ranged from 17 to 45% of the oxygen uptake reserve, which represented very light to moderate work. Energy expenditure was found to be well above the threshold for total body mass and fat weight loss in both males and females, although values for women were approximately half those of men. Because women had less muscle mass and experience than men, they had lower $\%VO_{2max}$ and energy expenditure values. There was no evidence of prolonged elevation of postexercise oxygen consumption in either gender. Hence, the disparities between studies and between genders were believed to be caused by differences in cardiorespiratory fitness levels, karate experience, skill levels, levels of kata studied, and amount of muscle mass.

Shaw and Deutsch (1982) demonstrated that pace is an important element in determining the training effect of a karate kata practice. If the practice is performed at a relatively fast pace, it may elicit a cardiorespiratory training effect. The addition of movements in the karate practice was found to increase the $\%VO_{2max}$ (Imamura et al., 1999, 2002). Although the overall VO_2 response was not sufficient to generate a cardiorespiratory training effect, adding movements to the practice increased the intensity of the exercise. The fact that the intensity was below the level recommended for eliciting a cardiorespiratory training effect may be attributed to differences in fitness level, karate experience, skill level, studied kata, amount of muscle mass involved, extent of arm movement, and rate of punching or kicking among studies.

Cardiorespiratory and Metabolic Responses to Cardio Kickboxing

Kravitz et al. (2003) measured metabolic responses of men and women during a fitness boxing routine that is typically utilized during a contact kickboxing class. The routine was a combination of contact kicks and punches using different boxing tempos. Participants varied in training status. The average intensity during the routine ranged from 68 to 72% of VO_{2max}. Kravitz et al. stated that contact fitness boxing could elicit a satisfactory VO_2 response for improving cardiovascular endurance. Faster tempos were not found to be as important for improved cardiovascular training.

Immel (1999) studied 15 healthy females (age range 21-46 years) with different cardio kickboxing experience. Ventilatory and metabolic responses to a 35-40 min hybrid cardio kickboxing class involving both contact and noncontact movements were recorded. The mean $\%VO_{2max}$ response to the total kickboxing session was 70%, which is above the threshold recommended by ACSM (1998). The mean HR_{max} response was 86%. It was concluded that cardio kickboxing is an effective mode of aerobic exercise for increasing cardiorespiratory endurance and positively altering body composition.

It seems that contact fitness boxing programs and those that are hybrid, involving both contact and noncontact movements, meet the criteria established by ACSM (1998) for the intensity of exercise to improve cardiorespiratory fitness. However, the question of whether noncontact cardio kickboxing can provide cardiorespiratory and metabolic benefits has not yet been answered. Some karate, taekwondo, and boxing studies have found benefits, while some karate studies have not. There are several factors that may play a role in determining the cardiorespiratory and metabolic responses. These include the contact or noncontact nature of the kickboxing routine, current fitness level, skill and experience of the individual, pace of the movement, techniques and movements employed in the practice, and whether the movements involve any arm or arm-leg combinations.

Chapter III – Methods

To better understand the physiological responses of women to noncontact cardio kickboxing, cardiovascular and metabolic data were analyzed during a 22 min kickboxing routine. Heart rate, oxygen consumption, and caloric expenditure responses were measured in this descriptive study.

Participants

In order to analyze the cardiovascular and metabolic responses to noncontact kickboxing exercise, a sample group of 18 apparently healthy, young (18-55 years of age) female participants were recruited to participate in this study. Since participants' VO_{2max} values were measured to determine their current aerobic fitness level, only individuals that were categorized as low risk according to ACSM guidelines (2000) were recruited for this study. Low risk is defined as young individuals (women 55 years of age and under) who have fewer than two coronary risk factors (high blood pressure, high blood cholesterol, smoking, diabetes, obesity, sedentary lifestyle, family history of coronary disease), and who do not have signs, symptoms, or known coronary, pulmonary, or metabolic disease.

Participants for the study were recruited from members of the Campus Recreation Program at San Jose State University, members of the Stanford Aerobics and Yoga Program at Stanford University, and the general population. Participants had completed at least 10 sessions of contact or noncontact kickboxing prior to data collection. Fitness instructors, particularly kickboxing instructors, were not accepted because this study analyzed the benefits of noncontact kickboxing for the population taking kickboxing classes, not teaching them. A letter (Appendix A) that briefly explained the study and the procedures was prepared and distributed directly and through e-mail to the potential population for recruitment. A medical history questionnaire (Appendix B) and the Consent Form (Appendix C) were mailed to prospective participants. A stamped envelope for returning the completed forms was also provided to the participants in the mail. A completed medical history questionnaire was requested from prospective participants to evaluate cardiac risk factors and ensure that participants met the ACSM criteria for low risk individuals. Women who did not meet the low risk criteria were not included in the study.

Instrumentation

This study was performed in the Exercise Physiology and Biomechanics Laboratory in the Department of Kinesiology at San Jose State University. Because kickboxing is a weight bearing activity, the treadmill was used for the graded exercise test to determine VO_{2max}. A sphygmomanometer and blood pressure cuff were used to measure blood pressure during the VO_{2max} test. During both the VO_{2max} test and the submaximal kickboxing routine, cardiopulmonary parameters (ventilation, VO_2, VCO_2, and respiratory exchange ratio [RER]) were continuously measured using standard open circuit spirometry with a Medgraphics CPX/D metabolic cart. A pneumotach attached to a face mask was used to measure ventilatory volumes and sample expired gases. The Borg RPE scale (a scale of 6-20) was used to measure ratings of perceived exertion (RPE). During the submaximal kickboxing performance, HR was monitored using a Polar heart rate monitor. During the VO_{2max} test, HR and rhythm were monitored using a

12-lead electrocardiogram (ECG). A digital video camera (Canon ZR-60) and tripod (SLIK) were used to record the kickboxing routine performed by the fitness instructor for participants' reference during the experiment. A video cassette recorder and television monitor were used to view the videotape during the submaximal kickboxing routine. A stadiometer and a calibrated, beam-type scale were used to measure height and weight, respectively. Skinfold analysis was performed using a C-130 Lange skinfold caliper. Chest press and leg press machines (Body Dynamics) were used to measure muscular strength of the upper and lower body, respectively.

The treadmill was calibrated before the data collection began. The metabolic cart was calibrated before each graded exercise test. A 3 L calibration syringe was used to calibrate the flow meter. Oxygen and carbon dioxide analyzers were calibrated using two gas mixtures.

Procedures

The study design was approved by the university's Human Subjects Institutional Review Board (Appendix D). A medical history questionnaire was completed (Appendix B), and participants provided written informed consent (Appendix C). Pretest instructions and directions to the laboratory were e-mailed to the participants once they were scheduled for the graded exercise test (Appendix E).

Guidetti et al. (2002) found that high aerobic power and handgrip strength were contributing factors to boxing performance in competitive boxers. For that reason, current fitness level of the individual was determined by measuring aerobic fitness as well as upper and lower body muscular strength. In addition to upper body strength, lower body strength was also determined because the lower body, along with the upper body, is used extensively in kickboxing. Aerobic fitness was measured by a graded exercise test to determine VO_{2max}, and muscular strength was measured by determining the maximal weight that could be lifted one time (1RM) on the chest press and leg press machines. Because strength was also expressed as a function of fat free mass (FFM), participants' body fat percentage was determined by the skinfold method.

Before the data collection process, the kickboxing routine, performed by a kickboxing certified fitness instructor, was recorded on videotape.   This routine was performed by the participants during the submaximal testing. The participants viewed this videotape during the kickboxing performance to ensure that the exercises were performed in the correct order. No corrections were made to punching and kicking styles during the submaximal kickboxing testing.

There were three visits to the exercise physiology laboratory. Each visit took place on a different day, and there was at least one day between each visit. Prior to the first day of testing, participants completed a medical history questionnaire (Appendix B) and provided written consent (Appendix C).

Day 1 – Max VO_2 test and skinfold measurement. On the first day, anthropometric measurements consisting of height, weight, and skinfolds were determined using a stadiometer, beam-type platform scale, and a Lange caliper, respectively. Body fat percentage was calculated using the relevant formula (Heyward, 2002). The sites for skinfold measurement were determined by the population-specific formula used for the individual.

