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Differences in VO_2 Between Kickboxing and Treadmill Exercise at Similar Heart Rates

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DIFFERENCES IN VO_2 BETWEEN KICKBOXING AND TREADMILL EXERCISE

AT SIMILAR HEART RATES

by

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ABSTRACT

DIFFERENCES IN VO_2 BETWEEN KICKBOXING AND TREADMILL EXERCISE AT SIMILAR HEART RATES

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Kickboxing has become increasingly popular as an alternative mode of aerobic exercise in the general public. The purpose of this study was to examine the differences in oxygen consumption (VO_2) during kickboxing and treadmill running at similar heart rates (HR).

Methods

Eleven female subjects (19$\pm$1 yrs; 165$\pm$5 cm; 62$\pm$12 kg) participated in a 25-minute kickboxing session. This consisted of 5-minute segments including a warm-up, punch, kick, combination (punch/kick) and cool down. The kickboxing stages were performed in a randomized, counterbalanced order. After a 30-minute rest period, the subjects performed a modified Bruce treadmill max test (5 minute stages). VO_2 and HR were measured during the two exercise sessions. Linear regression was used to interpolate the treadmill VO_2 that occurred at HR values elicited during kickboxing. A general linear model two factor repeated measures ANOVA was utilized to compare VO_2 results among the punch, kick, and combination phases of kickboxing and the results between the kickboxing VO_2 and the treadmill VO_2. The differences (Δ) between treadmill and kickboxing VO_2 that were determined at similar heart rates were analyzed utilizing t-tests.

Results

Significant differences in VO_2 were found among the kickboxing phases: punch, 14.4 ml $min^{-1}kg^{-1}\pm5.1$ (HR 133$\pm$16 bpm); kick, 18.9 ml $min^{-1}kg^{-1}\pm4.6$ (HR149$\pm$20 bpm); and

combination, 17.6 ml $min^{-1}kg^{-1} \pm 3.7$ (HR 144 ± 22 bpm). Treadmill running at HRs of 133, 149 and 144 bpm elicited VO_2 values of 17.5 ml $min^{-1}kg^{-1} \pm 5.3$; 21.3 ml $min^{-1}kg^{-1} \pm 4.8$; and 19.8 ml $min^{-1}kg^{-1} \pm 4.4$, respectively. The treadmill and kickboxing VO2 Δ at heart rates of 133 bpm (3.2 ml $min^{-1}kg^{-1} \pm 2.2$, t = 4.71), 149 bpm (2.4 ml $min^{-1}kg^{-1} \pm 2.2$, t = 3.66), and 144 bpm (2.3 ml $min^{-1}kg^{-1} \pm 1.6$, t = 4.73) were found to be statistically different.

Conclusion

The kick phase of kickboxing elicited a higher VO_2 than the punch and combination phases. Additionally, kickboxing elicited a lower VO_2 than treadmill running at similar heart rates in college-aged women.

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CHAPTER I

INTRODUCTION

Cardiorespiratory exercise reduces body fat and also reduces the risk of heart disease, type 2 diabetes and other health problems. According to the American College of Sports Medicine (ACSM), improvements in cardiorespiratory fitness occur when an individual performs exercise utilizing the larger muscle groups while reaching an intensity of 64/70 to 94% of maximum heart rate or 40/50% to 85% of VO_2 reserve (2006). While the guidelines are clear, the challenge lies in motivating individuals to exercise and adhere to an exercise program.

Fitness professionals constantly strive to develop new exercise programs, regimens and equipment to entice the public to exercise. One example is kickboxing. The concept has been around since the early 1990s when Stephanie Steele (*Knockout Workout*) and Kathy Smith (*Aerobox*) released home videos. Their routines consisted mostly of boxing movements such as punching and jumping rope. In the late 1990s, Billy Blanks, a seven-time World Martial Arts Champion, introduced *Tae Bo*. Incorporating boxing, self-defense, karate and aerobic dance movements, *Tae Bo* launched the kickboxing concept to fitness centers, gymnasiums and homes across the Unites States.

Kickboxing is a type of fitness class that incorporates aerobic dance movements, punching techniques from boxing and kicking movements from martial arts. The goal of kickboxing is to provide a fun exercise mode for the general public. Aerobic dance movements such as grapevines, shuffles, knee lifts, jogging in place and jumping jacks are utilized. Punches include the jab, cross, hook and uppercut. The front, side, back and roundhouse kicks are typical lower body movements. These exercises are performed to music (usually a cadence of 130 – 140 beats per minute) in various sequences and combinations as presented by a group exercise instructor. Segments of a kickboxing class may include arm-only exercises (punches), leg-only exercises (kicks) and/or a combination of arm and leg exercises.

Studies have shown that aerobic dance, arm/leg ergometry, martial arts and boxing are effective exercise modes, providing sufficient intensity to improve cardiorespiratory fitness. Berry, Cline, Berry and Davis (1992); Blyth and Goslin (1985); Claremont, Sirnowit, Boarman, Asbell and Auferoth (1986); Darby, Browder and Reeves (1995); DeAngelis, Vinciguerra, Gasbarri and Pacitti (1997); Foster (1975); Grant Armstrong, Sutherland, Wilson, Aitchison, Paul and Henderson (1993); Grant, Davidson, Aitchison and Wilson (1998); Milburn and Buts (1983); Parker, Hurley, Hanlon and Vaccaro (1989); Perry, Mosher, Perriere, Roalstad and Ostrovsky (1988); Schaeffer-Gerschutz, Darby and Browder (2000); Scharff-Olson, Williford and Smith (1992); Thomsen and Ballor (1991); and Williford, Blessing, Olson and Smith (1989) found that subjects reached heart rate and/or VO_2 levels within sufficient intensity levels while performing aerobic dance. Arm, leg and combined arm/leg ergometry studies conducted by Bergh, Kanstrup and Edblom (1976); Faria and Faria (1997); Lewis, Snell, Taylor, Hamra, Graham, Pettinger and Blomqvist (1985); Reybrouck, Higenhasuer and Falkner (1975); Sedlock (1991); Toner, Glockman and McCardle (1990); and Vokac, Bell, Bautz, Holter and Rodahl (1975) showed that exercise intensity achieved during these exercise modes was within ACSM guidelines.

Further research shows that martial arts (Francescato, Talon and diPramperio, 1995; Imamura, Yoshimura, Nishimura, S., Nakazawa, Nishimura, C. and Shirota, 1999;

Pieter, Taaffe and Heijmans, 1990; and Shaw and Deutsch, 1982) and boxing (Bellinger, Givson, Delofse, A., Delofse, R., and Lamberg, 1997, and Kravitz, Greene, Burkett and Wongsathikum, 2003) are also effective modes of exercise. Kickboxing research is extremely limited. One unpublished study by Immel found that kickboxing achieved intensity within the ACSM guidelines for heart rate and VO_2 (1999).

Statement of Purpose

The purpose of this study was to examine the VO_2 of kickboxing and treadmill exercise at similar heart rates. The protocol consisted of a 20-minute kickboxing routine that included a 5-minute warm-up, 5-minute punching phase, 5-minute kicking phase and a 5-minute combination (punching/kicking) phase. After a 30- minute rest period, a modified Bruce protocol was performed. Heart rate, VO_2 and rating of perceived exertion (RPE) were measured during both tests, and data was recorded for each 5-minute segment. For a given heart rate achieved in kickboxing, VO_2 during treadmill exercise was interpolated from the treadmill heart rate/VO_2 data using linear regression. A comparison between kickboxing and treadmill exercise VO_2 was made using two-factor repeated measures ANOVA.

Research Hypotheses

Null Hypothesis

There are no significant differences in VO_2 between the punching, kicking and combination phases of kickboxing.

There are no significant difference in VO_2 between kickboxing and treadmill exercise at similar heart rates.

Alternative Hypothesis

There are significant differences in VO_2 between the punching, kicking and combination phases of kickboxing.

There are significant differences in VO_2 between kickboxing and treadmill exercise at similar heart rates.

Independent Variables

The independent variables were the punch, kick and combination (punch/kick) phases of kickboxing and the modified Bruce protocol stages.

Dependent Variables

The dependent variables were heart rate, VO_2 and RPE.

Assumptions

Kickboxing incorporates aerobic dance, martial arts and boxing. Furthermore, there are segments of arm-only, leg-only and arm/leg combinations within the class design. Since studies have shown these modes to be effective for cardiorespiratory training, then kickboxing also provides sufficient intensity for cardiorespiratory training even though the execution of the moves by participants are performed differently (i.e., slower, less intense, less muscle recruitment, etc.) than highly skilled boxers and martial artists.

Delimitations

The subjects who volunteered for this study were recruited from the lead investigator's beginning aerobics and graduate classes and were females between the ages of 18 – 22 years. The subjects were all identified as low risk according to ACSM risk stratification and had previously participated in a kickboxing class. Therefore, the results of this study may only be applied to females between the ages of 18 – 22 years of age.

Limitations

Limitations included lack of male subjects, subject motivation and logistics. There were no male subjects tested. Subjects were recruited from aerobics classes, and the subjects had to have prior experience with kickboxing. These criteria lend themselves to excluding men because mostly females participate in aerobics classes. Subject motivation was another limitation. Some subjects were more motivated than others; the more motivated subjects performed the exercises with more effort and enthusiasm. Logistical factors such as lead investigator/instructor, subject, equipment and laboratory availability limited the scheduling of testing sessions.