VO_{2max} and actual HR_{max} ($HR_{max\text{-}actual}$) were determined with a continuous, incremental test of volitional fatigue using a standardized treadmill protocol. The individual walked or jogged on a treadmill while the speed and/or slope were slowly increased. The protocol (Appendix F) was designed so that the test lasted approximately 8-12 minutes, not including warm-up and cool-down. After the electrodes were placed on the chest, resting values of heart rate and blood pressure were obtained. Participants wore a face mask to breathe room air through a pneumotach so that ventilatory volume could be measured. During the test, heart rate was monitored continuously using an electrocardiograph, and blood pressure was measured every 2-3 min starting with the first minute after the warm-up. Blood pressure and heart rate were monitored periodically during the cool-down until they approached resting values.

Day 2- 1-RM test and videotape orientation. On their second visit, participants were tested for upper and lower body strength (1RM) on the chest press and leg press. They performed a light warm-up of 5 repetitions at 40 to 60% of their perceived maximum. Following a 1-min rest with light stretching, they completed 3 to 5 repetitions at 60% to 80% of perceived maximum. A small amount of weight was added and a 1RM lift was attempted. If the lift was successful, the participants rested for 3 min, then attempted another try by increasing the weight. This process continued until a failed attempt occurred. The 1RM was reported as the weight of the last successfully completed lift (ACSM, 2000). Participants cooled down doing static stretches that were held for 10-15 sec.

After the 1RM test on the second day, a brief orientation session was carried out using a handout that explained the 5 min warm-up (Appendix G) and the 22 min kickboxing routine (Appendix H) to be performed during the submaximal test on the third day. The handout was given to the participants for reference at the end of the orientation. A copy of the videotaped routine was offered to participants if they wanted to practice at home before Day 3.

Day 3 – Submaximal kickboxing test. On the third day, the cardiovascular and metabolic responses to the 22 min kickboxing routine were recorded. Body weight was measured using a platform scale, and a Polar heart rate monitor was placed around the participant's chest to monitor heart rate. Resting heart rate (HR_{rest}) was obtained. Initially, participants completed a prescribed warm-up for 5 min that included light punches, kicks, and stretches (Appendix G). After the warm-up, they wore a face mask for ventilatory volume measurements and performed the 22 min kickboxing routine (Appendix H) by viewing the prerecorded videotape. A trained evaluator observed each workout, but did not make any corrections to ensure the real life situation could be simulated as much as possible. The metabolic cart was calibrated before each test and used to measure VO_2, VCO_2, RER, METS, ventilation, and caloric expenditure (kcal/min). Breath-by-breath gas sampling was averaged over 30 seconds. Heart rates were obtained and recorded from the Polar HR monitor every 2 min. Ratings of perceived exertion were also collected at 2 min intervals. Participants cooled down doing static stretches that were held 10-15 sec.

Research Design and Data Analysis

The primary focus of this study was to evaluate cardiovascular and metabolic responses to a 22 min kickboxing routine. The intensity elicited during this performance was quantified with the following variables: $\%VO_2R$, %HRR, kcal/min, and RPE. Oxygen uptake reserve (VO_2R) was calculated by subtracting resting VO_2 (3.5 ml O_2/kg/min) from maximum VO_2 (ACSM, 2000). In order to calculate $\%VO_2R$, the following formula was used:

$$\%VO_2R = \frac{VO_2 - VO_{2rest}}{VO_2R}$$

The same method was used to calculate HRR and %HRR, using $HR_{max\text{-}actual}$ and HR_{rest} data that were gathered during Day 1 of testing. Descriptive statistics (means and standard deviations) were determined for those variables.

For the purpose of further investigation, the 22 min kickboxing routine was divided into segments based on the body part that was used for each minute of exercise. The “arms only” segment was classified as the total minutes in which arms were only used. The “legs only” segment refers to the total minutes in which only legs were used. The “arms+legs” segment of the workout refers to the total minutes in which both arms and legs were actively used. The intensity data were arranged according to the exercise segment classifications. Hence, there are %VO_2R, %HRR, kcal/min, and RPE data for these exercise segments as well as average values for the 22 min routine.

Aerobic and muscular fitness were measured to investigate whether there was a relationship between current fitness level and the intensity elicited during the submaximal noncontact kickboxing performance. This was to test the secondary hypothesis of the study. Aerobic fitness was measured by a graded exercise test to determine VO_{2max}. To compare participants of different ages, percentile values for VO_{2max} were assigned based on normative data from the Institute for Aerobics Research, Dallas, TX (as cited in ACSM, 1995).

Muscular strength was measured by determining 1RM on the chest press and leg press machines. Since strength is related to muscle mass, lean body mass, determined by skinfold measurements, was used to express strength relative to LBM.

Chapter IV – Results

The purpose of this study was to investigate whether noncontact cardio kickboxing is effective in eliciting intensities that are recommended by ACSM (1998) to improve cardiovascular fitness and produce effective caloric expenditure for weight loss and fat reduction in women. It was hypothesized that noncontact cardio kickboxing would require an intensity sufficient to improve cardiorespiratory fitness and promote weight loss over time. It was also hypothesized that current fitness level (both cardiorespiratory and muscular strength) would affect an individual's ability to exercise at an intensity recommended by ACSM to improve cardiovascular fitness. This was the secondary focus of the study.

The cardiovascular and metabolic responses to a 22 min noncontact kickboxing routine were measured in 18 healthy women. Data were analyzed using the Sigma Stat statistical program.

Table 1 shows the participants' descriptive characteristics. Means and standard deviations for %VO_2R, %HRR, kcal/min, and RPE are depicted in Figures 1, 2, 3, and 4, respectively. For this study's population of young, fit women, 50% was considered to be the low end of the %VO_2R or %HRR recommendation to improve and maintain cardiovascular fitness (ACSM, 1998). This value is represented on the three graphs in Figures 1 and 2 with a dashed line to compare the actual values of %VO_2R with the recommendation.

Table 1

Descriptive Statistics

Variable	Mean ± SD	Range
Age	29 ± 7	19 – 40
Height (cm)	166 ± 7	154 – 181
Weight (kg)	63.3 ± 9.5	49.1 – 76.8
% Body fat	23.7 ± 5.9	15.0 – 35.7
% Body fat percentile[a]	46 ± 28	5 – 90
Chest press percentile[a]	73 ± 19	30 – 90
Leg press percentile[a]	98 ± 4	85 – 99
Average strength percentile[a]	85 ± 10	65 – 99
VO_{2max} (ml/kg/min)	40.5 ± 5.0	32.1 – 52.1
VO_{2max} percentile[a]	77 ± 16	45 – 99
Actual HR_{max}	183 ± 10	163 – 200

[a]Percentile values are based on the normative data from the Institute for Aerobics Research, Dallas, TX (as cited in ACSM, 1995).

The mean and standard deviation of %VO_2R for the 22 min submaximal kickboxing routine was 49 $\pm$ 10%. Heart rate reserve was 63 $\pm$ 15% during the 22 min routine. The 22 min kickboxing routine produced a mean caloric expenditure of 6.8 $\pm$ 1.8 kcal/min. Participants' perceived level of exertion (RPE) was 12 $\pm$ 1 for the 22 min workout.

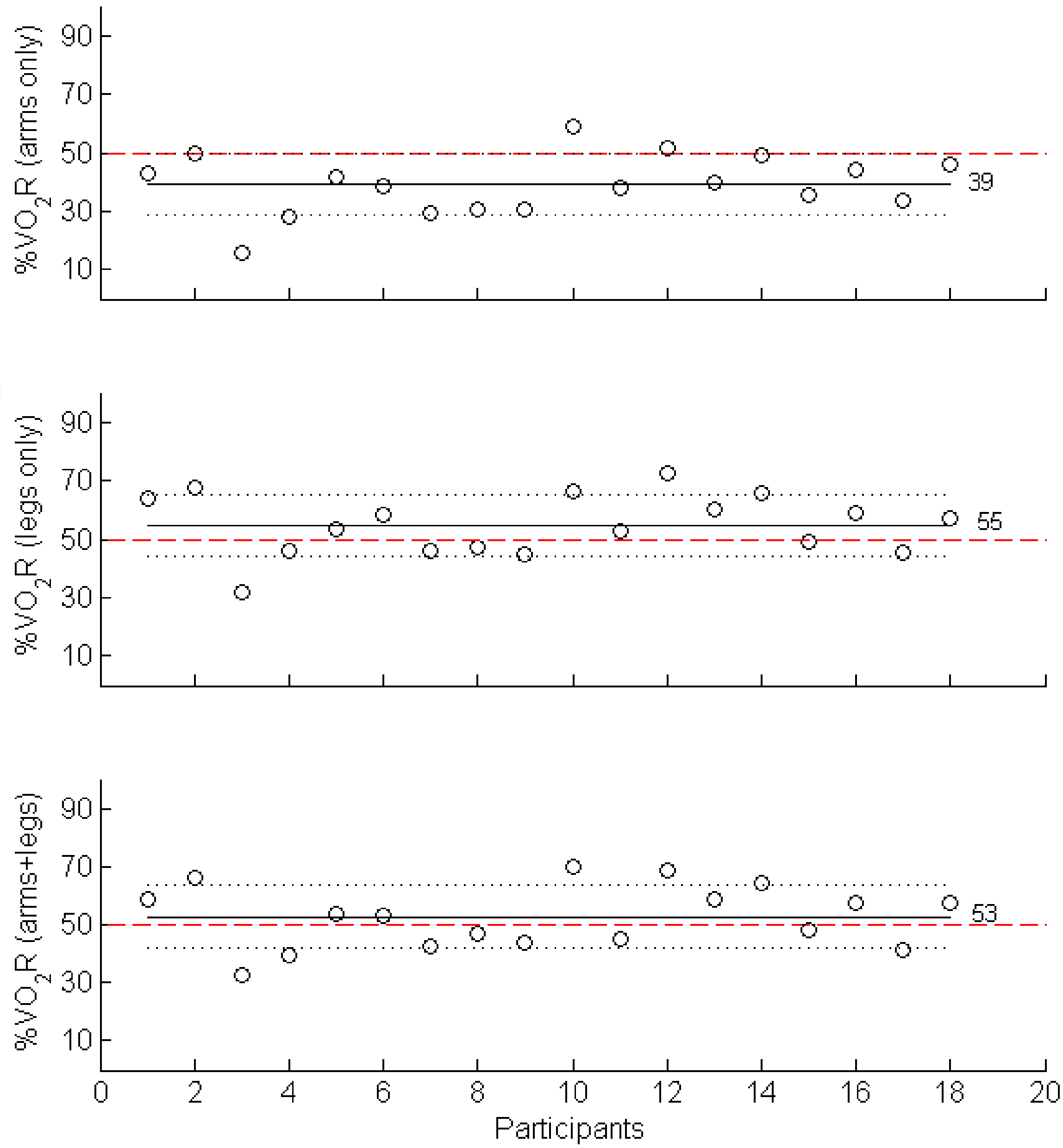

Figure 1. Percent oxygen uptake reserve (%VO_2R) during exercise segments. ○: individual responses; solid line (____): mean; dotted line (……): ± standard deviation; dashed line (------): Low end of the ACSM recommendation for a young, healthy population (50%).

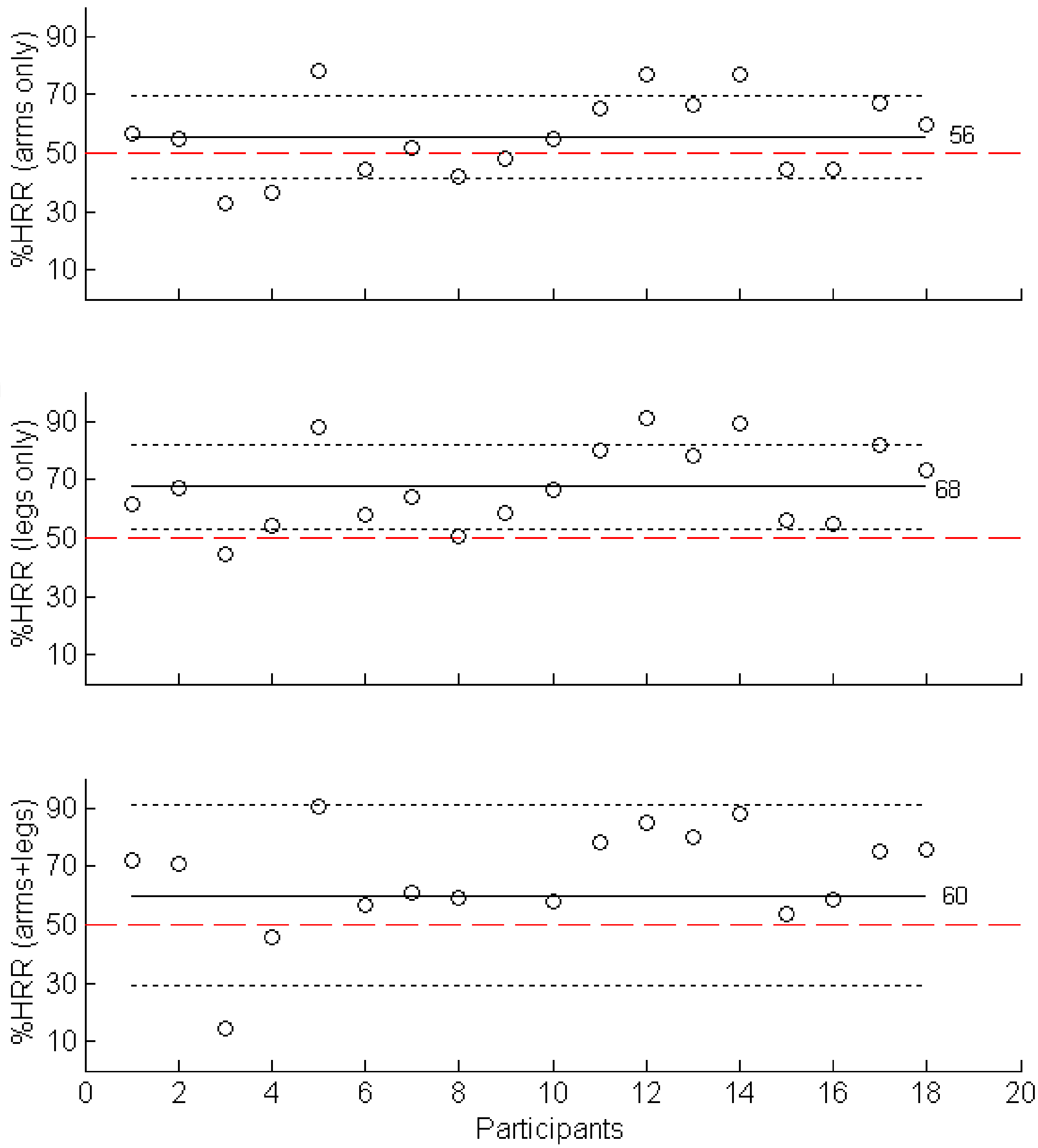

Figure 2. Percent heart rate reserve (%HRR) during exercise segments. ○: individual responses; solid line (____): mean; dotted line (……): ± standard deviation; dashed line (------): Low end of the ACSM recommendation for a young, healthy population (50%).