Operational Definitions

<u>Back kick</u> – a kick executed away from the body to the rear.

<u>Chamber</u> – hip and knee flexion that lifts the knee to the front or side of the body.

Cross – a punch executed similar to a jab, but the punch actually crosses the midline of the body, causing spinal rotation.

Front kick – a kick executed to the front of the body.

Hook – a punch executed by arm abduction and a neutral or pronated wrist that is aimed toward the midline of the body.

Jab – a punch executed straight out in front of the body.

Kick – a movement of the legs broken into four phases: the chamber, strike, re-chamber, and return.

Kickboxing - a fitness workout incorporating combinations of boxing, kickboxing, martial arts, and aerobic dance.

Punch – a ballistic movement of the arm broken down into two phases – the punch phase and the retraction phase.

Punch phase - the arm moves away from the body to the target.

Re-chamber – knee flexion returning the leg to the chamber position.

Ready position – stance facing forward or slightly to the side with one foot back and one foot front (staggered); knees slightly bent, abdominals contracted; and elbows bent with arms close to the body positioned in an inverted V; and fists at chin level.

Retraction phase - the arm moves back towards the body to ready position.

Return – hip extension performed bringing the leg to the floor.

Roundhouse kick – a kick executed to the side of the body with a pointed foot using the front of the foot to strike the "target."

Side kick – a kick executed to the side of the body with a flexed foot, using the heel of the foot to strike the "target."

Strike – knee extension occurs as the foot makes contact with the "target" with the ball or heel of the foot.

Uppercut – a punch that starts with a "windup" and is executed in front of the body with the elbow flexed, aiming for the ribs or chin of the "opponent."

Significance of the Study

To improve cardiorespiratory fitness, a person must perform exercise using the larger muscle groups at an adequate frequency, duration and intensity. Specifically looking at intensity, the exercise should invoke a cardiorespiratory response of 64/70 – 94% of maximum heart rate or 40/50 – 85% of oxygen consumption reserve (VO_2R) of or a rating of perceived exertion of 12 to 16 (somewhat hard to hard) on the Borg scale (ACSM, 2006). Research has shown aerobic dance, arm, leg and arm/leg ergometry, martial arts and boxing to provide intensity within these parameters. However, kickboxing research is very limited. Therefore, the purpose of this study was to examine VO_2 responses to the punches, kicks and combinations performed in kickboxing and compare them to treadmill exercise at similar heart rates.

CHAPTER II

REVIEW OF LITERATURE

The American College of Sports Medicine (ACSM) has determined treadmill exercise to be an effective mode of exercise to improve cardiovascular health, burn calories and promote weight loss (2006). Treadmill exercise has been used as a source of comparison against other modes of exercise, such as aerobic dance, arm/leg ergometry, martial arts and boxing. Researchers have examined heart rate, VO_2 and RPE results from these modes to determine if the exercise provides sufficient intensity.

Aerobic Dance

Kickboxing encompasses aerobic dance movements such as grapevines, shuffles, knee lifts, jogging and jumping jacks. Aerobic dance is recognized by the ACSM as an effective exercise mode (2006). Therefore, when examining the cardiorespiratory effects of kickboxing, aerobic dance research should be considered.

Studies by Foster (1975), Milburn and Buts (1983), Parker et al. (1989) and Berry et al. (1992) have compared aerobic dance to treadmill exercise. According to Foster, aerobic dance provides an intensity equivalent to exercise a 9.5 minute mile (1975). Four female subjects (28.3 $\pm$ 7.7 yrs) participated in the study. Results showed a mean VO_2 of 33.6 $\pm$ 5.8 ml $min^{-1}kg^{-1}$ (77 $\pm$ 13% of max). The subjects achieved a peak load of 39.2 $\pm$ 7.3 ml $min^{-1}kg^{-1}$ (90 $\pm$ 15.2% of max). Foster concluded that aerobic dance is just as effective as exercise and will provide effective cardiorespiratory training (1975).

Milburn and Buts concluded that aerobic dance can provide intensity comparable to jogging (1983). Forty-six females participated in the study, and they were divided into three groups: aerobic dance (21.4 yrs), jogging (19.3 yrs) and bowling (20.3 yrs). The exercise session for each group was thirty minutes long and was performed four days per week. The aerobic dance routine consisted of "rhythmical exercise, hopping, skipping, jumping, stretching and swinging motions" (Milburn and Buts, 1983). The jogging routine consisted of walking and exercise combinations. Heart rate results showed a range of 157 – 167 bpm (83% of max) for the joggers and a range of 157 - 176 bpm (84% of max) for the aerobic dancers. No significant difference was found in heart rate between the two groups. Post testing results showed that both aerobic dancers and joggers had a significant increase in maximum VO_2 levels after the training period (8.2% in the joggers and 10.2% the aerobic dancers). Maximum heart rate decreased slightly; the aerobic dance subjects experienced a 1.4% decrease while the jogging subjects experienced a 1.5% decrease. Therefore, aerobic dance and jogging both elicited similar heart rate and VO_2 training adaptations, showing that both provide sufficient intensity.

According to Parker et al., aerobic dance and treadmill exercise elicit similar VO_2 results; however, aerobic dance produces less of a VO_2 for a given heart rate as compared to exercise (1989). Fourteen females (19 ± 1 yrs) participated in an eight-week study performing a 20-minute aerobic dance routine with heart rate and oxygen consumption measurements taken. They also ran on a treadmill for 20 minutes. Heart rate was significantly different between aerobic dance (180 ± 3 bpm) and treadmill exercise (163 ± 3 bpm). However, no significant differences were found for VO_2. Additionally, the researchers pointed out that aerobic dance, performed at the same VO_2, resulted in more VO_2 and heart rate fluctuations than did treadmill exercise. This can be attributable to the effects of arm movements into the routine and/or the changes in leg movements during the aerobic routine while treadmill exercise leg movements remain constant with minimal to no arm movements.

Heart rate and VO_2 results for aerobic dance and treadmill exercise showed aerobic dance to elicit comparable intensity to treadmill exercise in a study by Berry et al. (1992). They examined the effects of two different aerobic dance routines and compared the results to treadmill exercise (TR). Nine females participated (25.6 $\pm$ 4.6 yrs) in the study. The subjects performed three 20-minute submaximal tests: aerobic dance with arms overhead (ABOVE), aerobic dance with arms at shoulder level (BELOW) and treadmill exercise (TR). Heart rate and VO_2 results were not significantly different among the three modes. According to the researchers, the results suggested that aerobic dance invokes similar heart rates as treadmill exercise at a constant VO_2 and therefore provides sufficient intensity.

Blyth and Goslin also found that aerobic dance meets ACSM guidelines for intensity (1985). Twelve female subjects (19.5 $\pm$ 0.6 yrs) performed a treadmill max test and a 30-minute aerobic dance session. Results showed that heart rate achieved (84.6 $\pm$ 7.8% of maximum) was not significantly different from the target heart rate (81.3% of maximum). Using linear regression, the researchers determined that the corresponding VO_2 achieved was 75.5% $\pm$ 11.3 of max. They concluded that aerobic dance provided sufficient intensity for cardiorespiratory training.

Grant, Armstrong, Sutherland, Wilson, Aitchison, Paul and Henderson studied the cardiorespiratory effects of a “popmobility” aerobic dance session (1993). “Popmobility” was a 30-minute aerobic dance class that consisted of 20 minutes of aerobics, 5 minutes of muscular endurance and 5 minutes of flexibility training. Ten females (21.2 $\pm$ 1.5 yrs) participated in the study. For the aerobic dance period, results showed that subjects achieved 75.6% of heart rate reserve and 76.4% of VO_2 max. A study conducted by Grant, Davidson, Aitchson and Wilson (1998) found similar results for high and low impact aerobics. Ten female subjects (22.9 $\pm$ 3 yrs) participated in three separate exercise sessions: high impact aerobic session, low impact aerobic session, and a maximal oxygen consumption test. During the high impact session, subjects achieved 64.7 $\pm$ 8.2% of VO_2 max and 76.7 $\pm$ 6% of maximum heart rate. Results for the low impact session showed subjects achieved 51.6 $\pm$ 9.1% of VO_2 max and 71.4 $\pm$ 7% maximum heart rate. Additionally, for a given heart rate, the high impact session invoked a higher VO_2. For example, at a heart rate of 157 bpm, the VO_2 during the low impact session was 29.0 ml $min^{-1}kg^{-1}$, and VO_2 during the high impact session was 33.6 ml $min^{-1}kg^{-1}$. However, results for both types (high and low impact) were within ACSM guidelines.

In a study of low and high impact aerobic dance sessions, DeAngelis et al. tested thirty female subjects (23.6 $\pm$ 3.4 yrs) for heart rate and VO_2 while performing a 25 minute aerobic dance session (1997). Subjects performed knee lifts, low kicks, directional movements, hopping, jumping jacks and skipping at a cadence of 130-140 bpm (established by music selection). A cycle ergometer protocol was performed to measure maximum heart rate and VO_2. Results showed a mean heart rate of 171 $\pm$ 8 bpm and a mean VO_2 of 34.4 $\pm$ 5.3 ml $min^{-1}kg^{-1}$(87.1 $\pm$ 3.8% and 72 $\pm$ 11.1% of maximum, respectively). According to these results, aerobic dance does provide sufficient intensity to promote a training effect.