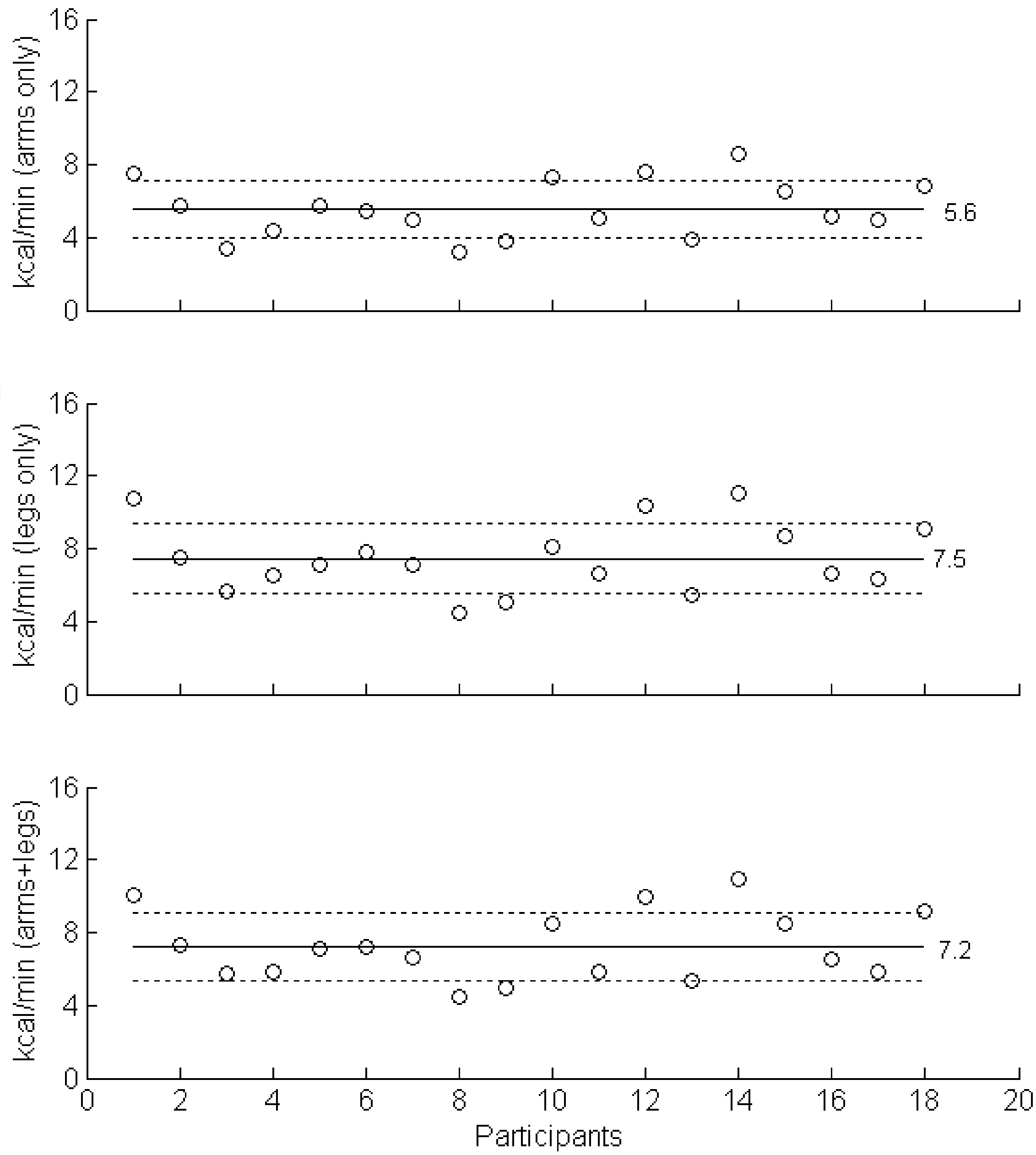

Figure 3. Kilocalories consumed per minute (kcal/min) during exercise segments. ○: individual responses; solid line (____): mean; dotted line (……): ± standard deviation.

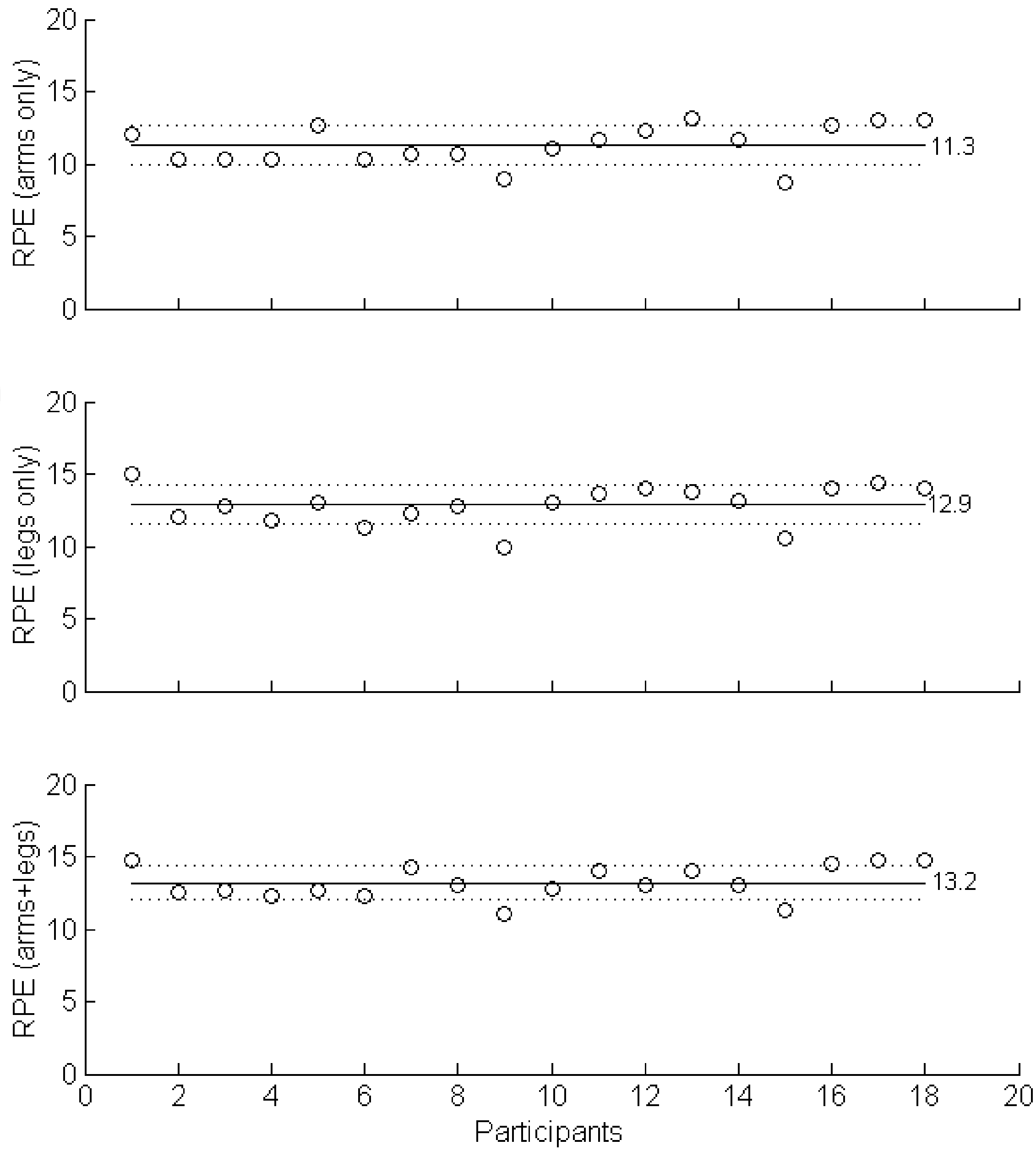

Figure 4. Ratings of perceived exertion (RPE) during exercise segments. ○: individual responses; solid line (____): mean; dotted line (……): ± standard deviation.

To investigate whether current fitness status affects exercise intensity during a noncontact kickboxing performance, a Pearson product-moment correlation coefficient was calculated. There was no significant relationship between upper body strength, expressed relative to LBM, and the arms only %VO_{2max} ($r(16) = -.17$, $p > .05$). There was no significant relationship between lower body strength, expressed relative to LBM, and the legs only %VO_{2max} ($r(16) = -.13$, $p > .05$). The relationship between average strength (upper and lower body percentiles) and average %VO_{2max} was not significant ($r(16) = -.03$, $p > .05$). The relationship between aerobic fitness (VO_{2max}) and average %VO_{2max} was not significant ($r(16) = -.3$, $p > .05$).

To further examine the relationship between strength and exercise intensity, participants were divided into 3 groups based on their current fitness level (Group 1: lowest fitness level, Group 2: moderate fitness level, Group 3: highest fitness level). The one-way ANOVA test conducted between the upper body strength, expressed relative to LBM, and the arms only %VO_{2max} revealed no significant difference in the mean values among the groups ($p > .05$). There was no significant difference in the mean values among the groups that were based on upper body strength when the one-way ANOVA test was conducted for the average %VO_{2max} ($p > .05$). The one-way ANOVA between aerobic fitness, expressed as VO_{2max}, and the intensity during the 22 min workout, expressed as average %VO_{2max}, did not reveal any significance difference in the mean values among the groups ($p > .05$). There was no statistically significant difference among the groups that were formed based on aerobic fitness, expressed as VO_{2max}

percentile, when the one-way ANOVA tested for the intensity during the 22 min workout, expressed as average $\%VO_{2max}$ ($p > .05$).

Percent HRR responses of the 18 participants plotted against the $\%VO_2R$ responses during 22 min noncontact kickboxing routine are shown in Figure 5. At the same $\%VO_2R$, noncontact kickboxing produced higher heart rates than running on a treadmill (Swain, Leutholtz, King, Haas, & Branch, 1998).

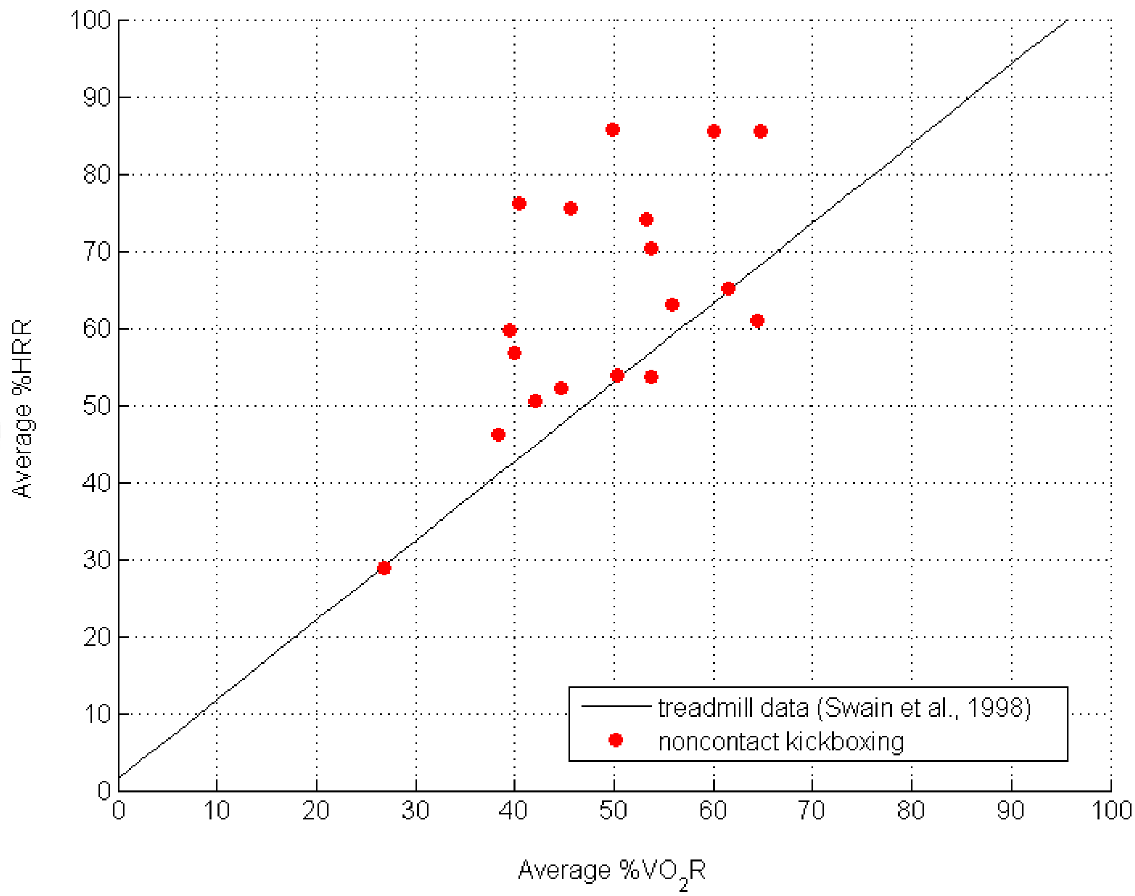

Figure 5. Relationship between %HRR and %VO_2R during noncontact kickboxing and a treadmill run. Noncontact kickboxing produced higher heart rates for the same intensity, expressed as %VO_2R, when compared to the treadmill run data.

Chapter V – Discussion and Conclusions

Summary and Discussion

The major purpose of this study was to investigate whether noncontact kickboxing is a physical activity that could elicit intensities recommended by ACSM (1998) to develop and maintain cardiovascular fitness and promote fat loss in women. The study analyzed cardiovascular and metabolic responses to a 22 min noncontact kickboxing workout. Participants included 18 young, healthy women.

The ACSM guidelines (1998) recommend exercising at an intensity that is 40/50-85% of oxygen uptake reserve (VO_2R) or heart rate reserve (HRR) to develop and maintain cardiorespiratory fitness. Although the recommended levels for VO_2R and HRR are equivalent, studies have shown that in martial arts-based noncontact activities, %HRR for a given $\%VO_2R$ is higher than reported for treadmill running (Swain et al., 1998). This response, also observed in this study (Figure 5), has been explained by the static nature of arm movements involved in blocks and punches, and the arm movements themselves (Shaw & Deutsch, 1982). Because %HRR response overestimates the exercise intensity, only $\%VO_2R$ was used to measure the exercise intensity of the 22 min submaximal noncontact kickboxing routine.

The minimal threshold for improving fitness and health is affected by the individual's fitness level, and is quite variable at the lower end of the intensity range (ACSM, 1998). Older people and persons with low fitness levels can achieve significant gains with a training stimulus as low as 40-50% of VO_2R or HRR (ACSM, 1998). Since the population of the present study was mainly young, fit individuals (mean ± SD VO_{2max}

percentile was 77 ± 16, see Table 1), the minimal threshold was kept at 50% of VO_2R for data analysis purposes.

The mean $\%VO_2R$ response for the 22 min kickboxing workout was 49 + 10%, which is the low end of the ACSM recommendation. When the 22 min workout was divided into segments based on the body part used, and $\%VO_2R$ responses were analyzed, the legs only (55 ± 11%,) and arms+legs (53 ± 11%) segments met the ACSM minimal intensity requirement, while the arms only segment did not (39 ± 10%). Although the minimal threshold (50% of VO_2R) was achieved for particular exercise segments, the exercise intensity range was still low for individuals with a current aerobic fitness level that is above average (77^{th} percentile). This may be a result of the testing environment. To measure oxygen consumption, participants wore a face mask with wires connected to a metabolic cart. The majority of the participants reported that they felt restricted and limited in their movements. They anticipated that they would have worked harder if the real life situation could be created during testing. Therefore, it is concluded that when cardio kickboxing workouts are performed in a real life, group exercise setting, participants can work at higher intensities sufficient to improve aerobic fitness for relatively fit individuals.

For total body mass and fat loss, ACSM (1998) recommends an energy expenditure of 250-300 kcal per exercise session when programs are conducted 3 days a week. It is also suggested that 200 kcal per session promotes weight reduction if the exercise frequency is at least 4 days a week. The mean caloric expenditure during the kickboxing performance was 6.8 ± 1.8 kcal/min. If noncontact kickboxing is performed approximately 30 min per session, and at least 4 times a week, sufficient calories would be expended, which could lead to successful fat loss in women. In a typical group exercise setting, the cardiovascular segment of a class lasts approximately 45 min. This would produce a caloric consumption of 300 kcal per exercise session. Therefore, participating in a noncontact cardio kickboxing class 3 times a week should be sufficient to promote weight and fat loss. The caloric expenditure response to the legs only and arms+legs exercise segments (7.5 $\pm$ 1.9 and 7.2 $\pm$ 1.9 kcal/min, respectively) were higher than the average caloric expenditure during the entire 22 min workout. Hence, a 45 min noncontact kickboxing workout that is mainly based on leg movements would expend 325-335 kcal per session.

Participants perceived the total workout, legs only, and arms+legs segments as somewhat hard (RPE = 12.6 $\pm$ 1.2, 12.9 $\pm$ 1.4, and 13.2 $\pm$ 1.1, respectively). The higher RPE for the arms+legs segment, despite the lower exercise intensity compared to the legs only segment, may result from the perception that the exercise is harder when the choreography is more complicated with the whole body moving.

The findings from the one-way ANOVA revealed that aerobic and muscular fitness have no effect on the exercise intensity elicited during noncontact kickboxing in women. The Pearson product-moment correlation coefficient was not significant to conclude that aerobic fitness and muscular strength affect exercise intensity.

Recommendations for Future Research

Several participants stated that it would have been easier to move, and they would have worked harder, if they were not wearing a face mask with attached wires. They thought the setting limited their range of motion and ability to work at higher intensities.