Claremont et al. examined the heart rate and oxygen consumption resulting from three different aerobic dance intensities based on exercise tempo (1986). Twelve subjects (20.5 $\pm$ 2.32 yrs), 10 females and 2 males, performed a maximal treadmill test and aerobic dance sessions performed at three different cadences: 110 (low), 128 (medium) and 158 (high) bpm. The low intensity aerobic dance showed a higher heart rate (137 $\pm$ 18 bpm) for a given VO_2 (24.6 $\pm$ 4.93 ml $min^{-1}kg^{-1}$). The medium and high intensities resulted in heart rates of 150 $\pm$ 16 bpm and 158 $\pm$ 15 bpm, respectively, and VO_2 of 33.4 $\pm$ 8.7 ml $min^{-1}kg^{-1}$ and 34.7 $\pm$ 6.4 ml $min^{-1}kg^{-1}$, respectively. Heart rate results were 72% to 79% of maximum; VO_2 results were 80% to 85% of maximum. Therefore, aerobic dance, performed at three cadences (110, 128 and 158 bpm) met the ACSM intensity guidelines.

Interval training is an exercise mode that intersperses high intensity with lower intensity exercise. Aerobic dance classes may be taught in this format to offer different intensity options and variety of exercises. Perry et al. looked at the cardiovascular effects of interval training and compared it to continuous aerobic dance training (1988). Sixty-six subjects participated in the study. They were divided into three groups: interval (19.6 $\pm$ 1.6 yrs), continuous (19.5 $\pm$ 1.6 yrs), and control (19.6 $\pm$ 2.0 yrs). The interval exercise session consisted of several routines that lasted three to five minutes to allow for the aerobic energy pathway to engage. The continuous aerobic dance session was 30-35 minutes in duration. The subjects participated in the sessions for 12 weeks. Significant differences in VO_2 were found among the groups. After the 12-week training period, results showed that the interval training group had a significantly higher relative (39.1 $\pm$ 6.9 ml $min^{-1}kg^{-1}$) and absolute (2.4 $\pm$ .5 l min^{-1}) VO_2 max than the continuous training group (34.9 $\pm$ 4.1 ml $min^{-1}kg^{-1}$ and 2.1 $\pm$ .4 l min^{-1}. Therefore, interval training is a more effective exercise mode than continuous aerobic dance programs.

Williford et al. tested ten females (five were aerobics instructors and five were aerobics students, 23.3 $\pm$ 3.7 yrs) while performing four different 20-minute sessions consisting of high intensity, high impact; high intensity, low impact; low intensity, high impact; and low intensity, low impact exercise (1989). High intensity movements included hip-level straight leg kicks as well as arm movements above the head and shoulders. High impact routines were performed with airborne movements where both feet came off the floor for a short period of time. Low intensity movements included arm exercises at or below the shoulders and kicks below midthigh level. Low impact routines were performed with one foot in contact with the floor at all times. A Bruce protocol was performed to determine maximum heart rate and VO_2. Significant differences were found for heart rate and VO_2. For heart rate, the high intensity, high impact session (174 $\pm$ 12 bpm) was significantly higher than the high intensity, low impact session (163 $\pm$ 12 bpm) and the low intensity, high impact session (164 $\pm$ 11 bpm). For VO_2, significant differences were also found. The high impact routines (high intensity, 37.2 $\pm$ 6.3 ml $min^{-1}kg^{-1}$ and low intensity, 31.6 $\pm$ 3.8 ml $min^{-1}kg^{-1}$) were significantly higher than the low impact routines (high intensity, 29.1 $\pm$ 4.3 ml $min^{-1}kg^{-1}$ and low intensity, 17.6 $\pm$ 2.0 ml $min^{-1}kg^{-1}$). Therefore, for this group of subjects, higher intensity aerobic dance movements elicited the most effective cardiorespiratory responses.

Thomsen and Ballor recruited twenty-seven females and divided them into three groups based on their fitness level and/or aerobic dance experience (27.4 $\pm$ 1.8 yrs, 27.5 $\pm$ 1.6 yrs and 27.9 $\pm$ 1.89 yrs) (1991). The subjects participated in three exercise routines of different intensity levels. The intensity was established by performing the exercise to three different music speeds (60, 70 and 80 bpm). The subjects also performed a cycle ergometer max test. Heart rate and VO_2 results were significantly different among the three intensity levels for all groups. There was also a significant group difference. Aerobic dance was found to be an effective mode of exercise while showing that untrained individuals as well as trained individuals should modify the exercises to decrease or increase the intensity as necessary to exercise within their individual training capacity.

Studying the cardiovascular effects of various aerobic dance movements such as the jumping jack, the power jack, jogging and marching, Darby et al. found significantly different results between the movements (1995). Sixteen female subjects participated in the study (23.0 $\pm$ 3.7 yrs). The subjects performed each exercise at two different cadences (124 and 138 bpm) for 1 minute each. The jog and march were lower body exercises whereas the jumping jack and power jack also included arm movements. The subjects also performed a treadmill VO_2 max test. The power jack resulted in a significantly higher heart rate (168 $\pm$ 17 bpm) than the march (155 $\pm$ 19 bpm). For VO_2, the jog elicited significantly higher results (34.9 $\pm$ 4.7 ml $min^{-1}kg^{-1}$) than the march (29.9 $\pm$ 5.4 ml $min^{-1}kg^{-1}$). Therefore, arm movements and impact affect the intensity of aerobic dance exercise.

Schaeffer-Gerschutz, Darby and Browder (2000) also examined the cardiovascular effects of low and high impact aerobic dance with dynamic and static arm movements. Twenty-five women (21.0 $\pm$ 1.0 yrs) participated in the study and performed various aerobic dance movements consisting of dynamic versus static arm movements and low versus high intensity. All exercises were performed to music (cadence of 136 bpm). Dynamic movements included arms above the head while static movements included arms below the head. The high impact exercise elicited a significantly higher heart rate (dynamic, 173 $\pm$ 17 bpm and static, 179 $\pm$ 15 bpm) and VO_2 (dynamic, 31.9 $\pm$ 3.4 ml $min^{-1}kg^{-1}$ and static, 33.7 $\pm$ 3.3 ml $min^{-1}kg^{-1}$) than the low impact exercise heart rate (dynamic, 157 $\pm$ 20 bpm and static, 157 $\pm$ 21 bpm) and VO_2 (dynamic, 25.1 $\pm$ 4.1 ml $min^{-1}kg^{-1}$ and static, 25.0 $\pm$ 4.0 ml $min^{-1}kg^{-1}$). Additionally, no significant differences were found for heart rate and VO_2 between the static and dynamic modes. This study suggests that the impact and arm movements affect intensity of aerobic dance.

In summary, aerobic dance provides intensity comparable to treadmill exercise (Foster, 1975; Milburn and Buts, 1983; Parker et al., 1989; and Berry et al., 1992). Aerobic dance has also been shown to meet ACSM intensity guidelines (Blyth and Goslin, 1985; Grant et al., 1993; Grant et al., 1998; DeAngelis et al., 1997 and Claremont et al., 1986). Interval training aerobic dance, where high intensity exercise is interspersed with low intensity exercise, has also been shown to be an effective exercise mode (Perry et al., 1988). Other studies have shown that high impact aerobics elicits more sufficient intensity than low impact aerobics (Williford et al., 1989; Thomsen and Ballor, 1991; Darby et al., 1995; and Schaeffer-Gerschutz et al., 2000). Therefore, aerobic dance exercise can elicit sufficient intensity levels.

Arm/Leg Ergometry

Exercise intensity is affected by the amount of muscle recruitment and contraction. Research on arm and/or leg ergometry exercise has been done to determine cardiorespiratory effectiveness. In 1975, Reybrouck et al. tested three men (35 $\pm$ 10.8

yrs) who performed three different exercise sessions arm, leg and arm/leg ergometry. No significant differences were found for VO_2 among arm, leg and arm/leg ergometry. However, in arm ergometry, heart rate increased at a quicker rate than in leg and combined arm/leg ergometry. Additionally, heart rate was higher in combined arm/leg ergometry than in leg ergometry.

Vokac et al., however, found that at relative work loads, arm and leg exercise resulted in similar VO_2 at similar heart rates (1975). Seven male subjects (22 – 25 yrs) performed leg and arm exercises, independently, while either sitting or standing. While the standing position provided the opportunity for more power to be achieved while performing arm exercise, there was no significant difference in power when performing the exercises in either sitting or standing positions. VO_2 was not significantly different between the sitting arm exercise and the standing arm exercise. Arm cranking at 600 and 900 kpm/min elicited significantly higher heart rates than the leg exercise. At higher given work load levels, arm exercise resulted in higher heart rate and oxygen consumption values as compared to leg exercise. This could be attributable to local muscle fatigue in the arms suggesting that maximum levels were reached in the arms.

In 1976, Bergh et al. found that the addition of arm work will decrease oxygen consumption and stabilize the heart rate. These researchers compared arm/leg ergometry with treadmill exercise. Ten males (23.6 ± 2.7 yrs) participated in the study. The subjects performed uphill treadmill exercise, arm cranking, cycling, and combined arm cranking and bicycling. Subjects achieved a VO_2 of 4.12 ± 0.56 l min^{-1} during cycling (93% of max) and 3.01 ± 0.40 l min^{-1} during arm cranking (68% of max). In combined arm and leg ergometry, VO_2 achieved during the 40% of arm work was significantly lower than the other stages (10%, 20% and 30% arm exercise). When comparing arm and leg ergometry to exercise, VO_2 was the same as exercise when the arm output was 20% and 30%. Heart rate was significantly higher in exercise (193 $\pm$ 10 bpm) than in arm (176 $\pm$ 9 bpm), leg (189 $\pm$ 8 bpm) and arm/leg exercise (range from 188 $\pm$ 9 bpm to 189 $\pm$ 8 bpm). VO_2, therefore, depends on the muscle mass used during the exercise as well as the level of arm movements. It appears that the more arm muscle mass is recruited, the lower the VO_2.

Toner et al. found conflicting results (1983). They compared the cardiovascular effects of arm cranking with leg cycling. Six males (22.7 $\pm$ 4.2 yrs) participated in the study. The subjects performed exercise sessions for 7 minutes each at 76 W and 109 W with various percentages of arm movements (0%, 14%, 43%, 57% and 100%). They also rested for 5 – 15 minutes between exercise bouts. At 76 W, the VO_2 at 14% (1.29 $\pm$ 0.07 l min^{-1}) was significantly lower than the 57% arm exercise (1.48 $\pm$ 0.02 l min^{-1}). Heart rate at 100% (143 bpm) was significantly higher than at 57% (114 bpm). At 109 W, VO_2 and heart rate were both significantly higher at 100% (2.33 $\pm$ 0.05 l min^{-1} and 175 bpm). Therefore, this study shows that while oxygen consumption did increase as more arm movements were added, heart rate did not increase.

Lewis et al. looked at static and dynamic hand grip and knee extension exercises (1985). Their findings conflicted with Toner et al. (1983). Six men (27 $\pm$ 3 yrs) performed static and dynamic handgrips and knee extensions. VO_2 and heart rate were both significantly higher for the static two-knee extension (780 $\pm$ 76 ml min^{-1} and 134 $\pm$ 11 bpm, respectively) compared to the static handgrip (358 ml min^{-1} and 91 $\pm$ 4, respectively). Furthermore, VO_2 and heart rate were also significantly higher for the dynamic two-knee extension (1,195 $\pm$ 64 ml min^{-1} and 128 $\pm$ 8 bpm, respectively) compared to the dynamic handgrip (430 $\pm$ 73 ml min^{-1} and 99 $\pm$ 8 bpm, respectively). Therefore, the amount of muscle mass recruited during exercise does affect intensity.

Arm and leg cranking have been found to produce similar levels of postexercise oxygen consumption (EPOC). A study conducted by Sedlock found that EPOC was not significantly different between arm cranking (RER 0.88 $\pm$ 0.05) and cycle ergometer exercise (RER 0.90 $\pm$ 0.05) (1990). Eight subjects (22.3 $\pm$ 1.5 yrs), 4 males and 4 females, participated in the study and performed peak arm cranking and leg cranking tests. Arm cranking elicited a heart rate of 137 $\pm$ 17 bpm (73.6% of peak) and a VO_2 of 1.18 $\pm$ 0.34 l min^{-1} (60.7% of peak). Leg cranking elicited a heart rate of 137 $\pm$ 14 bpm (72.9% of peak) and a VO_2 of 1.63 $\pm$ 0.47 l min^{-1} (60.3% of mode-specific peak). The researchers concluded that EPOC may be primarily related to the relative metabolic rate of the active muscles rather than the amount of active muscle mass or absolute exercise VO_2.

Heart rate and VO_2 responses are similar in upper and lower body exercise when the exercise performed is of the same relative intensity according to Faria and Faria (1997). Twelve trained female rowers (22.8 $\pm$ 1.3 yrs) performed four exercises: arm rowing, leg extension, arm rowing/leg extension and arm rowing/leg extension at different workloads. The workloads were performed with the "arms doing 20% of 3-RM (3 repetition maximum) for arm rowing and the legs doing 20% of 3-RM for leg extension or …the arms doing 20% of 3-RM for leg exercise and the legs doing 0% of 3-RM for arm rowing" (Faria and Faria, 1997). VO_2 was not significantly different between arm rowing (17.5 $\pm$ 1.6 ml $min^{-1}kg^{-1}$) and leg extension (17.3 $\pm$ 1.8 ml $min^{-1}kg^{-1}$)

exercises. However, VO_2 was significantly different between combined arm rowing and leg extension (38.3 ± 2.8 ml $min^{-1}kg^{-1}$) and combined arm rowing and leg extension at the different workloads (41.7 ± 2.3 ml $min^{-1}kg^{-1}$). Heart rate for arm rowing (117 ± 9 bpm) and leg exercise (110 ± 13 bpm) were not significantly different. Combined arm and leg exercise elicited a heart rate of 134 ± 12 bpm while combined arm and leg exercise performed at various workloads elicited a heart rate of 155 ± 18 bpm. The researchers concluded that for relative workloads, upper body and lower body exercise elicit similar VO_2 and heart rate responses.

In summary, several studies have shown that arm ergometry increases the heart rate but does not increase VO2 (Reybrouck et al., 1975; Bergh et al., 1976; and Lewis et al., 1985). Other studies have shown that for relative work loads, arm ergometry can elicit similar heart rate and VO2 results (Vokac et al., 1975; Toner et al., 1983; and Faria and Faria, 1997). Additionally, arm and leg cranking have been found to produce similar levels of postexercise oxygen consumption (EPOC) (Sedlock, 1990).

Martial Arts

Kickboxing includes martial arts movements such as punches and kicks; therefore, studies examining the cardiorespiratory effects of marital arts should also be considered. Shaw and Deutsch examined heart rate and VO_2 responses to karate kata (choreographed arm and leg movements) (1982). Ten karate practitioners (1 female and 9 males) (21.8 ± 4.0 yrs) participated in the study. Maximum oxygen consumption and heart rate were tested using a modified discontinuous treadmill protocol designed by Taylor, Buskirk and Henschel (1955). They performed continuous kata (with no rest periods) and discontinuous kata (with a 1-minute rest period) each at two different time frames (30 seconds and 45 seconds). Heart rate (158 $\pm$ 3 bpm) and VO_2 (28.4 $\pm$1.1 ml $min^{-1}kg^{-1}$) in continuous kata were significantly higher than in discontinuous kata (139 $\pm$ 3 bpm and 18.8 $\pm$ .7 ml $min^{-1}kg^{-1}$). Additionally, the 30 second pattern was significantly greater for heart rate (154 $\pm$ 3 bpm) and VO_2 (25.7 $\pm$ 1.1 ml $min^{-1}kg^{-1}$) compared to the 45 second pattern (143 $\pm$ 3 bpm and 21.5 $\pm$ 1.0 ml $min^{-1}kg^{-1}$). Therefore, karate can provide sufficient intensity when performed continuously and at a faster pace.

Taekwondo combinations were studied by Pieter et al. (1990). According to this study, taekwondo provided sufficient intensity whether or not arm exercises (punches) were added. Seven male taekwondo students (21.1 yrs) participated in the study. They performed two "forms" and two combinations. The combinations consisted of a series of kicks and punches similar to kickboxing. Combination I consisted of kicks only (front, side, back and roundhouse kicks); combination II consisted of punches/jabs and kicks. There were no significant differences in heart rate between combination I (182 bpm) and combination II (181 bpm). However, heart rate for the combinations was significantly higher than the forms (160 bpm and 158 bpm).

Francescato et al. studied the energy cost and energy sources of *Pinan ni dan* (a series of blocks, punches and open hand movements performed in a fight simulation) (1995). Eight males, trained in karate for 1-3 years, participated in the study (23.7 $\pm$ 4.3 yrs). They performed a cycle ergometer VO_2 max test and also performed a series of the *Pinan ni dan* of varying time lengths of 10, 20, 30, 40, 60, and 80 seconds. Heart rate increased from 134 $\pm$ 22 bpm (10 second phase) to 163 $\pm$ 12 bpm (80 second phase). VO_2 also increased from 14.4 $\pm$ 4.2 ml $min^{-1}kg^{-1}$ (10 second phase) to 27.5 $\pm$ 4.6 ml $min^{-1}kg^{-1}$ (80 second phase).

Imamura et al. studied physiological effects of performing S-Basics, M-Basics, TECH I, and other patterns executed in karate training (1999). They found that heart rate was higher during the exercise modes for a given VO_2 compared to treadmill exercise. Seven males (21.3 $\pm$ .5 yrs) holding first degree black belts performed a Bruce protocol maximum treadmill test to determine maximum VO_2. They also performed S-Basics, M-Basics, Tech I and Tech II. The S-Basics pattern consisted of arm and leg movements executed in a stationary position. The M-Basics pattern was similar to the S-Basics with the addition of formal stances. Tech I was comprised of "sparring" upper and lower body movements without a partner; Tech II was the same as Tech I, but performed with a partner. Significant differences were found for VO_2 and for heart rate among the different karate modes. Results showed a higher heart rate for all the karate forms for a given VO_2 than during treadmill exercise. The addition of the arm movements has been shown to elicit a higher HR at a given VO_2 than exercise using only leg movements.