It seemed that the laboratory environment altered the participants' level of exertion from reality due to the difficulty in movement when the face mask they wore was connected to the metabolic cart, and when they were alone in the laboratory doing the 22 min kickboxing routine. It would likely be more effective to collect the data in a real life setting (i.e., in a group fitness class) rather than in a laboratory environment if the necessary equipment (portable metabolic analyzer) is readily available for future research on this topic.

Conclusion

Martial arts-based group exercise classes, particularly noncontact cardio kickboxing, have been a popular mode of cardiorespiratory training. Results from this study indicate that this mode of exercise may elicit intensities sufficient to develop and maintain aerobic fitness and promote weight loss in women over time. The failure of %VO_2R to meet the minimal intensity threshold during arms only movements suggests that a kickboxing exercise session that involves leg exercise routines that are combined with some arm movements will require an intensity that is sufficient to improve aerobic fitness. This regimen will also guarantee adequate caloric expenditure (325-335 kcal/session) for fat loss over time when performed at least 3 days a week. Although the exercise segments that utilized exclusively arms in this study could not elicit sufficient intensities to develop and maintain cardiorespiratory benefits, such movements should not be totally excluded from the choreography. Punching is an essential part of kickboxing, and it is important to practice punches to perfection in order to learn the correct technique. Performing the moves, punches and kicks, correctly is vital for generating a sufficient stimulus to gain exercise adaptations. Thus, workouts that are mainly based on lower body movements that are combined with arm movements should also utilize only arm movements (i.e., single punches) to maximize fitness benefits that can be attained through cardio kickboxing programs.

It is recommended that the exercise prescription be based on %VO_2R rather than %HRR for noncontact cardio kickboxing programs. A kickboxing training program that is based on %HRR values could overestimate the exercise intensity, causing the participant to work less and not see the expected results over time. On the other hand, prescribing exercise based on VO_2R requires measuring VO_{2max} with an exercise test to volitional fatigue, or estimating VO_{2max} from a submaximal test. This may be impractical in a group exercise class. Participants' RPE, however, can be a useful tool to monitor intensity during a kickboxing workout. Participants perceived the exercise intensity as somewhat hard in this study. Therefore, maintaining an intensity that is perceived as somewhat hard should provide an effective cardio kickboxing workout. Another option would be using a higher %HRR when prescribing kickboxing exercises and monitoring intensity during those workouts. As shown in Figure 5, heart rate responses (%HRR) to a cardio kickboxing workout are higher than those for a typical aerobic workout (treadmill running) for a given intensity (%VO_2R). The heart rate reserve is quantitatively compatible with VO_2R during treadmill running. Findings of this study, however, indicate that, on average, %HRR during cardio kickboxing is 13% greater than $\%VO_2R$. Hence, adding approximately 10% to the target %HRR would be a relatively easy method for prescribing exercise and monitoring intensity during cardio kickboxing workouts.

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Appendix A

Participant Recruitment Letter

Participant Recruitment Letter

We are looking for active women for a research study that is being performed in the Department of Human Performance at San Jose State University. Participants will need to come to San Jose State University on three days – the first day will be a max VO_2 test (a measure of your cardiorespiratory fitness) and body fat analysis (skinfold measurements). The second day will be one repetition maximum tests (chest press and leg press) to measure your muscle strength. We will also perform a brief videotape orientation session to be prepared for the third day. The third day will be a 20 min sub-maximal kickboxing test (predetermined routine will be performed watching a videotape). Each test will take about 1 hour, including warm-up and cool down. Although these tests otherwise cost over $200, by participating in the study, you will receive the results at no charge.

The requirements to participate in this study are:

1. Being a physically active young woman (18-55 years old)
2. Moderate experience in kickboxing (participated in at least 10 sessions of contact or noncontact kickboxing)
3. Participation is limited to low risk individuals, as defined by the American College of Sports Medicine. We cannot include individuals who are classified as moderate or high risk. Individuals with moderate risk have two or more coronary risk factors (high blood pressure, high blood cholesterol, smoking, diabetes, obesity, sedentary lifestyle, family history of coronary disease) or have signs/symptoms of coronary, pulmonary, or metabolic disease. High risk individuals have known coronary, metabolic, or pulmonary disease.

If you meet the selection criteria indicated above and are interested in participating, please contact me from my phone numbers or my e-mail address. I will send you a medical history questionnaire along with an informed consent. After you return these documents back, I will contact you and we will set up an appointment for the testing depending on whether you meet the selection criteria. If you have questions about the study and procedures, I will be happy to provide additional information and answer all your questions.

Thanks,

Alev Tug Ergun
Graduate Student
San Jose State University
Human Performance Department
Exercise Physiology and Biomechanics Laboratory
alev@piezo.stanford.edu
Phone: 650-965-4665

Appendix B

Medical History Questionnaire

Appendix C

Consent Form

Appendix D

Human Subjects Institutional Review Board Approval Letter

Appendix E

Pretest Instructions for the Graded Exercise Test

(P. Plato, personal communication, 2001)

Sport and Fitness Evaluations

(408) 924-3032 (phone)
(408) 924-3053 (fax)

Department of Human Performance
San José State University

Evaluation: Graded Exercise Test (max VO_2)

Date: **Time**: (procedure will take about 1 hour)
Place: Spartan Complex, Room 208 (exercise physiology laboratory)

Directions to San Jose State University:

- From 280, take the 7th St. exit. Go north on 7th St. The 7th St. garage is located on the corner of San Salvador & 7th St. — the entrance is on 7th St. just before you reach barricades closing the street to through traffic. A campus map is available on the university web site: www.sjsu.edu

Parking:

- The 7th St. garage is closest to Spartan Complex. In the 7th St. garage, parking permits may be purchased for $6.00. Machines where permits may be purchased are located on floors 2, 3, 4, and 5. Exact change is required (bills or coins). The main entrance to Spartan Complex has "Physical Education and Recreation" over the glass doors. After entering through the glass doors, turn left and go up the stairs at the end of the hall.
- Metered parking is available on streets surrounding the university.

Pre-Test Instructions:

- Wear exercise clothing and shoes (no leotard tops).
- Avoid eating, smoking, and drinking carbonated or caffeine-containing beverages for 3-4 hours prior to your appointment. You may eat breakfast and lunch, but keep in mind that you will be exercising to exhaustion, so avoid a large, heavy meal within a few hours of your appointment.
- Avoid unusual or exhaustive exercise on the day of your appointment.
- Be well rested and hydrated (lots of water).
- Graded exercise tests are conducted on a treadmill or bicycle ergometer. If you will be using the bicycle ergometer and would like to use your own pedals, please bring them and any specialized tools you might need to change pedals.

We look forward to seeing you!

Appendix F

Standardized Protocol for the Treadmill Graded Exercise Test

Standardized Protocol for the Treadmill Graded Exercise Test

Noncontact cardio kickboxing is a weight bearing physical activity. In addition to basic punches and kicks, this activity includes high impact traditional aerobic moves such as jumping, bouncing, and running. Hence, a graded exercise test (GXT) that is performed on a treadmill will reflect an individual's aerobic fitness that is pertinent to kickboxing.

The standardized protocol for the treadmill GXT will be selected so the test lasts approximately 8-12 minutes, not including warm-up and cool-down (ACSM, 2000). The individual will walk and jog during the test to better reflect both low and high impact aspects of noncontact cardio kickboxing. The maximum speed will be kept at 6.5 mph as an average cardio kickboxing participant is not accustomed to speed training. ACSM (2000) recommends smaller increments (1 MET per stage or lower) for sedentary or older individuals, and it is stated that the increments can be larger for younger and/or physically active individuals. Therefore, the elevation and speed combination will be adjusted to set the increments in the protocol at 1 MET or slightly greater. The VO_{2max} of an individual who is moderately active should fall in the 50^{th} or greater percentile (ACSM, 2000). The 50^{th} percentile for young women is approximately 30-35 ml O_2/kg/min. In the protocol, these values will be reached after approximately 5 to 6 min. This protocol will accommodate higher VO_{2max} values (> 50^{th} percentile) that may be obtained from the participants in the study (see Table F1).