In summary, karate provides sufficient intensity to achieve a cardiorespiratory effect (Shaw and Deutsch, 1982; and Francescato et al., 1995). Further, the addition of arm movements to the exercise, as in combination II movements in Taekwondo, still provides adequate intensity based on heart rate measurements (Pieter et al., 1990). Imamura et al. found that karate elicits a higher heart rate for a given VO_2 than during treadmill exercise.

Boxing

Bellinger et al. studied the energy expenditure of a noncontact boxing session and compared it to treadmill exercise (1997). Eight males who had performed noncontact boxing at least once per week participated in the study (30 $\pm$ 4 yrs). The subjects participated in a 1-hour routine which included the use of focus pads, heavy bags and boxing gloves. The researchers determined that an energy expenditure of 2821 $\pm$ 190 kcal/hr was achieved during the boxing session conducted in the laboratory which was comparable to exercise on a treadmill at 9.2 $\pm$ 0.8 km per hour. Therefore, the researchers concluded boxing session performed provided sufficient intensity to create a training effect.

Kravitz et al. investigated the cardiovascular responses to punching executed in fitness boxing (2003). Twelve men and six women (22.0 $\pm$ 2.8 yrs) participated in the study. The boxing sessions were 2 minutes long, and each session was performed at different tempos, 60, 72, 84, 96, 108 and 120 bpm measured by a metronome. The sessions consisted of contact punching movements against a boxing device while the subjects wore 0.34 kg boxing gloves. Participants rested for 3 minutes in between each session. Heart rates at the 96, 108 and 120 cadences (175 $\pm$ 22, 177 $\pm$ 20 and 182 $\pm$ 16 bpm, respectively) were significantly different from the 60, 72 and 84 cadences (165 $\pm$ 26, 170 $\pm$ 24, 173 $\pm$ 24 bpm, respectively). VO_2 results (26.8 $\pm$ 13.3 ml $min^{-1}kg^{-1}$ to 29.5 $\pm$ 8.0 ml $min^{-1}kg^{-1}$) were not significantly different among the cadences. This study showed that boxing performed at these six cadences provides sufficient oxygen consumption to produce a training effect.

Kickboxing

In his master's thesis, Immel examined the physiological responses of cardio kickboxing and compared the results as a percentage of VO_2 max (determined from a Bruce protocol treadmill test) (1999). Fifteen female subjects, ages 21 – 46 years, participated in the study. The kickboxing session was 45- 60 minutes long with a 25-30 minute period of the higher intensity kickboxing movements. Towards the end of the 25-30 minute period, the subjects wore boxing gloves (10 oz.). Heart rate results were 163 $\pm$ 10 bpm, and VO_2 results were 25.7 $\pm$ 2.7 ml $min^{-1}kg^{-1}$. Since these values represented 86% and 73% of maximum values for heart rate and VO_2, respectively, Immel concluded that kickboxing provides sufficient intensity to produce a training effect (1999).

Summary

Kickboxing is an exercise class that incorporates aerobic dance, martial arts and boxing movements. Additionally, some exercises consist of leg only movements (kicks) and other exercises consist of arm only movements (punches). Previous research has shown that aerobic dance is an effective mode of exercise (Berry et al., 1992; Blyth and Goslin, 1985; Claremont et al., 1986; Darby et al., 1995; DeAngelis et al., 1997; Foster, 1975; Grant et al., 1993; Grant et al., 1998; Milburn and Buts, 1983; Parker et al., 1989; Perry et al., 1988; Schaeffer-Gerschutz et al., 2000; Scharff-Olson et al., 1992; Thomsen and Ballor, 1991; and Williford et al., 1989). Since some movements in kickboxing require arm or leg only exercises, arm, leg and arm/leg ergometry research was studied and showed that for relative work loads, arm and leg exercise performed independently or combined can provide adequate intensity (Bergh et al., 1976; Faria and Faria, 1997; Lewis et al., 1985; Reybrouck, et al., 1975; Sedlock, 1991; Toner et al., 1990; and Vokac et al., 1975). Martial arts has also been shown to be an effective mode of exercise (Francescato et al., 1995; Imamura et al., 1999; Pieter et al., 1990; and Shaw and Deutsch, 1982). Boxing has been shown to produce energy expenditure equivalent to exercise 9.2 miles in 1 hour (Bellinger et al., 1997), and it has also been shown to provide intensity within ACSM intensity guidelines (Kravitz et al., 2003). Kickboxing research is limited. Immel (1999) concluded that kickboxing did elicit effective heart rate and VO_2 responses to create a training effect in his master's thesis. Therefore, the purpose of this study is to compare the VO_2 differences between kickboxing and treadmill exercise at similar heart rates.

CHAPTER III

METHODOLOGY

Subjects

The subjects were recruited from Christopher Newport University (CNU) and Old Dominion University (ODU). Flyers were posted (see *Appendix A*), and announcements were made in CNU Beginning Aerobics classes. Eleven females (ages 18 – 22 yrs) participated in the study. The subjects completed a health/medical questionnaire based on the American College of Sports Medicine guidelines (see *Appendix B*) as well as an informed consent form (see *Appendix C*). The protocol was approved by Old Dominion University's Institutional Review Board and by Christopher Newport University's Human Subjects Review Board.

The subjects reported to the laboratory for approximately a two-hour testing session. One session was conducted at the ODU Human Performance Lab while ten sessions were conducted at the CNU Dr. Robert L. Cummings Human Performance Lab. The lead investigator explained the informed consent form, the procedures, the protocol and the equipment. The Borg (1973) rating of perceived exertion scale was also explained, and a picture of one was available as a reference during the testing (see *Appendix D*). The first part of the session involved obtaining height, mass and resting heart rate measurements (after the subjects rested for ten minutes). The subjects were then set up with the appropriate equipment.

The online $K4b_2$ Portable Metabolic System (Rome, Italy) was utilized during the kickboxing and treadmill sessions to measure VO_2. Calibration tests were performed prior to each testing session. This included gas analysis using standard concentration commercial gases as well as a flow meter analysis using a 3.0 L syringe. Heart rate was measured using a Polar Heart Rate Monitor (Sweden). Rating of perceived exertion was determined using the Borg scale (1973).

Kickboxing Protocol

The subjects participated in five-minute kickboxing segments including a warm-up, a punching phase, a kicking phase and a combination phase (punches and kicks). The phases were performed in a counterbalanced order. The phases were: punching-kicking-combinations; kicking-combinations-punching; combinations-punching-kicking; punching-combinations-kicking; kicking-punching-combinations; and combinations-kicking and punching. The exercises were performed to music (Dynamix, Janis Saffell's "Kick It, Vol.1"). The warm-up included marches, bob and weaves, jabs, crosses, hooks, upper cuts, knee lifts, side kicks, front kicks, roundhouse kicks and back kicks. The warm-up was performed at a cadence of 135 bpm (set by the music). The subject rested for two minutes before performing the next segment. These rest periods were interspersed between the segments.

The punching phase consisted of jabs, crosses, hooks and upper cuts while the lower body remained still in ready position. The kicking phase included knee lifts and front, side, back and roundhouse kicks. During the kicking phase, the arms remained in ready position with the elbows bent and hands at chin level. The combination phase included sequences such as: jab/jab/cross/knee/front kick; front kick/side kick/back kick/cross; jab/cross/jab/cross/front kick/roundhouse; and side kick/side kick/uppercut/hook, alternating lead sides. These segments were performed at a cadence of 130 bpm (set by the music). The session ended with a 5-minute cool down consisting of marches, grapevines and side steps. The subject then rested for thirty minutes before performing the treadmill test.

Treadmill Protocol

A modified Bruce protocol was utilized for the treadmill test. Five minute stages were performed. The Quinton Q-Stress TM55 treadmill system (Bothell, WA) was utilized to regulate the speed and grade during treadmill exercise. The $K4b_2$ Cosmed Portable Metabolic System and a Polar Heart Rate Monitor were utilized to measure VO_2 and heart rate, respectively. The Borg scale (1973) was utilized to measure RPE. The speed and/or grade were increased every five minutes until the subject reached exhaustion or the final stage. The stages consisted of the following speed and/or grade combinations: stage 1, 1.7 mph, 0% grade; stage 2, 1.7 mph, 5% grade; stage 3, 1.7 mph, 10% grade; stage 4, 2.5 mph, 12% grade; stage 5, 3.4 mph, 14% grade; stage 6, 4.2 mph, 16% grade; and stage 7, 5.5 mph, 20% grade.

Statistical Analysis

Descriptive data were computed. Linear regression was utilized to interpolate the treadmill VO_2 that occurred at heart rate values elicited during kickboxing. A general linear model two-factor repeated measures ANOVA was utilized to compare VO_2 results among the punch, kick and combination phases of kickboxing and the results between the kickboxing VO_2 and the treadmill VO_2. The differences (Δ) between treadmill and kickboxing VO_2 at similar heart rates were analyzed using t-tests.

The significance level was set at $p < 0.05$. The statistical software package, SPSS (v. 13.0) was utilized to compute the results.

CHAPTER IV

RESULTS

Table 1 shows the physical characteristics of the subjects including age, height, body mass, resting heart rate, VO_2 max and maximum heart rate. There were a total of 11 subjects who participated in the study.

Table 1. Subject characteristics

N=11	Age (yrs)	Height (cm)	Mass (kg)	Resting HR (bpm)	VO_2 max (ml min^{-1} kg^{-1})	Max HR (bpm)
Mean	19	165.3	62.6	75	27.8	170
SD	1	5.0	12.2	11	6.6	16

Table 2 summarizes the heart rate results from the punch, kick and combination phases of kickboxing.

Table 2. Kickboxing heart rate results

N=11	Punch HR	Kick HR	Combo HR
Mean	133	149	144
SD	16	20	22

Table 3 summarizes the VO_2 results for the punch, kick and combination phases of kickboxing.

Table 3. Kickboxing VO_2 results

N=11	Punch VO_2 ml min^{-1} kg^{-1}	Kick VO_2 ml min^{-1} kg^{-1}	Combo VO_2 ml min^{-1} kg^{-1}
Mean	14.4*	18.9 *	17.6*
SD	5.1	4.6	3.7

*$p < 0.05$; VO_2 results were significantly different among the kickboxing modes ($p = 0.043$)

Table 4 summarizes the RPE results for the punch, kick and combination phases of kickboxing.

Table 4. Kickboxing RPE results

N=11	Punch RPE	Kick RPE	Combo RPE
Mean	12	13	13
SD	2	2	2

Table 5 shows the heart rate, VO_2 and RPE results for each treadmill stage.

Table 5. Treadmill HR, VO_2 and RPE results

	Stage 0	Stage .5	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
HR	98 ± 12	109 ± 11	122 ± 14	146 ± 18	164 ± 18	173 ± 17	166 ± 0
VO_2 (ml min^{-1} kg^{-1})	8.6 ± 1.5	10.9 ± 1.6	14.7 ± 2.7	21.1 ± 3.6	25.2 ± 3.6	31.5 ± 7.0	35.9 ± 0
RPE	7 ± 1	9 ± 2	11 ± 2	14 ± 2	18 ± 2	18 ± 2	19 ± 0
N	11	11	11	11	11	5	1

To compare kickboxing VO_2 and treadmill exercise VO_2 at similar heart rates, linear regression was used to interpolate treadmill exercise VO_2 that occurred at heart rates elicited during kickboxing (Fig. 1). The differences (Δ) between kickboxing and interpolated treadmill exercise VO_2 at similar heart rates were analyzed using t-tests and were found to be statistically significant (Table 6).

Figure 1. Linear regression interpolating treadmill VO_2 from kickboxing VO_2 at similar heart rates (for Subject 1)

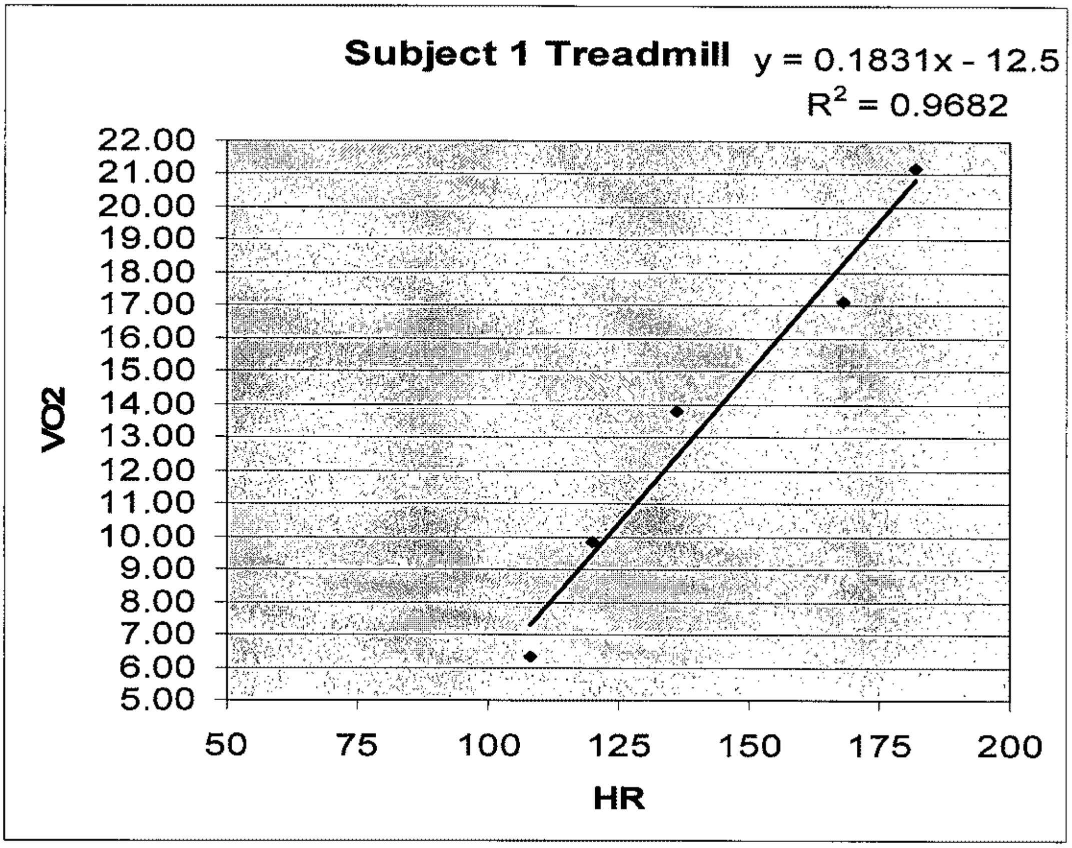
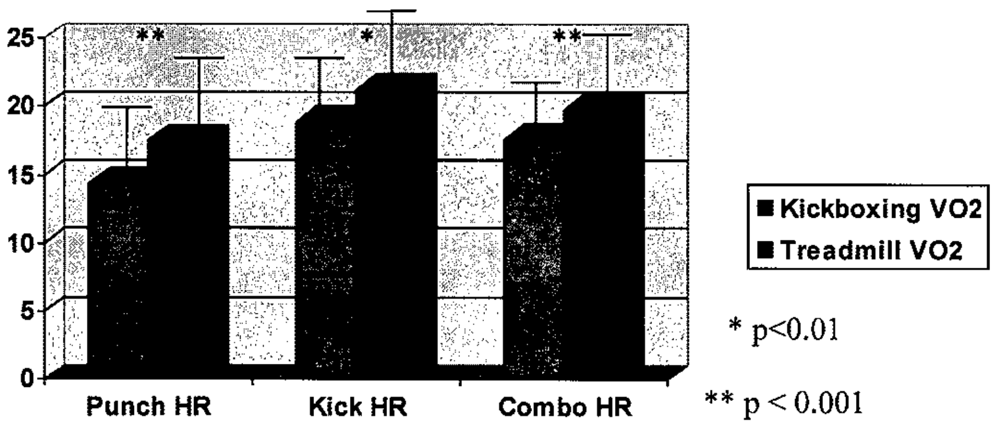


Table 6. Differences between interpolated treadmill exercise VO_2 and kickboxing VO_2

	Punch HR	Punch VO_2	TM VO_2 I	Punch diff	Kick HR	Kick VO_2	TM VO_2 I	Kick diff	Combo HR	Combo VO_2	TM VO_2 I	Combo diff
Mean	**133**	**14.4**	**17.5**	**3.2**	**149**	**18.9**	**21.3**	**2.4**	**144**	**17.6**	**19.8**	**2.3**
SD	16	5.1	5.3	2.2	20	4.6	4.8	2.2	22	3.7	4.4	1.6

The treadmill and kickboxing VO_2 Δ at heart rates of 133 bpm (3.2 ml $min^{-1}kg^{-1}$ $\pm$2.2, t = 4.71), 149 bpm (2.4 ml $min^{-1}kg^{-1}$ $\pm$2.2, t = 3.66), and 144 bpm (2.3 ml $min^{-1}kg^{-1}$ $\pm$1.6, t = 4.73) were found to be statistically different (Fig. 2).

Figure 2. Comparison of Kickboxing VO_2 and Interpolated Treadmill VO_2 at similar heart rates



As shown in Figure 2, t-tests revealed significant differences between the kickboxing VO_2 and interpolated treadmill VO_2 at similar heart rates. The punch phase elicited a heart rate of 133 $\pm$ 16 bpm, a kickboxing VO_2 of 14.4 $\pm$ 5.1 ml $min^{-1}kg^{-1}$ and an interpolated treadmill VO_2 of 17.5 $\pm$ 5.3 ml $min^{-1}kg^{-1}$. The kick phase elicited a heart rate of 149 $\pm$ 20 bpm, a kickboxing VO_2 of 18.9 $\pm$ 4.6 ml $min^{-1}kg^{-1}$ and an interpolated treadmill VO_2 of 21.3 $\pm$ 4.8 ml $min^{-1}kg^{-1}$. The combo phase elicited a heart rate of 144 $\pm$ 22 bpm, a kickboxing VO_2 of 17.6 $\pm$3.7 ml $min^{-1}kg^{-1}$ and an interpolated treadmill VO_2 of 19.8 $\pm$ 4.4 ml $min^{-1}kg^{-1}$. T-tests revealed significant differences in VO_2 (Δ) for each heart rate achieved (punch, kick and combo): 4.71 ($p<0.001$), 3.66 ($p<0.01$) and 4.73 ($p<0.001$), respectively.

CHAPTER V

DISCUSSION

Comparison of kickboxing phases (punch, kick, combination)

The kick phase of kickboxing elicited a higher VO_2 than the punch and combination phases while VO_2 for all three phases were significantly different from each other. Previous research showed similar results. Bergh et al. (1976) found that VO_2 decreased when arm ergometry was added to leg ergometry. In another study, static two-knee extension elicited a significantly higher VO_2 than static handgrip (Lewis et al., 1985). One explanation is that exercise intensity depends on the muscle mass recruited. As defined by the American College of Sports Medicine, effective modes of exercise are those that use the larger muscle groups, requiring more oxygen and engagement of the aerobic system (2000). Another explanation for this difference is that arm muscles are relatively smaller in size than lower body muscles and are therefore more susceptible to localized muscle fatigue. As a result, an individual will reduce his or her intensity because he/she feels the exercise is hard enough.

Other previous studies found results that conflicted with the present study. Vokac et al. found that arm and leg exercise resulted in similar VO_2 at similar heart rates (1975). At higher work levels, arm exercise actually elicited higher heart rate and oxygen consumption which could be attributable to engagement of the sympathetic drive causing an increase in heart rate. Reybrouck et al. (1975) found no significant VO_2 difference between arm, leg and arm/leg ergometry. However, heart rate was significantly lower in arm ergometry compared to leg ergometry and combined arm/leg ergometry at similar

VO_2 measurements. Toner et al. (1983) found that as more arm movements were added, VO_2 increased significantly while heart rate did not increase. Faria and Faria showed that for relative workloads, upper body and lower body exercise elicited similar VO_2 and heart rate responses (1997). Even post exercise oxygen consumption levels have been shown to be similar between arm and leg cranking (Sedlock, 1980).

Comparison of kickboxing VO_2 and treadmill exercise VO_2 at similar heart rates

The present study also found significantly lower VO_2 in kickboxing and treadmill exercise at similar heart rates. Parker et al. (1989) found that aerobic dance produced a VO_2 comparable to treadmill exercise; however, heart rate was significantly higher in aerobic dance. Therefore, at a given target heart rate, VO_2 was lower in aerobic dance compared to treadmill running. The researchers compared heart rate and VO_2 in subjects who participated in 20 minutes of aerobic dance and then 20 minutes of treadmill exercise. Arm exercises increase sympathetic drive which causes the heart rate to increase. Additionally, the difference in VO_2 could be explained by the fluctuations of movements during the aerobic dance routine. During aerobic dance, engagement of the arm and/or leg muscles vary whereas in treadmill exercise, the leg muscles are in constant motion (Parker et al., 1989).

Imamura et al. (1999) also found that S-Basics, M-Basics, Tech I and Tech II karate exercises elicited higher heart rates during exercise for a given VO_2 compared to treadmill exercise. They examined heart rate and VO_2 for 7 male black belts who performed the various karate exercises. Further, they found that the S-Basics did not provided sufficient intensity (% of VO_2 max and % of heart rate max) while the M-

Basics, Tech I and Tech II did provide sufficient intensity. The karate basics exercises consist of "punching, kicking, blocking and striking" (Imamura et al., 1999). The S-Basics exercises consist of these movements in a stationary position while the M-Basics exercises consist of these movements performed in various stances. Tech I and Tech II are sparring techniques where defensive and offensive movements are either performed without an opponent (Tech I) or with an opponent (Tech II). An explanation for the S-Basics not providing sufficient intensity could be the low impact nature of the exercise. In other words, performing the movements in a stationary position would involve keeping one foot on the floor at all times. High impact exercises include ballistic movements where both feet may leave the floor simultaneously for short periods of time (Grant et al., 1998). Intensity increases in high impact movements due to the higher ground reaction forces and loading rates (Grant et al., 1998).

Foster (1975) found that mean aerobic dance VO_2 was comparable to exercise a mile in 12 minutes and peak aerobic dance VO_2 was comparable to exercise a mile in 9.5 minutes. Milburn and Buts (1983) concluded that aerobic dance provided intensity comparable to jogging. A study by Berry et al. showed that aerobic dance elicits comparable intensity to treadmill exercise (1992). Bellinger et al. (1997) found that boxing expended calories comparable to exercise on a treadmill.

Excessive use of the arms causes an increase in sympathetic drive (Williford et al., 1989 and Parker et al., 1989). During submaximal exercise, the upper body muscles are strained because of their reduced force capability. The sympathetic drive is then triggered. Engagement of the sympathetic drive releases epinephrine and norepinephrine. These catecholamines rapidly depolarize the S-A node and as a result, heart rate increases, a condition known as tachycardia (McCardle, Katch & Katch, 1996). Also, because of this increase in heart rate due to the use of arms overhead and increased sympathetic drive, subjects may feel they are working at a higher intensity than they actually are and as a result, will lower their intensity (Perry et al., 1988).

Additionally, the kickboxing choreography used in the present study included punches (jab, cross, hook, and uppercut), as well as kicks (front, side, back, roundhouse). These movements were performed with one foot on the floor at all times. Therefore, the movements were low impact. Treadmill exercise, however, is a high impact exercise mode. There are brief periods of time where both feet are "airborne," that is, lifted off the treadmill. Higher impact moves involves movements with both feet airborne for a short period of time. Williford et al. (1989), Darby et al. (1995) and Schaeffer-Gershutz et al. (2000) found significant VO_2 differences between low and high impact movements.

Limitations

Limitations of this study include the population in which the results can be applied, lengths of the exercise phases, and the lead researcher serving as the testing instructor. The findings can only be generalized to college-aged females. The subjects who participated in this study represented a sample of this population (females, age 19 $\pm$ 1 yrs.). It could also be argued that the phases were too short (five minute segments). However, the aerobic pathway engages after two minutes of exercise; therefore, five minute segments should have provided a sufficient time to approach steady-stage cardiovascular responses. The lead investigator served as the instructor during the testing and was certified in kickboxing instruction. The movements performed during the testing phases were predetermined, and the random order of the phases performed was selected by the subject as described in the "Methodology" section. One further point for consideration when evaluating the results is that "it should be noted that not all cardio kickboxing classes are equal in regard to instructors, equipment and facilities" (Immel, 1999).

Conclusion

In conclusion, the present study showed that the kick phase of kickboxing elicited a higher VO_2 than the punch and combination phases. Additionally, kickboxing elicited a lower VO_2 than treadmill exercise at similar heart rates in college-aged women. Further research should be conducted to examine the cardiovascular effects of kickboxing compared to treadmill exercise. Different modes of kickboxing should be examined (for example, "Tae Bo" routines compared to in class routines). Longer sessions might also be part of further research criteria (20 minutes instead of 5 minutes). The testing of men and women at various ages should also be included.

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APPENDIX A

SUBJECT RECRUITMENT FLYER

Student Volunteers Needed!

Volunteers are needed to participate in a study designed to compare the oxygen consumption and heart rate responses between treadmill exercise and the components of a kickboxing class.

Subjects will participate in a 30-minute kickboxing class which will consist of a 5-minute warm-up, a 5-minute punching phase, a 5-minute kicking phase, a 5-minute punch/kick combo phase, and a 2-3 minute cool down. Subjects will also perform a maximal exercise test.

To participate, you should:

- ✓ Have participated in kickboxing classes
- ✓ Be apparently healthy
- ✓ Not be pregnant
- ✓ Be female
- ✓ Be between the ages of 18-25 years

Dates: (Saturdays) April 6, 27 Times: 10 a.m. or 1 p.m.

To be considered, please sign up and indicate date and time you are available:

NAME	PHONE#	E-MAIL	DATE/TIME

APPENDIX B

SUBJECT QUESTIONNAIRE

Title of Research Project:
A comparison of VO_2 between kickboxing and treadmill exercise at similar heart rates.
Primary Investigator: Lisa Wingfield

Name:________________________________ Date:____________________

I. Risk Factors (two or more places individual at "moderate risk")

___ 1. Have any of your parents, brothers or sisters had a heart attack, bypass surgery, angioplasty or sudden death prior to the age of 55 (male relatives) or 65 (female relatives)?

___ 2. Have you smokes cigarettes in the past 6 months?

___ 3. What is your usual blood pressure (≥ 140/90)? Do you take blood pressure medication?

___ 4. What is your LDL cholesterol (>130)? If you don't know your LDL, what is your total cholesterol (>200)? ALSO, what is your HDL cholesterol (<35)? [Either LDL (substitute total if LDL not known) or HDL is a risk. (note: "negative risk factor: HDL > 60].

___ 5. What is your fasting glucose (≥110)?

___ 6. What is your height and weight (BMI ≥ 30)? Also, what is your waist girth (>100 cm, ≥ 39.5")?

___ 7. Do you get at least 30 minutes of moderate physical activity most days of the week (or its equivalent)?

II. Symptoms (one or more placed individual at "high risk")

___ 1. Do you ever have pain or discomfort in your chest or surrounding areas? (i.e., ischemia)

___ 2. Do you ever feel faint or dizzy? (Other than when sitting up rapidly)

___ 3. Do you find it difficult to breathe when you are lying down or sleeping?

___ 4. Do your ankles ever become swollen? (Other than after a long period of standing)

___ 5. Do you ever have heart palpitations, or an unusual period of rapid heart rate?

___ 6. Do you ever experience pain in your legs? (i.e., intermittent claudication)

___ 7. Has a physician ever said you have a heart murmur?

___ 8. Do you feel unusually fatigued or find it difficult to breathe with usual activities?

III. Other

___ 1. How old are you? (men ≥ 45, women, ≥ 55 are at "moderate risk")

___ 2. Do you have any of the following diseases? Heart disease, peripheral vascular disease, cerebrovascular disease, chronic obstructive pulmonary disease (emphysema or chronic bronchitis), asthma (chronic), interstitial lung disease, cystic fibrosis, diabetes mellitus, thyroid disorder, renal disease, or liver disease (yes to any places individual at "high risk").

___ 3. Do you have any bone or joint problems such as arthritis or a past injury that might get worse with exercise? (exercise testing may need to be delayed, or modified)

___ 4. Do you have a cold or flu, or any other infection? (exercise testing must be delayed)

___ 5. Do you have any other problem that might make it difficult for you to do strenuous exercise?

INTERPRETATION

Low Risk (young, and no more than 1 risk factor): can do maximal testing or enter a vigorous exercise program
Moderate Risk (older, or 2 or more risk factors): can do submaximal testing or enter a moderate exercise program
High Risk (one or more symptoms, or disease): can do no testing without physician presence; can enter no program without physician clearance

Have you participated in a kickboxing fitness class? ___ Yes ___ No
If yes, how often (ex., 2 – 3 times per week, etc.)? ______________
If yes, for how long (one month, 6 months, a year, etc.)? ______________
Is there any chance you may be pregnant? ___ Yes ___ No
I attest that the above information is true to the best of my knowledge.

Printed Name:______________________________

Signature:_________________________________

APPENDIX C

INFORMED CONSENT FORM

Informed Consent Document

for

OLD DOMINION UNIVERSITY

INFORMED CONSENT DOCUMENT
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES.

TITLE OF RESEARCH: A comparison of VO_2 between kickboxing and treadmill exercise at similar heart rates.

RESEARCHERS: Primary Investigator - Lisa Wingfield, B.S., College of Education, Department of Health, Physical Education, and Recreation; Assisting Investigators - Elizabeth A. Dowling, PhD; J. David Branch, PhD; Sheri Colberg, PhD; and David Swain, PhD.

DESCRIPTION OF RESEARCH STUDY:
Kickboxing is a fitness class that incorporates different types of punching and jump roping techniques from boxing as well as different types of kicking from karate and other martial arts training into one class session. The concept has actually been around since the early 1990s with the release of home videos by Stephanie Steele ("Knockout Workout") and Kathy Smith ("Aerobox"). These videos focused only on the boxing aspect, teaching only punches and/or jump roping. However, it was not until Billy Blanks and his "Tae Bo" classes in 1998 that kickboxing become a popular mode of fitness classes for people of all ages. He introduced a fitness class designed of a combination of punches, kicks, jump roping and their combinations. Because of the increasing popularity of "Tae Bo," fitness clubs around the country developed similar classes to attract patrons. It has been suggested that kickboxing classes improve fitness and cause weight loss. The purpose of this study is to compare the oxygen consumption of the kickboxing phases with treadmill exercise at similar heart rates to determine if appropriate intensity levels are reached to invoke an improvement in cardiovascular fitness.

You are being asked to participate as a subject in this study. Prior to being selected you will complete a screening questionnaire to determine your eligibility to participate. You must be apparently healthy, non-pregnant, and familiar with kickboxing techniques. If selected, you will schedule one session (2 hours long) with the primary investigator to participate in an exercise session consisting of a 5 minute warm-up (to prepare your body for the exercise), 5 minutes of punching, 5 minutes of kicking, and 5 minutes of punching/kicking combinations. A 2-3 minute cool down period will follow. The exercises will be performed to music with a cadence of 135 beats per minute during the warm-up and 130 beats per minute during the kickboxing exercise phases. During the entire exercise session, you will be wearing the Cosmed Portable Gas Analyzer device which will include a mask secured around your mouth and nose as well as a small device strapped around your chest and back. Oxygen consumption and heart rate readings will be taken from this device constantly throughout the exercise session. You will also determine your rating of perceived exertion using the Borg RPE scale of 6 – 20. The Borg Scale is a subjective rating of how you feel during exercise with 6 indicating a very, very light exertion and 20 indicating a very, very hard exertion.

Next, you will rest for 30 minutes. Then, you will undergo a maximal exercise test in which your oxygen levels will be measured while you perform increasing levels of walking and exercise on a treadmill where the speed and grade will be increased at the end of each 5-minute stage. This test will measure your maximum oxygen uptake and will be conducted at the Human Performance Laboratory at Old Dominion University. Oxygen consumption and heart rate measurements will be measured by the Cosmed analyzer . You will also rate your perceived exertion using the Borg scale.

EXCLUSIONARY CRITERIA:
You should have completed the subject questionnaire prior to participation. You cannot be pregnant. You cannot be considered "moderate" or "high" risk as per the American College of Sports Medicine (a determination made upon completion of the subject questionnaire). You must not be taking medication that alters heart rate or your ability to exercise. You must also have participated in a kickboxing class to be familiar with the techniques and proper body alignment.

RISKS AND BENEFITS:
RISKS: If you decide to participate in this study, in addition to normal fatigue and muscle soreness following strenuous exercise, you may face a risk of musculoskeletal injury, abnormal blood pressure, fainting, irregular heart beat, and rarely, heart attack, stroke or death. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFIT: The main benefits to you include knowledge of your maximum oxygen consumption (determining your fitness level) and knowledge as to whether or not a kickboxing class provides sufficient intensity so that you can exercise in your target heart rate zone.

COSTS AND PAYMENTS:
The researchers are unable to give you any payment for participating in this study.

NEW INFORMATION:
If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY:
Any information obtained from this study, including questionnaires, medical history and laboratory findings, will be kept confidential. Only the primary investigator and the assistant investigators will have access to your files, in which you will be assigned a random identification number. The records will be kept in a locked file and destroyed after 3 years. The data derived in this study could be used in reports, presentations and publications, but you will not be referred to by more than your identification number. However, your records may be subpoenaed by court order or may be inspected by federal regulatory authorities.

WITHDRAWAL PRIVILEGE:
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY:
If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of injury or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact Lisa Wingfield at 757-220-3430 or Dr. David Swain at 757-683-6028 at Old Dominion University, who will be glad to review the matter with you.

VOLUNTARY CONSENT:
By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Lisa Wingfield 757-220-3430

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. David Swain, at 757-683-6028, or the Old Dominion University Office of Research and Graduate Studies, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Name & Signature: Date
Witness' Name & Signature: Date

INVESTIGATOR'S STATEMENT:

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Name & Signature: Date:

APPENDIX D

RATING OF PERCEIVED EXERTION SCALE
(Borg Scale)

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

VITA

Lisa Wingfield
Old Dominion University
College of Education
Department of Exercise Science, Physical Education and Recreation
Norfolk, VA

Education

Old Dominion University, Norfolk, VA

M.S. Ed., Physical Education (Exercise Science) candidate, May 2006 (anticipated)

Thesis: *A comparison of VO_2 between kickboxing and treadmill exercise at similar heart rates.*

University of Maryland, Heidelberg, Germany

B.S., Business and Management, December 1994

Professional Affiliations & Certifications

- Health/Fitness Instructor Certification and Member, ACSM
- Primary, Step, Kickboxing and Personal Trainer Certifications, AFAA
- Basic Pilates, AAAIHED
- R.A.D. (Rape Aggression Defense) Instructor Certification, R.A.D.
- Spinning Certification – Madd Dogg Athletics
- Adult CPR/First Aid/AED Certification, American Red Cross

Employment History

Christopher Newport University, Newport News, VA

The Freeman Center

Trieshmann Health and Fitness Pavilion Director, September 2004 - present

Office of Human Resources

Coordinator, Recruitment, Training and Development, August 2002 – September 2004

Center for Community Learning

Director, December 2000 – August 2002; Coordinator, July 1997 – December 2000; Program Support Technician, September 1996 – July 1997

Department of Recreation, Sports and Wellness

Adjunct Instructor, Aerobics and Health, August 1998 – December 2002

University of Maryland, Illesheim, Germany

Field Representative, July 1992 – July 1995

Pines Golf Course, Fort Eustis, VA

Office Assistant, May 1991 – September 1991
Recreation Aide, Seasonal, May 1988 – May 1991