Table F1

Standardized Protocol for the Graded Exercise Test

Duration (min)	**Speed (mph)**	**Elevation (% grade)**	**VO_2 (ml O_2/kg/min)**	**METS**	**Notes**
3	3	0	11.5	3.3	Warm-up
2	3	2	14.4	4.1	Test starts here
1	3.5	3	18.0	5.1	
1	4	3	20-27.9*	5.7-8.0*	*: First value if walk, second value if jog at 4 mph
1	4.5	3	30.9	8.8	
1	5	3.5	34.5	9.9	
1	5.75	3.5	39.2	11.2	
1	6	5	42.9	12.3	
1	6.5	5	46.2	13.2	
1	6.5	7	49.4	14.1	
3-5	3	0			Gradual cool-down

Appendix G

Prescribed 5-min Warm-up for the Submaximal Kickboxing Test

Prescribed 5-min Warm-up for the Submaximal Kickboxing Test

Rhythmic Exercises

Double shoulder shrugs (8x)

Double shoulder rolls (8x)

Half neck circles (4x)

Lower back stretch (4x)

Alternating elbow circles (4x)

Alternating arm circles (4x)

Alternating leg curls (16x)

Alternating knee lifts (16x)

Squats (16x)

Stretches

Stretches indicated below will be held for 5-8 seconds.

Shoulder

Triceps

Upper back

Chest

Lats (side of the body)

Quads/Hip flexors

Hams/Buttocks

Calves

Appendix H

Submaximal Kickboxing Test Routine

Submaximal Kickboxing Test Routine

Drills

1. Single jab (16x RIGHT)

   Single jab (16x LEFT)

2. Single cross (16x RIGHT)

   Single cross (16x LEFT)

3. Single uppercut (16x RIGHT)

   Single uppercut (16x LEFT)

4. Single hook (16x RIGHT)

   Single hook (16x LEFT)

5. Elbow strike SIDE ALTERNATING (RIGHT lead) 16x

6.
   a. Knee strike ALTERNATING (RIGHT lead) 16x

      RIGHT KICK with touch back 16x

   b. Knee strike ALTERNATING (LEFT lead) 16x

      LEFT KICK with touch back 16x

7.
   a. SQUAT 16x

      RIGHT side kick with offset 16x

   b. SQUAT 16x

      LEFT side kick with offset 16x

8.

a. TOUCH FW/BW (RIGHT lead) 16x

   LEFT Back Kick with touch FW 16x

b. TOUCH FW/BW (LEFT lead) 16x

   RIGHT Back Kick with touch FW 16x

Combinations

1. ROUTINE #1

JAB-CROSS-JAB-KICK

a.

   i. Jab RIGHT 4x, Cross LEFT 4x (2x)

   ii. Break it down to 2x (4x)

   iii. Break it down to 1x (8x)

b.

   i. Jab RIGHT 4x, Kick RIGHT 4x (2x)

   ii. Break it down to 2x (4x)

   iii. Break it down to 1x (8x)

c. Combine **a** & **b** (8x)

d. Double time **c** (8x)

2. **ROUTINE #2**

Jab-Jab-Jab-Cross

Jumping Jack 2x

Repeat for other lead

a. (4x)

i. MOVE TO RIGHT SIDE: Jab RIGHT 3x - Cross LEFT 1x

MOVE TO LEFT SIDE: Jab LEFT 3x - Cross RIGHT 1x

b. Double time **a** (4x)

c. Jumping jack in place (16x)

d. Combine all (8x) : Jab RIGHT 3x + Cross LEFT 1x

Jumping Jack 2x

Jab LEFT 3x + Cross RIGHT 1x

Jumping Jack 2x

3. **ROUTINE #3**

Grapevine RIGHT + Elbow Strike (2x) LEFT

(Uppercut RIGHT + Hook LEFT) 2x

Repeat for the other lead

a. Grapevine RIGHT + Grapevine LEFT (4x)

b. Grapevine RIGHT + Elbow strike 2x LEFT

   Grapevine LEFT + Elbow strike 2x RIGHT

c. Uppercut RIGHT + Hook LEFT (16x)

   Uppercut LEFT + Hook RIGHT (16x)

d. Combine all (16x) : Grapevine RIGHT + Elbow strike 2x LEFT

   Uppercut RIGHT + Hook LEFT (2x)

   Grapevine LEFT + Elbow strike 2x RIGHT

   Uppercut LEFT + Hook RIGHT (2x)

4. **ROUTINE #4**

RIGHT Front Kick

LEFT Side Kick

RIGHT Front Kick

LEFT Back Kick

a.

i. Front kick 4x RIGHT + Side kick 4x LEFT (2x)

ii. Break it down to 2x (4x)

iii. Break it down to 1x (8x)

b.

i. Front kick 4x RIGHT + Back kick 4x LEFT (2x)

ii. Break it down to 2x (4x)

iii. Break it down to 1x (8x)

c. Combine all (4x): Front kick RIGHT

Side kick LEFT

Front kick RIGHT

Back kick LEFT

d. REPEAT **a + b + c** for LEFT lead

NOTE: When a new routine is introduced, it is first performed alone as a single routine. Then, all the routines from the beginning (Routine #1) are performed sequentially, including the one recently introduced.

Appendix I

Raw Data

Medical and Activity History

Please complete this form to the best of your ability. All information will be kept confidential. Please print and answer questions as accurately and completely as possible.

Name ____

Phone ________________ (work) ________________ (home or cell) e-mail ______________________

Address: ____

Person to contact in case of emergency ____

Relationship to you ___________________________________ Phone _____________________________

Personal physician ___________________________________ Phone _____________________________

Age: ______________ Date of Birth _____________

Personal Medical Information

In the past, have you ever had:

Yes	No	Don't Know		Yes	No	Don't Know	
G	G	G	Heart attack or stroke	G	G	G	Elevated cholesterol (>200 mg/dl)
G	G	G	Heart surgery	G	G	G	Low HDL cholesterol (<35 mg/dl)
G	G	G	Diseases of arteries	G	G	G	Severe leg pain while exercising
G	G	G	Heart rhythm problems	G	G	G	Diabetes (age at onset ________)
G	G	G	Heart murmur	G	G	G	Orthopedic problems
G	G	G	High blood pressure	G	G	G	Arthritis
G	G	G	Asthma	G	G	G	Injuries to back, knees, ankles
G	G	G	Pulmonary (lung) disorders	G	G	G	Osteoporosis
G	G	G	Peripheral circulatory disorders				

In the past 12 months, have you had:

Yes	No		Yes	No	
G	G	Pain or discomfort in the chest or arms	G	G	Lightheadedness or dizziness
G	G	Heart palpitations or rapid heart rate	G	G	Ankle swelling
G	G	Awakened short of breath	G	G	Loss of coordination or balance
G	G	Shortness of breath at rest	G	G	Chronic muscle soreness
G	G	Shortness of breath with usual activities	G	G	Joint soreness or swelling
G	G	Unexplained loss of consciousness	G	G	Back pain
G	G	Unexplained extreme weakness	G	G	Unusual fatigue with usual activities
G	G	Pain or discomfort with mild exertion			

OVER OVER OVER OVER OVER OVER OVER

Describe any illnesses, hospitalizations, medical problems, or surgeries you have had in the past 12 months:

____

Do you have any limitations that may affect your ability to exercise? G Yes G No

If yes, please explain ____

Are you currently under a physician's care? G Yes G No

If yes, please explain ____

List any allergies you have (including drug allergies): _____________________________________

List all medications (prescribed or self-prescribed) that you currently take:

Medication	Condition being treated or reason for taking
______________________________	____________________________________
______________________________	____________________________________
______________________________	____________________________________

How would you describe your general health? G Excellent G Good G Average G Fair G Poor

Has a physician ever advised you not to exercise because of a medical problem? G Yes G No

If yes, please explain ____

Family History

Has your father, brother, or son had a heart attack, coronary revascularization, or sudden death before 55 years of age? G Yes G No G Don't know

Has your mother, sister, or daughter had a heart attack, coronary revascularization, or sudden death before 65 years of age? G Yes G No G Don't know

Lifestyle Information

Have you ever smoked cigarettes, cigars, or a pipe? G Yes G No

Do you presently smoke? G Yes G No

If you previously smoked but have quit, please answer the following:

How many years did you smoke? _______yrs When did you quit (year) _________

Please check the one category that best describes your current level of physical activity:

G **Inactive**: Most of your day is spent sitting, and you do no regular physical activity.

G **Relatively Inactive**: Your day includes 3-4 hours of standing or walking, but you do very little other physical activity.

G **Somewhat Active**: Your day requires some physical activity and you occasionally participate in recreational activities (e.g., tennis, golf), or you occasionally do physical activities such as gardening, housecleaning, dancing, etc.

G **Moderately Active**: Your day requires physical activity and/or you participate in regular recreational or fitness activities (e.g., walking, jogging, swimming, cycling, weight lifting) for at least 20 minutes, 3 days each week.

G **Very Active**: Your day requires extensive physical activity and/or you exercise moderately to vigorously for more than 30 minutes, 4 or 5 times each week.

If you are moderately or very active, please indicate the type and amount of exercise you do:

Type of Activity	Frequency (days/week)	Duration (minutes)	Intensity (light, moderate, hard)
____________________________	____________	__________	_______________________
____________________________	____________	__________	_______________________
____________________________	____________	__________	_______________________

I certify that, to the best of my knowledge, the above answers are accurate and true.

Signature ____ Date __________________

* * * * * * * * * ** * * * *

For office use:

ID ___________________

Agreement to Participate in Research

Responsible Investigators: Alev Tug Ergun, B.S.
Peggy Plato, Ph.D.

Title of Protocol: Cardiovascular and metabolic responses to noncontact cardio kickboxing in women

I have been asked to participate in a research study to investigate whether noncontact cardio kickboxing elicits intensities sufficient to improve cardiovascular fitness, and whether caloric expenditure during this exercise is sufficient to promote weight loss and fat reduction in women. Testing will take place in Spartan Complex, Room 208 and Uchida Hall, Room 202 at San Jose State University.

I will be asked to complete a medical history questionnaire. On the first day, prior to testing, a fingerstick blood sample (approx. 25 uL) will be obtained to measure blood glucose and/or cholesterol if it is deemed necessary for risk stratification. My body weight and height will be measured. Skinfold measurements will be taken to calculate my body fat percentage. Ten electrodes will be placed on my chest to monitor heart rate and rhythm during the exercise test. Before starting to exercise, my resting heart rate and blood pressure will be measured. I will warm-up by walking on the treadmill at a speed of 3 mph. After warming up for 3 min, the intensity will be gradually increased every 1-2 min (speed and/or elevation will be increased). When I am no longer able to maintain the exercise intensity, the speed and elevation of the treadmill will be reduced, and I will cool down by easy walking. During the test, I will be breathing room air, but will be wearing a face mask so that the air I exhale can be measured and analyzed. These data will be used to determine my maximal oxygen consumption (max VO_2). Max VO_2 is considered the single best indicator of my aerobic fitness. My blood pressure will be measured every 2-3 min during the test, and I will be asked to subjectively rate the difficulty of the exercise. The actual test will last approximately 8-15 min. My heart rate and blood pressure will continue to be monitored as I cool down.

On a different day, I will perform the muscle strength testing on two different exercises: chest press and leg press. I will do a light warm-up of 5 repetitions at 40 to 60% of my perceived maximum. I will rest for 1 min doing light stretching. After I do 3 to 5 repetitions at 60% to 80% of my perceived maximum, a small amount of weight will be added, and I will attempt to lift the weight. If the lift is successful, I will rest for 3 min, then I will attempt another lift with increased weight. The process will continue until I fail to lift the weight. I will then be given a brief orientation using the videotape with the 20-min kickboxing routine that I will be performing on the next test day.

On the third day of testing, I will perform the kickboxing routine. My body weight will again be measured, and a heart rate monitor will be strapped around my chest to monitor heart rate while exercising. After doing a 5-min prescribed warm-up, I will perform the 20-min kickboxing routine as shown

____
Initials

on the videotape. During the test, I will again wear the face mask so that oxygen consumption can be measured. A trained evaluator will observe while I am exercising to ensure that the movements are performed as demonstrated on the video and to make corrections. My heart rate will be recorded every 2 min, and I will be asked to subjectively rate the difficulty of the exercise at 2 min intervals. After completing the routine, I will cool down doing static stretches.

I understand that the treadmill test (1st day of testing) and muscular strength test (2nd day of testing) require maximal effort, and there are risks associated with physical exertion. The discomforts commonly associated with exercise may be experienced (e.g., sweating; increased heart rate, breathing rate, and temperature; fatigue). Changes that may occur at or near maximal exertion include abnormally high blood pressure, fainting, dizziness, muscle fatigue or cramps, nausea and, in very rare instances, heart attacks, stroke, or other serious abnormalities of heart rhythm. The occurrence of the most serious risks is rare. Every effort will be made to minimize these risks by conducting tests in accordance with American College of Sports Medicine guidelines and by providing appropriate supervision during testing. Test administrators are trained in cardiopulmonary resuscitation (CPR), and an automatic external defibrillator (AED) is available. The treadmill test will be stopped if abnormal heart rhythms are noted. Tests will also be stopped at my request, or if I experience and report unusual fatigue, dizziness, lightheadedness, muscle cramps, pain or pressure. Following the treadmill test, I may be extremely fatigued, lightheaded, or slightly nauseous for a short period of time. Performing the kickboxing routine does not require maximal effort; however, discomforts commonly associated with exercise (mentioned above) may be experienced. In addition, I may experience some muscle soreness after the test days. If emergency medical attention is required, the test administrator will call 911. I understand that I assume costs for medical treatment and/or transport to a medical facility.

I may benefit by obtaining an accurate laboratory assessment of my current fitness level, including aerobic fitness (max VO_2), muscular strength, and body composition (body fat percentage). I will also obtain information regarding my individual exercise intensity and caloric expenditure during a cardio kickboxing workout.

I understand that I may ask any questions that I have about the procedures. Questions about the research may be directed to Peggy Plato, Ph.D. (408-924-3032). Complaints about the research may be presented to V. Gregory Payne, P.E.D., Human Performance Department Chair (408-924-3010). Questions about research, participants' rights, or research-related injury may be presented to Pamela Stacks, Ph.D., Interim Academic Vice President for Graduate Studies and Research (408-924-2480).

I understand that the results of this study may be published or presented, but no information that could identify me will be included without my express written permission.

I agree to participate in the study described above. The procedures, discomforts, and risks will be verbally explained to me. I am aware of the possible risks and discomforts associated with the tests and consider them to be acceptable relative to my participation in them. I understand that I may decide not to participate or that I may withdraw from participation at any time without prejudice to my relations with San Jose State University. I will receive a signed and dated copy of this consent form.

- The signature of a participant on this document indicates agreement to participate in the study
- The signature of a researcher on this document indicates agreement to include the above named participant in the research and attestation that the participant has been fully informed of her rights.

________________________________ __________________

Signature Date

________________________________ __________________

Investigator's Signature Date

1RM TESTING DATA SHEET

ID ______________________________ Date ______________ Time __________

Hours of Sleep _______ Last Exercise ______________ Last Meal ______________

Age __________

	60% - 80% perceived max	2^{nd} Attempt	3^{rd} Attempt	4^{th} Attempt	5^{th} Attempt
CHEST PRESS	Weight: Reps:	Weight: Reps:	Weight: Reps:	Weight: Reps:	Weight: Reps:
LEG PRESS	Weight: Reps:	Weight: Reps:	Weight: Reps:	Weight: Reps:	Weight: Reps:

<u>FINAL SCORES:</u>

1RM Chest Press:

1RM Leg Press:

GRADED EXERCISE TESTING
DATA SHEET

ID ______________________________ Date ______________ Time __________

Hours of Sleep _______ Last Exercise _______________ Last Meal _______________

Age __________ Height _________ inches Body Weight ________ kg

P_{bar} ______ mm Hg T_{air} _____ EC RH _____%

Resting HR ________ bpm Resting BP __________

Time	Workload	HR (bpm)	BP (mm Hg)	RPE	Comments
0-1:00					
1:00-2:00					
2:00-3:00					
3:00-4:00					
4:00-5:00					
5:00-6:00					
6:00-7:00					
7:00-8:00					
8:00-9:00					
9:00-10:00					
10:00-11:00					
11:00-12:00					
12:00-13:00					
13:00-14:00					
14:00-15:00					
Recovery		HR	BP	Comments	
Time:					
Time:					

Reason for stopping test: