Motor Fitness Profiling of Elite and Novice Karate Practitioners

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ABSTRACT

Despite the popularity of karate as a sport and its rise to Olympic status, evidence-based data to guide approaches to talent identification/development and training practices are lacking. Thus, the aims of this study were to assess in elite and novice karate practitioners: (i) general and karate-specific motor fitness characteristics that discriminate these two groups; (ii) the energetic demands of karate sparring; and (iii) decrements in performance following simulated karate sparring. Elite male national and international sparring competitors (black belt and above; N=12) were compared to a group of novice karate participants (green belt and lower; N=12). Between the groups, there were differences in punching power ($P<0.05$), punching speed ($P<0.01$), karate agility ($P<0.05$), seated lateral leg flexibility ($P<0.01$), sit and reach flexibility ($P<0.05$), static balance ($P<0.01$), Margaria-Kalamen power test ($P<0.05$), peak arm ergometer cadence ($P<0.001$), and Wingate peak power ($P<0.05$), with no differences in $\dot{V}O_{2\,max}$ or Wingate mean power. Results from the discriminate analysis identified that general motor fitness and karate-specific tests discriminated karate sparring abilities with almost equal effectiveness, with the discriminant analysis stepwise method showing that punching speed and seated lateral leg flexibility have the best capacity to differentiate elite from novice practitioners. Measures of oxygen consumption during a three-minute bout of simulated sparring showed a similar average aerobic relative demand between groups (elite: 61%$\dot{V}O_{2\,max}$; novice: 63%$\dot{V}O_{2\,max}$; $P=0.79$; effect size = 0.08), while peak values for the elite group (68% $\dot{V}O_{2\,max}$) were lower than the novice group (80%$\dot{V}O_{2\,max}$; $P=0.07$; effect size = -0.88). Fatigue from simulated sparring resulted in elite and novice participants displaying decreases in punching speed and punching power, increases in punching response time to a stimulus, and increased blood lactate concentrations. While elite participants still performed better in these measures post sparring, the reductions in performance occurred at similar rates, except for a greater relative loss in punching speed in the elite group. Taken together, the data suggest that both general and karate-specific motor fitness characteristics related to peak anaerobic power, agility and flexibility can discriminate between elite and novice practitioners. Assessment of these qualities, together with an understanding of energy utilisation and fatigue decrements during sparring, may assist in (i) identifying and/or developing talent at early stages of karate participation, and (ii) designing training programs that focus on performance characteristics that best discriminate between elite and novice karate practitioners, to optimise karate sparring preparation for all standards of participant.

STATEMENT OF AUTHORSHIP

Except where reference is made, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified or been awarded another degree or diploma.

No other person's work has been used without acknowledgment in the main text of the thesis.

This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

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JAPANESE TERMS USED IN THE THESIS

Karate: Empty hand. Using arms and legs for attacking and defending.

Kumite: Sparring or fighting.

Kata: katas are pre-planned, controlled movement sequences consisting of kicking, blocking and punching techniques.

Kihon: Basic karate techniques. Usually practiced to improve sparring ability.

Heian Shodan: First of twenty four katas practiced in the Shotokan Karate style.

Seinsan kata: Basic kata in Chito-Ryu karate style.

Green belt: Fourth of ten color belt levels in karate.

Black belt: The highest of karate colour belts.

Karateka: An individual who practices karate (Kanazawa, 1990).

CHAPTER ONE

1.1 Introduction

Karate is the art of hand and foot fighting with basic techniques such as punching, kicking, blocking and striking practiced either in a stationary position or with body movements in various formal stances. In Japanese, the term karate means “empty hand” to illustrate the techniques of fighting with the body’s natural weapons (Plee, 1967). The sport of karate has been in existence for approximately five thousand years and is probably the oldest Martial Art: that is to say, the oldest set of fighting techniques for killing and avoiding being killed (Naidu, 1994). With respect to participation, karate is one of the ten largest sports in the world and has achieved international recognition by its inclusion in the Modern Olympic Games since 2000 (AKF, 2012). In Australia, the Australian Karate Federation (AKF) includes all styles of karate in its rules. There are now 105 affiliated styles and an individual membership of over 58,000 practitioners, making it the largest of the martial art organisations recognised by the Australian Sports Commission (AKF, 2012).

Competition rules from one karate style to another may differ significantly (e.g. full contact, semi-contact, and non-contact sparring), and the sparring rules and duration vary from one karate school to another (i.e. WKF/AKF rules – see Appendices 18, 19 & 20). Therefore, existing research on karate sparring conducted in specific styles may not be representative of All Styles of Karate, where competition rules have been designed by the World Karate Federation (WKF), of which Australia is a member. All Styles of Karate (in which this research was undertaken) represents over 100 styles worldwide, but the sparring rules are the same for all the participating members. The rules in this organisation are those that are recognised by the World Olympic Committee (WKF, 2012).

In Australia, different karate schools have their own tournaments, and the most successful practitioners are then chosen to represent their style in AKF competitions under All Styles of Karate rules. These successful competitors may or may not perform with the same success as they have done in their own karate style. Therefore, the successful athletes in AKF championships are the best representatives of all the karate styles. As a result, choosing participants for a research study from this group is a better representation of the ability standards of Australian karate athletes (WKF, 2012).

1.2 Kumite and Kata

Kumite is the Japanese term for sparring and is the execution of defensive and offensive techniques while freely moving against an opponent (Plee, 1967). The duration of the sparring is three minutes, but normally due to stopping of the bout to give scores, refereeing decisions and injury management, it is between four and five minutes. Even though karate matches will normally last between four and five minutes, in theory competitors only have to strike sixteen accurate punches to win the match. However, at the elite level, competitors often score few points. The main reason is that a participant wants to encourage the other to initiate the attack because it is believed to be easier to score a point if you are the defender. Thus, the scores could be as low as four points between the two competitors, meaning that little attacking was initiated (WKF, 2012).

Attacks in karate are normally made with hand or fist (punches) and foot (kick). The main goal is to deliver the punch or kick with as much force as possible during sparring. The body parts must be moved rapidly and, therefore, muscle shortening must be achieved quickly. In a karate sparring match, often only one fast movement is needed in order to score a point. The use of speed and power is dictated by the purpose of the techniques (Adrian & Cooper, 1995).

Competition sparring in karate uses a greater distance between the opponents than in many other styles of martial arts because of the longer kicks used in the sparring. The competitors move regularly, searching for an opening target before they strike. On average, the participants may engage in sparring between 11% and 17% of the time spent in the court, with the duration that participants engage each other to score a point being between one to three seconds (WKF, 2012; Beneke, Beyer, Jachner, Erasmus, & Mutler, 2004).

Karate kata are pre-planned, controlled movement sequences consisting of kicking, blocking and punching techniques, but can also include stepping, jumping, turning and sliding movements. Kata practice is normally used to improve kumite and it is believed that by training in kata regularly, it will increase body strength, power, balance and agility. The speed, timing and duration of each kata will vary depending on the degree of difficulty of the kata. Individuals can change the speed of the katas that they are practicing depending on their level, age and rank. The goal of the training affects how the kata is performed; for example, whether the goal of training is for competition, fitness or health (Kanazawa, 1990). However, in senior WKF championships, generally the kata competitors do not participate in the kumite division and vice versa (WKF, 2012). The reason may be that in order to be successful in each discipline at the elite level, specific motor fitness skills are required.

1.3 Rationale of the Research

The ideas and explanations of the authors of karate text books are primarily based on their own anecdotal experiences, with a lack of empirical evidence to support their statements. Often the views of instructors regarding the training and conditioning of athletes for sparring in karate are in conflict with each other and, thus, competition training is also largely based on experience or traditional practices.

There is minimal research on karate within the sport and exercise science databases, with the following databases searched for the literature review to follow: Academic Search Premier, Clinical Reference Systems, Health Source: Nursing/Academic, SPORTS Discus, MEDLINE, Springer Link, Highwire Press-free journals, Expanded Academic ASAP, Human Kinetics Journals, Australian Sport Database and Meditext. Of the literature available, most were based on karate kata training, basic karate exercises and basic sparring rather than competition sparring. The participants in many of these studies included children and female karate athletes. Furthermore, some of the studies were based on martial arts that are not considered to be karate. There was also an absence of WKF/AKF rules and regulations during the simulated sparring matches in all except one study by Roschel, Batista, Monteiro, Bertuzzi, Barroso, Loturco, Ugrinowitsch, Tricoli and Franchini (2009). Thus, the current study focuses on male karate athletes and the use of WKF/AKF rules. With these rules and durations of sparring often differing significantly from other karate styles, the examination using WKF/AKF rules in this study makes it justifiably different to the existing research. Appendices 24-26 contain detailed information on competition sparring, kihon (basic karate techniques) sparring, WKF/AKF sparring rules and regulations, and the martial arts that are not considered to be karate.

In practical terms, the All Styles of Karate coach has a very difficult task when approaching training with state or national teams because the members of the team will be from different schools of karate and, thus, have their own ideas about techniques which originate from their particular karate schools. Therefore, the profiling of motor fitness components (i.e. energy system utilisation and general and karate-specific motor fitness characteristics) as they relate to karate ability under WKF/AKF rules may shed light on discriminators of successful performance. These data could contribute to evidence-based approaches to the practice of karate, enabling athletes to train more efficiently, achieve higher standards in the sport, and assist with the creation of reliable and objective performance benchmarks.

CHAPTER TWO

2.0 Review of the Literature

Current practice in training and competition for karate is mainly experiential and traditionally based. At this point in time, it is unclear which motor fitness and skill factors differentiate the high performance athlete in karate from lesser skilled practitioners. While there is some research available on the sparring and general fitness aspects of karate, the majority of this research does not involve elite male karate participants from karate schools that utilise World Olympic Committee sparring rules and regulations (i.e. WKF/AKF rules – see Appendices 18, 19 & 20). Thus, the following review includes literature from a range of martial arts schools, male and female athletes of different ability levels, young/adolescent athletes performing a variety of sparring types, general karate training and kata performances. A review of these studies will provide an insight into the knowledge gaps that exist in the current literature.

2.1 Physical Fitness Discriminators in Karate Athletes

Roschel, Batista, Monteiro, Bertuzzi, Barroso, Loturco, Ugrinowitsch, Tricoli and Franchini (2009) investigated, in international level karate athletes, the relationship between strength/power abilities and performance in a simulated sparring match. Fourteen male black belts aged 27 ± 4 years participated in this study. Following a simulated championship sparring competition (WKF rules) among the fourteen participants, the winners and the losers were allocated to two separate groups. Between the two groups, there were no differences in strength, bench press and squat power using 60% 1RM, vertical jump height, anthropometric data, or blood lactate concentrations post-simulated matches (5.1 ± 1.2 and 5.2 ± 2.2 $mmol.L^{-1}$, respectively). However, the winners had significantly greater values for bench press and squat power using 30% 1RM compared to the defeated group. Similarly, Keshishian (1998) investigated the physical qualities of high performance karate by comparing 10 elite male karate players with 10 male novices. The elite group performed better in long jump, push ups, agility, balance, and sit and reach test, while there were no significant differences in stature, body mass and shuttle run tests for aerobic power. Ravier, Grapper and Rouillon (2004) also reported international level

Karate competitors to have greater values for cycle sprinting velocity, optimal pedalling velocity and squat jump performance when compared to the national level competitors. Taken together, these data suggest that international/elite level karate athletes are characterised by greater levels of upper and lower limb power production and greater overall alactic power generation capabilities. Therefore, power appears to play an important role in karate performance. These findings might be expected given that awarding points in a sparring match depends on the power and the speed of an attack (WKF, 2012). While these studies have increased the understanding of the physical qualities related to karate, all studies utilised general tests of motor ability. The measurement of qualities specific to the movement demands of karate may provide greater insight into the sport-specific traits necessary for success in the sport.

When examining both anaerobic and aerobic capacities of highly competitive and novice karate athletes, Imamura, Yoshimura, Uchida, Nishimura and Nakazawa (1998) found significant differences between the two groups in lean body mass, bench press strength, half squat strength and maximum pulmonary ventilation, but no differences in percentage body fat, maximal oxygen uptake ($\dot{V}O_{2\max}$), peak blood lactate concentration or maximum heart rate. The greater strength of the elite compared to the novice karate participants may have been influenced by their greater training history. In contrast, Jui-Chia, Lin and Esposito (2003) investigated the variation in heart rate and oxygen consumption for Tae-Kwon-Do participants during training performance and showed that experienced players had significantly greater $\dot{V}O_{2\max}$ than novice competitors.

Shaw and Deutsch (1982) investigated the $\dot{V}O_2$-heart rate relationship during continuous and intermittent karate in regular training. Ten karate practitioners were chosen to perform the Heian Shodan kata (first of twenty four katas). These katas were performed in four different ways: (a) the kata was performed 15 times without rest at two different paces; the slow pace (45 s) and fast pace (30 s), with the total time spent doing these katas continuously being 7.5 and 11.2 minutes, respectively, and (b) the kata was performed 15 times with one minute rest between each kata at these two different paces, with the total time spent doing these katas continuously being 21.5 and 25.2 minutes, respectively. The heart rate and $\dot{V}O_2$ responses were below 50% $\dot{V}O_{2\max}$ in all protocols except for kata performed at the continuous 30 seconds pace, indicating that, in general, the performance of Heian Shodan kata is of low aerobic intensity.

Ravier, Dugue, Grapper and Rouillon (2006) investigated anaerobic and aerobic fitness in ten male international competitors from the French national team and eight competitors at national level. The two groups had similar maximal oxygen uptake (57.6 vs. 59.4 $ml.kg^{-1}.min^{-1}$, respectively) and maximal accumulated oxygen deficit. However, international class athletes had lower blood lactate, hydrogen ion and plasma ammonia concentrations after exhaustive exercise (2-3 minutes at 140% $\dot{V}O_{2\,max}$ velocity) on a treadmill ergometer. The greater concentration of these metabolites in the national karate group post-exhaustive exercise may be related to either a higher anaerobic contribution to energy supply or, alternatively, a more efficient removal of these metabolites in the international group. Unfortunately, Ravier et al. (2006) did not include other more sport-specific tests of energy utilisation, such as sparring responses, in their study.

2.2 Training and Sparring Responses in Karate Athletes

Imamura, Yoshimura, Uchida, Nishimua and Nakazawa (1996) investigated, in trained karate athletes ($\dot{V}O_{2\,max}$ 57.4 ± 7.6 $ml.kg^{-1}.min^{-1}$), the changes in heart rate and perceived exertion of 20 continuous karate sparring matches, each of two minutes duration. Mean resting heart rate before the match was 83.5 ± 11.3 beats per minute. The average heart rate during the matches was 191.8 ± 9.4 beats per minute, equal to 96.7 ± 4.2% of the predicted heart rate maximum. The rating of perceived exertion at the end of the match was 19 ± 2 using Borg's 20-point scale therefore, the karate participants were able to continue the 20 sparring matches with an intensity close to the maximum heart rate.

Zehr and Sale (1993) investigated the acute training response to Seinsan kata (basic kata in Chito-Ryu karate style) in four male black belt athletes (age 28 ± 4.2 y). These athletes performed Seinsan kata continuously for 10 minutes at medium pace and fast pace. The average $\dot{V}O_2$ during the medium pace kata was 73 ± 3% and during fast pace was 94 ± 2% of the leg cycling $\dot{V}O_{2\,peak}$. The average heart rate for medium pace was 93 ± 6% and for fast pace was 101 ± 3% of the heart rate maximum achieved during the cycle test. The blood lactate concentration in the post-kata performance for the medium and fast paced performances were 12 ± 4% and 22 ± 6%, respectively, of the peak value attained from the cycling $\dot{V}O_2$ peak test. These results indicate that Seinsan kata induce significant metabolic stress in karate practitioners, but sparring duration is only 3 minutes compared to 10 minutes of kata performance. Moreover, katas are often performed continuously while karate sparring is intermittent in nature.

Imamura, Yoshimura, Nishimura, Teshima, Miyamoto and Nakazawa (2002) examined the physiological responses to five types of karate exercises in six female black belt athletes. These exercises included fundamental karate techniques with and without leg movements, sparring techniques with and without opponents, and kata. The excess post-exercise oxygen consumption (EPOC) that generally replenishes the high-energy phosphates depleted by exercise was assessed in the five minutes immediately following the 70 minutes of karate exercises. EPOC did not differ from resting $\dot{V}O_2$, and blood lactate responses to the five types of karate exercises ranged from 1.2 to 2.2 mmol.L^{-1}.

A study by Markovic, Vucetic and Cardinale (2008) examined the heart rate and blood lactate responses prior to, during and post-competition in seven female international Tae-Kwon-Do (a Korean martial art) competitors (age 22.9 ± 3.5 y; $\dot{V}O_{2\,max}$ 49.8 ± 2.8 ml.kg^{-1}min^{-1}). The heart rate response during the match was 91.7 ± 2.6% HR_{max}, while mean lactate concentration at 3 minutes post-sparring was 82% of lactate peak values (14.1 ± 1.1 mmol.L^{-1}) measured after the $\dot{V}O_{2\,max}$ test, indicating that competitive Tae-Kwon-Do sparring provokes significant physiological stress.

Vujkov, Obadov and Vujkov (2009) compared the differences in physical fitness in kumite and kata performances in elite female karate participants. The mean $\dot{V}O_{2\,max}$ for the kata athletes was 56.9 ml.kg^{-1} min^{-1} and for the kumite group was 49.7 ml.kg^{-1} min^{-1}. The female athletes performed four katas with 15 minutes rest between each kata. The kumite athletes each performed four kumite matches of two minutes in duration and 15-20 minutes rest between the sparring. The heart rate and blood lactate responses were measured for both groups pre and post-kata and kumite. Heart rate responses of kata and kumite athletes were 96% and 90% of age-predicted maximal heart rate, respectively. Mean blood lactate concentration at five minutes post activity for kata athletes was 9.4 ± 1. 7 mmol.L^{-1} and for the kumite athletes was 6.8 ± 0.4 mmol.L^{-1}. Doria et al. (2009) investigated blood lactate responses of karate athletes following a 30-second Wingate anaerobic test and compared them to those for simulated karate sparring. Blood lactate concentration following the anaerobic Wingate tests was 12.0 ± 1.8 mmol.L^{-1}, while for the simulated fight, blood lactate concentrations was an average 7.5 ± 2.4 mmol.L^{-1}. This suggests that three minutes of simulated fighting has a lower anaerobic glycolytic demand than the Wingate anaerobic test.

Overall, a number of studies have reported smaller increases in blood lactate concentration in elite karate athletes compared to non-elite athletes during high intensity exercises, karate sparring and associated techniques.

2.3 Energy Systems in Karate

Beneke et al. (2004) investigated the energetics of karate kumite in ten nationally/internationally ranked male karate athletes. They performed four sparring matches each, and were judged as per a championship. Oxygen uptake was measured continuously with a portable spirometric device, and blood lactate concentration was determined immediately before and after each sparring match. The average peak $\dot{V}O_{2\,max}$ per sparring match was 52.4 ml.kg^{-1}.min^{-1}, while blood lactate concentrations rose from a resting 1.7 mmol.L^{-1} to a post-sparring value of 7.6 mmol.L^{-1}. During sparring, the high intensity actions (punches, kicks and blocks) were 1 to 3 seconds in duration and there was a mean of 3.4 high intensity actions per minute. The proportions of aerobic, anaerobic alactic, and lactic energy contributions were 77.8%, 16.0%, and 6.2%, respectively, suggesting that overall metabolism of karate sparring is not anaerobically dominated. However, $\dot{V}O_{2\,max}$ of the participants was not measured and, thus, the relative intensity that the peak $\dot{V}O_2$ attained during sparring represents cannot be determined.

Iide, Imamura, Yoshimura, Yamashita, Miyahara, Miyamoto and Moriwaki (2008) examined the physiological responses of simulated karate sparring in six black belt men (age 18-20 y) and six black belt boys (16-17 y). The peak $\dot{V}O_2$ and the blood lactate during two minutes of sparring was 42.3 ± 1.9 ml.kg^{-1}min^{-1} and 3.1 ± 1.0 mmol.L^{-1}, respectively. The peak $\dot{V}O_2$ and the blood lactate for three minutes of sparring was 47.8 ± 8.0 ml.kg^{-1}min^{-1} and 3.4 ± 1.0 mmol.L^{-1}, respectively, with this peak $\dot{V}O_2$ representing 84.9 ± 8.1% $\dot{V}O_{2\,max}$. Therefore, the physiological demands of three minutes sparring were significantly greater than the two minutes of sparring.

Imamura, Yoshimura, Nishimura, Nishimura and Sakamoto (1999) investigated the oxygen uptake, heart rate and blood lactate responses during five forms of karate training. Seven first degree black belts had a mean $\dot{V}O_{2\,max}$ of 58.6 ± 6.8 ml.kg^{-1}.min^{-1} [measured by the Bruce et al. (1973) treadmill protocol], heart rate maximum (HR_{max}) of 198.1 ± 8.3 beats·min^{-1} and peak blood lactate of 7.9 ± 1.3 mmol.L^{-1}. When practicing basic karate techniques practiced in a stationary position (S-Basics) for 15 minutes, basic karate techniques practiced with leg movement in different stances (M-Basics) for 10 minutes, shadow sparring (TECH I) for 10 minutes, pre-arranged sparring with a partner (TECH II) for 15 minutes and kata for 20 minutes, blood lactate concentrations ranged from 1.4 to 3.0 mmol.L^{-1}. The mean percentage $\dot{V}O_{2\,max}$ and the percentage HR_{max} for the entire 70 minute practice were 47.4 ± 5.9% and 72.6 ± 9.2%, respectively. The results indicated that the $\dot{V}O_2$ and percentage HR_{max} for these forms of training were substantially low.

Doria et al. (2009) examined the energy system requirements in 12 male and female karate athletes. The total energy cost of pre-arranged kumite, showed that the aerobic system was predominant (70%), followed by the alactic system (20%) and the anaerobic glycolytic system (10%).

The research on the energetics of karate sparring indicates variability in the reported aerobic demands in elite karate practitioners, with different sparring durations used throughout the literature. Moreover, these studies have not used WKF rules for their sparring bouts and, thus, data cannot be generalised to all styles of karate. Similarly, there is substantial variability in the data concerning the metabolic demands of karate kata and other training methods. Importantly, much of this existing research does not include novice practitioners for comparison.

2.4 Fatigue and Karate Sparring

Fatigue is defined as the inability to maintain power output or work during long or frequent muscular contractions (Shea & Wright, 1997), and when a person fatigues, their performance usually suffers. Different forms of muscular activity can be limited by various types and sites of fatigue (Allen, Lamb & Westerblad, 2008). Fatigue experienced by a marathon runner has a dissimilar biochemical basis to that experienced by a participant in a three-minute karate sparring match (Deschenes &

Kraemer, 1989). The different sites of fatigue that ultimately hinder muscular function include the central nervous system, the neuromuscular junction, and the muscle fibre (Deschenes & Kraemer, 1989; Allen et al., 2008).

Fatigue in a karate sparring may be characterized by a decrease in the karate athlete's speed, power and response time (Appendix 13). Continued sparring therefore leads to and progresses a decrease in the athlete's performance during the match. Most of the points in a karate match are scored at the beginning of the match (Appendix 13), suggesting that the fatigue that develops throughout a sparring bout progressively reduces the competitors' ability to perform at optimum work rates.

Work rates during martial arts contests likely cause significant fatigue, as demonstrated by Markovic, Vucetic & Cardinale (2008) who reported that heart rate responses during competition Tae-Kwon-Do (TKD) reached 91.7 ± 2.6% of the $HR_{max.}$ Similarly, in simulated karate sparring, Iide, Imamura, Yoshimura, Yamashita, Miyahara, Miyamoto and Moriwaki (2008) reported that the peak VO_2 during three minutes of sparring was 84.9 ± 8.1% of VO_{2max}. Therefore, the physiological demands of three minutes of sparring were significantly greater than the two minutes of sparring.

2.5 Summary of Literature Review

While there is some evidence of the metabolic demands of karate sparring, there are also many limitations recognised that may affect the transfer of these findings to other karate styles and abilities **(**Jui-Chia, Lin & Esposito, 2003; Beneke et al., 2004; Imamura et al., 1998; Ravier et al., 2006; Keshishian, 1998). It has been noted that karate training in general, and karate kata in particular, contribute to increasing general physical/cardiovascular fitness (Jui-Chia, Lin & Esposito, 2003). However, only a few studies have investigated maximal oxygen uptake ($\dot{V}O_{2\max}$) of karate practitioners, with none of the studies having addressed the physical characteristics of highly competitive practitioners. While strength was not a significant variable in discriminating between the elite and novice karate participants, a number of studies reported differences between elite and novice karate participants in power, speed, agility, balance and flexibility (Ravier, Grappe & Rouillon, 2004; Roschel et al., 2009; Douris et al., 2004; Violan et al., 1997; Fredrick & Hobusch, 1990; Schmidth, 1988).

A review of the karate texts in English from 1957-2012 make recommendations based on traditional approaches and experiential learning via coaching and competition, as to which factors should be developed for elite level karate performance. The texts mainly focus on the technical aspects, strategies of sparring, mental preparations, stretching, weight training and conditioning in a number of different karate styles. Only a limited number of evidence-based research studies evaluated aerobic and anaerobic contributions for simulated sparring. Moreover, there are limited data on the physical qualities that discriminate karate athletes of different levels, the metabolic and fatigue characteristics of karate performance, and the energy systems used during karate sparring and basic karate exercises, with many limitations in these studies. These limitations affect the generalisability of findings to other karate styles and ability levels, and their usefulness to talent identification and development, and to training program design.

2.6 Research Questions

The preceding discussion raises several research questions:

1. Which physical qualities discriminate elite and novice karate practitioners?

2. Do karate-specific motor fitness tests discriminate elite and novice karate practitioners?

3. Does three minutes of simulated sparring produce significant changes in punching speed, power and response time, and in blood lactate concentration?

4. If punching speed, power and response time and blood lactate concentrations change after three minutes of simulated sparring, are these changes significantly different between elite and novice karate practitioners?

5. What is the oxygen consumption of karate sparring for elite and novice karate participants?

2.7 Aims

The aims of this study were:

1. To identify general and karate-specific motor fitness tests that discriminate between elite and novice karate practitioners.
2. To determine and compare the fatigue characteristics of simulated karate sparring between elite and novice karate practitioners.
3. To determine and compare the energetic demands of simulated karate sparring between elite and novice karate practitioners.

2.8 Experimental Hypotheses

1. It is hypothesised that there are general and karate-specific motor fitness tests that discriminate elite from novice karate practitioners.

2. It is hypothesised that three minutes of simulated karate sparring causes significant decrements in punching speed, punching power and punching response time to a stimulus in both elite and novice karate practitioners.

3. It is hypothesised that three minutes of simulated karate sparring will not significantly increase blood lactate concentrations above resting levels in elite and novice karate practitioners.

4. It is hypothesised that there is a high aerobic demand during three minutes of simulated sparring for both elite and novice karate practitioners.

CHAPTER THREE

3.0 Methodology

3.1 Introduction

Choosing and designing tests to assess physical performance requires an understanding of those factors that contribute to success in a particular sport or athletic event. In general, physical performance is determined by the individual's capacity for maximal energy output – that is, maximal oxygen transport, aerobic and anaerobic processes, muscular strength and coordination. Many types of athletic events require a combination of the above factors for outstanding performance to occur. This work focuses on determining the variables that most influence the performance of a karate practitioner.

3.2 Research Design

This research was a combination of descriptive comparative research and intervention action research. The study was approved by the Human Research Ethics Committee of the Australian Catholic University (see Appendices 1, 2 & 3 for ethics approval letter, informed consent form and information letter to participants).

The first part of this study involved descriptive comparative research based on the karate ability of an elite and a novice group of practitioners. This research described motor fitness characteristics of these karate competitors and involved univariate (independent t-tests) and multivariate (discriminant function analysis) analyses.

The intervention action research component of the study involved testing the elite and novice participants before and after an exercise intervention with respect to specific motor fitness variables. The exercise intervention performed was a simulation of a karate match, with participants performing shadow sparring in a similar time frame to actual competition, being one round of three minutes. The three-minute round was divided into a number of fast and relaxed intervals of sparring that reflected a typical karate match. In this context, the research focused on which energy systems were utilised through measurement of oxygen consumption during the sparring and with blood lactate concentration as an index of anaerobic glycolytic demand. Several motor fitness variables were measured pre and post-sparring to assess decrement (fatigue) in performance in terms of speed, power, response time and lactate concentration.

This intervention action research also involved comparing $\dot{V}O_{2\,max}$ data (from a graded treadmill test) to $\dot{V}O_2$ data obtained during three minutes of simulated sparring. The elite and novice groups were compared to determine whether there was an interaction effect and whether one group had significantly greater $\dot{V}O_2$ demands during simulated karate sparring.

3.3 Sample Selection Criteria

The convenience sample was based on volunteer participants who signed an informed consent form, cleared by the Human Research Ethics Committee of the Australian Catholic University, and completed a health questionnaire.

The two classifications were:-

- Elite male karate competitors who had achieved success at state level in All Styles of Karate championships (winning first, second or third place), who had been practicing karate for over five years, and held a black belt or higher, with no known illnesses or injuries (n = 12; age, 33.0 ± 3.5 y; stature, 179 ± 8 cm; body mass, 76.3 ± 8.7 kg).
- Novice males who had been practicing karate for less than one year and held a green belt (fourth of ten color belt levels) or lower, with no known illnesses or injuries (n = 12; age, 30.0 ± 12.6 y; stature, 176 ± 10 cm; body mass, 76.6 ± 19.5 kg).

The sample of participants in the study came from the membership of the Australian Karate Federation (AKF). The federation consists of many karate styles, and the participants in this study were from a number of karate styles and not a single karate school. This provides a better cross-section of the karate practitioners in Australia.

3.4 Anthropometric measures

Participants dressed in light clothing and without shoes. Standing height (stature) was reported to the nearest 1 cm using a stadiometer (Wedderburn UW 150, Sydney). The stadiometer had an accuracy of ± 0.25 cm. Body mass was measured to the nearest ± 0.1 kg using a lever balance (A & D Personal Precision Scale UC-321, Tokyo, Japan). At this time, resting heart rate was also measured, with the pparticipants sitting in a chair with straight posture for three minutes, at which time heart rate was recorded using Polar CE0537 heart rate monitor (Polar Electro, Finland).

3.5 Motor Fitness Tests

General motor fitness is the ability to perform motor skills of a fundamental nature, exclusive of highly specialised sports (Baumgartner & Jackson, 1995), while karate-specific fitness tests focus on core components thought to underlie competition sparring. The tests that measure general motor abilities of the karate participants were selected to identify similarities and differences between the elite and novice participants. Table 3.1 lists the general motor fitness tests and the karate-specific motor fitness tests assessed in this study.

Table 3.1 General and karate-specific motor fitness tests

General Motor Fitness Tests

1. Margaria-Kalamen anaerobic power test
2. Standing long jump
3. Hand grip strength
4. Static balance
5. Sit and reach flexibility
6. Arm crank ergometry
7. Maximal oxygen consumption ($\dot{V}O_{2\,max}$)
8. Wingate anaerobic cycle ergometer test

Karate-specific Motor Fitness Tests

1. Karate agility
2. Seated lateral leg flexibility
3. Punching power
4. Punching speed
5. Punching response time
6. Simulated karate sparring (physiological responses)

3.6 General Motor Fitness Tests

3.6.1 Margaria-Kalamen Anaerobic Power Test

The objective of the Margaria-Kalamen test is to assess maximum anaerobic power. A staircase of sixteen stairs was used, with the steps measuring 15 cm in height. A hand-held stop watch (Sport Timer, QC B017 China) was used to assess the time taken to ascend the staircase. Previous work has shown that when measuring a 40 yard dash, stop watch scores were 0.19 ± 0.14 seconds faster than an electronic timer (Mayhew et al., 2010), indicating that variability does exist between times gathered using a stop watch versus use of an electronic timing system.

A lead-in sprint of two metres before the stairs was allowed so that participants began the stair climb at a faster velocity. Participants ascended two steps at a time, with the timing interval performed between the fourth and twelfth steps. To remove concerns of parallax error, timing was initiated at foot contact on the fourth step, and ceased at foot contact on the twelfth step. The protocol followed the recommendations of Schell and Leelarthaepin (1994). Participants performed three trials, with two minutes rest between each trial. The average of three trials, to the nearest 0.01 second, was used as the timed score and this was converted to watts (Johnson & Nelson, 1986).

The unit of power for Margaria-Kalamen anaerobic test is $Kgm.s^{-1}$. This measurement is the product of the vertical distance travelled (m) and the person's body mass (kg). This score is divided by the time (s) in which the task was completed to give $Kgm.s^{-1}$. The scores were then converted to watts by multiplying it by 9.81.

Figure 3. 1 Margaria-Kalamen Anaerobic Power Test

3.6.2 Standing Long Jump

The standing long jump was used as an indicator of leg power (Johnson & Nelson, 1986). A tape measure was used (Stanley Power Locks, Tokyo, Japan) to measure the distance when jumping forward, and the floor surface was linoleum. The reliability coefficient of the test is reported as 0.90 (Johnson & Nelson, 1986). Participants stood with feet parallel to each other and behind the starting mark; they then bent the knees, swung the arms, and jumped as far as possible. Three trials were permitted with the measurements taken from rear of the heel, and the best of the three trials (to the nearest 1 cm) was used as the final score (Johnson & Nelson, 1986).

3.6.3 Hand Grip Strength

Muscular strength is the maximum force that a muscle group can exert over a brief period. The hand grip dynamometer was used to measure upper limb strength (Grip dynamometer, S32910, Tokyo, Japan). The reliability coefficient has been reported as 0.90 (Johnson & Nelson, 1986). The pointer was reset to zero before each use. Participants were asked to grip the hand grip dynamometer with their preferred hand while standing with their feet shoulder width apart. They then raised the hand grip dynamometer above the head and brought it down to their side while simultaneously squeezing the handle. They were also asked to breathe out on the way down. Participants performed three trials and their best score recorded. Calibration was performed using weights of known standardised mass.

3.6.4 Static Balance

Balance is the ability to maintain body position, which is essential to the successful execution of motor skills. Two general types of balance are commonly recognised. Static balance is the ability to maintain total body equilibrium while standing on one spot, and dynamic balance is the ability to maintain equilibrium while moving from one point to another (Baumgartner & Jackson, 1995). A properly balanced position is important for effectiveness of the kick. It also affords protection against a possible counterattack to the groin area (Fredrick & Hobusch, 1990). The ability to counter an attack under any circumstances depends largely on the maintenance of correct form. For techniques to be powerful, fast, accurate and smoothly executed, they must be launched from a strong and stable base (Nakayama, 1983).

For static balance, a wobble board (AOK Health, Sydney, Australia) was used to measure the static balance of the karate players (Figure 3.2). The wobble board was a tri-level circular board with a height of 10 cm and a diameter of 53 cm. Participants had to balance on the board on two feet (wearing shoes) for as long as possible. A stop watch with 0.01 second accuracy (Sport Timer; QC B017, China) was used to time the static balance of participants. Previous research (Mayhew et al., 2010) supports acceptable precision in hand-held timing using a stopwatch. Test-retest reliability was conducted for this test, with participants ($n = 5$) performing the test twice, separated by three minutes. A dependent t-test showed no difference between times for the two trials ($P = 0.07$), with a Pearson’s $r = 0.99$ ($P = 0.001$) and a typical error of 0.024%. For the experimental trials, participants performed three trials and the best time was recorded.

Figure 3. 2 Static Balance Test

3.6.5 Sit and Reach Flexibility

The sit and reach test is a general flexibility test for the lower back and hamstring muscle groups (Howley & Thompson, 2012; Johnson & Nelson, 1986). A Sportech sit and reach box (12" x 12" x 2") (Gays Mills, WI, USA) with measuring scale was used to scored sit and reach flexibility (in cm) (Baumgartner & Jackson, 1995). Participants sat down at the testing box with knees fully extended and feet shoulder-width apart, placed against the end board. The arms were extended forward and the hands were placed on top of each other. The participants reached forward, palms down along the measuring board four times, and held the maximum reach on the fourth trial for one second. The score was the farthest point reached on the fourth trial, to the nearest cm (Johnson & Nelson, 1986). The reliability coefficient ranges from r = 0.91 to 0.97 (Adams & Beam, 2008).

Figure 3. 3 Sit and Reach Test

3.6.6 Arm Crank Ergometer

The objective of this test was to measure the anaerobic power of the upper body. The arm crank ergometer (Monark Rehab Trainer 881E, Sweden) was secured on a height-adjustable table. The subjects stood in a comfortable position in relation to the ergometer during the arm ergometer test, and crank length was 16 cm. The participants cranked the handles as fast as possible for ten seconds. Three trials were performed and the best score (peak RPM) was recorded. Two minutes rest was provided between each trial. The load was set on the machine to 50 watts. This machine was calibrated as per the manufacturer's instructions (Monark, 2008, Monark Exercise AB Manual English, Monark Rehab Trainer 881E).

3.6.7 Maximal Oxygen Consumption ($\dot{V}O_{2\,max}$)

In exercise performances of three minutes duration, 60% of ATP production is derived from aerobic processes (Powers & Howley, 2004). Karate competition sparring is three minutes in duration and, thus, the aerobic system may be the predominant energy system. Physiological testing has become progressively tailored to the specific demands of the sport, and tests are developed to more precisely simulate the movements in which the athlete participates. The first karate-specific $\dot{V}O_{2\,max}$ test was developed by Nunan (2006). This protocol had the karate athlete striking a punching bag with competition style attacks. The time to perform the strike sequence remained the same, whilst the time among strike sequence performances was gradually reduced. It is hard to distinguish whether participants are giving a maximal effort each time they perform the activity. The AKF rules in sparring are non-contact. Therefore, striking the punching bag does not precisely simulate karate competition sparring movements.

After reviewing different $\dot{V}O_{2\,max}$ protocols (e.g. in Heyward, 2010), it was decided that Bruce et al. (1973) was the most suitable protocol. It was designed to be used for asymptomatic (and cardiac) patients. Many of the other protocols were developed either for highly trained athletes or for cardiac and high risk participants. In the current study, participants were elite and novice karate practitioners. Thus, the Bruce et al. (1973) protocol was deemed a safer and more appropriate test to measure the maximum aerobic consumption of the selected group. Several pilot trials with this method were performed, and these confirm that it was an appropriate method for both elite and novice karate athletes. This test was widely used in a number of other research articles, including Imamura et al. (1996, 1998, 1999 & 2002) and Iide et al. (2008).

Aerobic power was measured with a MOXUS II metabolic system using the Bruce et al. (1973) treadmill test. The exercise protocol (Bruce et al., 1973) is used to bring the subject to a state of maximum effort on a treadmill by gradually increasing the workload in a stepwise format. Each stage of the test lasted three minutes, with the speed of the treadmill starting at 2.7 km/h and increasing by increments of 1.3, 1.5, 1.2, 1.3, 0.8, 0.8 and 0.8 km/h. The grade of the treadmill was increased by increments of 2% with a starting grade of 10%. During the test, participants wore a nose clip and mouthpiece (Hans Rudolph valve), and ventilatory data were monitored every thirty seconds (Figure 3.9).

Calibration of the Moxus gas analysers was performed using gases of known concentration, and volume calibration was performed using a 3 litre calibrated syringe (Moxus-II Instruction Manual, 2008). The degree of accuracy of the oxygen analyser was ± 0.01%, carbon dioxide analyser was ± 0.02%, and the volume measurement system was < 1% (AEI Technologies). The test-retest reliability coefficient of the $\dot{V}O_{2\,max}$ treadmill exercise test is approximately 0.95 to 0.99 for the Moxus metabolic cart (Adams, 1994). Open-circuit indirect calorimetry was used to determine oxygen consumption. This entails calculating the pulmonary ventilation and comparing inspired and expired carbon dioxide and oxygen concentrations. $\dot{V}O_{2\,max}$ was expressed as liters per minute (L/min) and relative to body mass (ml.kg^{-1}.min^{-1}) (Gore, 2000). Biological and technical variability for $\dot{V}O_{2\,max}$ is 5.6%, and the biological variability accounts for 90% of the total error (Gore, 2000). The standard error of the $\dot{V}O_{2\,max}$ test ranges from 2.5% to 6% of the mean score. Therefore, an individual is likely to vary by about 2 to 4 ml.kg^{-1}.min^{-1} even when tested weeks apart. The $\dot{V}O_{2\,max}$ test is very reliable over a four-month period, with an average coefficient of variation of approximately 4.3% (Adams, 1994).

The following criteria were used to indicate attainment of $\dot{V}O_{2\,max}$:

The test was terminated when any one of the following occurred. These were determined a priori:

- Plateau in oxygen consumption despite an increase in workload (Heyward, 2010).
- The respiratory exchange ratio (RER) exceeded 1.10. (Schell & Leelarthaepin, 1994)
- Peak heart rate within +/- 10 beats of age-predicted HR_{max}. (Heyward, 2010)

The test was terminated if any one of the following occurred:

- The subject was unable to maintain the workload
- The subject felt dizzy
- The subject looked unsteady in gait (Heyward, 2010)

3.6.8 Wingate Anaerobic Cycle Ergometer Test

The Wingate Anaerobic Cycle Ergometer test (Lode, Groningeu S20041039, Nederlands) was used to measure anaerobic glycolytic capacity for a period of 30 seconds. It is an all-out test with the work rate established in the initial two to three seconds. The subject attempts to maintain maximum pedal revolution for the remainder of the 30-second test (Schell & Leelarthaepin, 1994).

The test can measure:

- Peak power, which is the greatest mechanical power elicited during the test
- Mean power that corresponds to the average power sustained throughout the 30-second test
- Fatigue decrement (%), being the degree to which power declines during the 30 seconds. The decline in power output from peak to the end of the test is expressed as percentage of peak power

For the test, the resistance (braking torque, Nm) selected for the Wingate test was set at 0.7 Nm. This is a standard protocol used for adult males (Wingate operator manual, 2001). The participants cycled for five minutes at a comfortable standardised resistance as a warm-up. The test began after the warm-up, with the participant attempting to maintain maximum pedal revolution for the 30 seconds of the test. After the test, participants pedalled at a slow pace for three minutes to cool down.

3.7 Karate-specific Motor Fitness Tests

3.7.1 Karate Agility

Agility is defined as "a rapid whole body movement with a change of velocity or direction" (Sheppard & Young, 2005), and is proposed to be an important attribute of karate ability, leading to competition sparring success. The karate agility test used in this study was designed by the researcher using his background and knowledge in elite level sparring, as well as using data from notational analysis of video footage of sparring movements of elite male athletes at AKF Karate Championship bouts, where most sparring time is spent moving forwards and backwards in similar proportions of time (Appendix 8).

The aim of this karate-specific experiment was to complete the agility test as fast as possible. In this test, participants assumed a free fighting stance and began punching while stepping forward to a 3 m distance (Figure 3.4). Once they touched the 3 m line with one foot, they stepped back at a 45 degree angle for a distance of 3.5 m and performed blocking techniques. When their foot touched the line, they changed their direction again, going forward on the same 45 degree angle while punching. When the foot touched the line they changed direction and returned to the starting point. Their score was recorded to the nearest 0.01 of a second using a stopwatch.

Test-retest reliability was conducted for 'karate agility', where participants (n = 5) performed the test twice, separated by three minutes. There was a significant Pearson's r = 0.901 (P = 0.037) between the two trials, with a typical error of 0.086%. A dependent t-test showed a significant difference between times for the two trials (P = 0.031), with the second trial faster than the first trial; therefore, participants completed a familiarisation trial before performing the timed test.

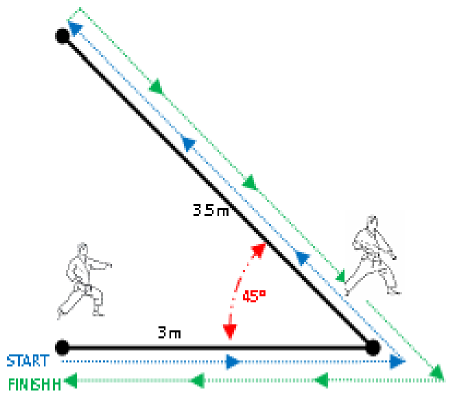

Figure 3. 4 Diagram of the Karate Agility Test

3.7.2 Seated Lateral Leg Flexibility

In All Styles of Karate competition, competitors are given three points for kicks scored to the head of an opponent during sparring, while one point is given if hands are used to score to the same region of the body (WKF, 2006). This encourages competitors to use kicks more frequently than hand techniques and, thus, a high degree of lateral flexibility of the legs is required in order to execute this kicking skill (Shirley, 1992).

The Harley Stretch Rack (Model number A8399, Roanoke, VA) was used to measure the lateral leg flexibility of the participants (Figure 3.5). After warming up with lateral leg swings, participants were seated on the apparatus with their legs positioned on either side of the stretch-rack leg spaces. Once the subject felt comfortable in this position, the handle on the stretch rack was turned clockwise in order to abduct the legs further. Termination of the test occurred at the participant's self-perceived limit of flexibility.

Calibration was performed by using a goniometer to verify the angular displacement and distance between the two levers, with the scores for the measurements compared using Pearson correlation. The correlation between the Harley stretch machine and angular displacement was r = 0.975 and the correlation between the Harley stretch machine and the distances calculated between the two levers was r = 0.965 (refer to Appendix 9 for more information concerning reliability of measurements.)

Figure 3. 5 Seated Lateral Leg Flexibility

3.7.3 Measures of Punching Technique in Karate

The reverse punch (Gyako Zuki) in front stance is the dominant hand striking technique in karate. It is the most popular scoring technique in competition sparring (Stull & Barham, 1988). The execution of the reverse punch begins by the powerful extension of the back leg which produces the initial drive. This is continued by the rotation of the hips, trunk and shoulders. The extension of the arm is the last stage of the execution of an effective reverse punch (Beneke, 2006; Taylor, 1994). During a reverse punch, the non-punching hand is extended well forward (Figure 3.6). As the non-punching hand is pulled back, it helps initiate a whipping shoulder rotation about the rotating hips. The momentum of the fighter is quickly transferred from the back to the front leg as the striking fist moves forward (Figure 3.7). A skilled practitioner also tries to step toward the target to add as much momentum to the punch as possible (Walker, 1975).

Figure 3. 6 Preparation for Reverse Punch in Karate

Figure 3. 7 Final Stage of the Reverse Punch in Karate. This figure also demonstrates the test of punching power

An Impec Mega-Strike punching bag (S0516, United Kingdom) includes an electronic device that measures the power, speed and response time of a punch or a kick to 0.01 second. The parameters assessed using the Mega-Strike punching bag were:

1. **Punching power -** to measure the power of a punch, subjects had to strike the bag with maximum effort. The participants were given three trials and the highest score was recorded.

2. **Punching speed -** participant striking distance was kept constant at one metre from the punching bag to the fist position prior to the commencement of the striking action. The subjects had to wait for an auditory signal (beep) before striking the punching bag. The subjects were given three trials with the fastest time recorded.

3. **Punching response time -** the distance between the punching bag and the participant's fist was 10 cm. Participants had to wait for an auditory signal (beep) before striking the bag, providing a measure of response time to the nearest 0.01 second. Note: Response time is the total time involving both reaction time and movement time, where reaction time is the time between the onset of a stimulus and the initiation of a response (Magill, 1993). As stated above, in this study, the time taken for the participant to react to a stimulus (i.e., beep sound from the punching bag) to making contact with the punching bag was defined as the 'punching response time'.

The impact scores ('punching power') from striking the Mega-Strike punching bag are arbitrary. Therefore, calibration was undertaken to ascertain the accuracy and reliability of 'punching power' scores of the Mega-Strike punching bag. This was performed by releasing a number of weights ranging from two, three, four, five and six kilograms over a distance of one metre to strike the punching bag. This occurred with the punching bag placed on both a soft surface and a hard surface, because the scores may vary depending on the surface on which the punching bag is placed (Mega-Strike Punching Bag, 2007). Using Pearson correlation statistics, results indicated a high correlation between tests ($r = 0.938$) when dropping weights onto the punching bag placed on a hard surface. There was also a high correlation ($r = 0.975$) when the same process was performed with the punching bag placed on a soft surface (refer to Appendix 10 for further details). That is, as the weight of impact increased, so did the scores from the punching bag in a linear fashion. To statistically support reliability, a paired sample correlation was performed on the test-retest reliability data derived from the calibration of the Mega-Strike punching bag. These tests were performed on both hard and soft surfaces. The results indicated a high correlation ($r = 0.955$) between the two testing protocols based on test-retest scores (refer to Appendix 10 & 11 for further information).

Test-retest reliability was conducted for 'punching speed' and 'punching response time'. For 'punching speed', participants (n = 5) performed the test twice, separated by three minutes. A dependent t-test showed no difference between punching speeds for the two trials (P = 1.00), with a Pearson's r = 0.79 (P = 0.11) and a typical error of 0.032%.

For punching response time, the dependent t-test showed no difference between times for the two trials (P = 0.21), with a Pearson's r = 0.96 (P = 0.008) and a typical error of 0.004%.

Figure 3.8 Punching Response Time Test

3.7.4 Physiological Measures during Simulated Karate Sparring

Participants performed three minutes of simulated karate sparring (see Figure 3.9). Participants were told the duration of the sparring and provided information about the time remaining in the test, on a minute by minute basis. However, they were not verbally encouraged to try harder at any point during the simulated sparring. The test was to be terminated if at any time a participant felt dizzy or appeared uneasy in gait.

Oxygen consumption was measured via indirect calorimetry using the MOXUS II metabolic system (see section 3.6.7 for more details regarding the set up and calibration) during three minutes of simulated karate sparring. This assessment provided information on the aerobic contribution during the three minute simulated sparring match. The participants wore a Hans Rudolph re-breathing valve with nose clip. The novice karate participants had no previous experience in championship sparring; however, they all had seen karate sparring competitions previously.

Figure 3.9 Test of Oxygen Consumption during Simulated Karate Sparring

Measurement of blood lactate concentration may also give an indication of energy utilization during three minutes of simulated karate sparring (Boston, Martin & Logan, 2000). Therefore, blood lactate concentration was measured both pre and post-sparring using a portable lactate analyser (Lactate Pro CE LT-1710, Tokyo, Japan). The analyser was calibrated before each use by following manufacturer's instructions, with a reliability coefficient of r = 0.99. The finger puncture technique was used and the site was warmed by massaging gently and cleaned thoroughly using an alcohol swab (Francescato et al., 1995; Imamura et al., 2002; Imamura et al., 1998). Blood was sampled with participants sitting comfortably, with the post-parring blood lactate concentration measured five minutes post-exercise (di Prampero, 1981). This protocol has been used by other researchers when investigating karate performance (Francescato et al., 1995; Imamura et al., 2002; Imamura et al., 1998).

3.8 Testing Procedure

To minimise the practice effect (order effect), where improvements in performance occur as a result of repeated practice (Cozby, 2001), three practices for each test were allowed so that the athletes could familiarise themselves with the tests. The exceptions to this practice were the Wingate cycle test, arm ergometry, simulated sparring and aerobic fitness tests, in order to avoid undue fatigue prior to test commencement. The karate agility tests were practiced in slow motion to familiarise participants with the task whilst avoiding fatigue. The order of the tests was arranged to minimise fatigue, with participants provided rest periods prior to the more physically-demanding tests (Table 3.2). The total time to complete the test battery was approximately two hours, including rest periods between tests.

Table 3.2 The order of testing for the general and karate-specific motor fitness tests on the testing day.

1. Anthropometric measures

   Warm-up: For 2 min, participants did their own warm up – this comprised of slow arm movements and preparation for punching the Impec Mega-strike punching bag.
2. Punching power, speed and punching response time (Impec Mega-Strike bag)

   10 min rest
3. Margaria-Kalamen anaerobic power test

   10 min rest
4. Static balance

   5 min rest
5. Grip strength

   5 min rest
6. Standing long jump

   5 min rest
7. Karate agility
8. Sit and reach flexibility
9. Seated lateral leg flexibility
10. Arm crank ergometry

    10 min rest
11. Simulated karate sparring ($\dot{V}O_{2\,max}$ measures)

    5 min rest
12. Post-sparring blood lactate concentration; Post-sparring punching power, punching speed and punching response time (Impec Mega-Strike bag)

    20 min rest
13. Maximal oxygen consumption ($\dot{V}O_{2\,max}$) test

    20 min rest
14. Wingate anaerobic cycle ergometer test

Laboratory testing was performed at an ambient temperature of 20 ^{o}C. For all testing, participants wore shorts and shirt instead of their normal karate uniform. It should be noted that this dress is not comparable to that normally worn when competing in championships; however, given that karate uniforms vary in weight from 0.5 to 2 kg, it was decided that wearing shorts and shirt would eliminate any bias between participants wearing differently weighted uniforms. All participants were tested by the same researcher, using the same equipment and at the same venue. To standardise dietary patterns, participants were asked to avoid caffeine consumption prior to testing and have a similar serving of food (two hours prior to tests) as they would normally have before competition.

3.9 Criteria for Selecting Tests

3.9.1 Validation and Relevance of the Tests to the Study

Before designing the tests for the research, karate bouts at AKF Championships were filmed by the researcher (see Appendix 8). This enabled the researcher to undertake notational analysis of the movements utilized in karate sparring, thereby informing the design of karate-specific (karate agility test) and general fitness tests for the study. In order to verify the current sparring rules used in AKF championships, the researcher also attended two referring seminars (for the researcher's background in karate sparring and karate judging qualifications, refer to the Appendix 17).

3.9.2 Biological Variability

To minimise the effects of biological change in this experiment, the researcher attempted to control for several factors. Participants were asked to not eat a large meal within two hours of testing. All the participants were asked whether their body mass measured was their standard body mass (i.e. the weight category they perform in for karate tournaments). They all were offered similar quantities of water to drink during the testing, drinking *ad libitum*.

3.10 Statistical Analysis

3.10.1 Parametric Analysis

Parametric variables at baseline level were tested for normality using the criterion that baseline data were considered normally distributed if double standard deviation values were smaller than the means (Peat & Barton, 2009). (Refer to Appendix 10). For the subsequent statistical analyses (below), the level of statistical significance was set to 0.05. This also minimized variability and the probability of the type II error occurring (Rothstein, 1985). All statistical analyses were completed using the SPSS statistical program (2009).

The first part of the study assessing differences in motor fitness variables between the elite and novice karate groups used univariate (independent t-tests) and multivariate (discriminant function analysis) analyses.

The intervention action component of the study, where elite and novice participants were assessed and compared before and after a simulated sparring match, used a mixed factor ANOVA (multivariate model) design. Specifically, this statistical analysis was used to determine the post-sparring (fatigue) effects on punching speed, punching power, punching response time and lactate concentration between and within participants. The between group factor was player ability (elite vs. novice) and the within group repeated measures factor compared pre to post-intervention conditions. This intervention action research also involved assessing absolute and relative $\dot{V}O_2$ (average and peak) data during data during three minutes of simulated sparring. The elite and novice groups were compared to determine whether there was an interaction effect and whether one group had significantly greater $\dot{V}O_2$ demands during simulated karate sparring. Independent sample t-testing was also used to determine any differences between the two groups, with effect sizes [Cohen's *d* ± 95% confidence interval (CI)] calculated. A score less than 0.2 was considered a small effect size, a score of 0.5 a medium effect size, and a score of 0.8 a large effect size (Cohen, 1992). For test-retest reliability analysis of motor fitness tests, a dependent t-test, Pearson's product-moment correlation coefficient, and typical error (%) were calculated.

3.10.2 Discriminant Analysis

Multivariate discriminant analysis was used to classify subjects into groups based on their motor fitness abilities (Vincent, 2005). In this method, variables that were significantly different between the two groups from independent t-tests were used in the analysis. Discriminant analysis stepwise method is a statistical tool that determines which variables are the most important in discriminating the physical fitness abilities of elite and novice karate participants and disregards the less significant variables (Vincent, 2005). Please note: Box's M test was very sensitive to meeting the assumptions of multivariate normality. These data from the karate study were not significant ($P > 0.05$). The values for the two groups did not differ from their covariance matrices and, therefore, the assumptions of discriminant analysis were not violated (refer to Appendix 16).

CHAPTER FOUR

4.0 Results

- Section 4.1 focuses on the descriptive differences between the elite and novice participants.

- Section 4.2 examines multivariate differences and classification accuracy based on this difference to assess whether general motor fitness, karate-specific motor fitness, and a combination of general and karate-specific tests can discriminate karate ability level as defined in this research.

- Section 4.3 addresses the energetic demands and fatigue characteristics of simulated karate sparring between the elite and novice groups.

4.1 Motor Fitness Variables that Discriminate Karate Sparring Abilities

4.1.1 Descriptive Statistics and Independent T-Test Results

There were significant differences found between the elite and novice groups with respect to nine general and karate-specific motor fitness tests. As shown in Table 4.1, elite karate subjects showed significantly greater scores in the Margaria-Kalamen power, punching power, peak arm ergometer cadence (rpm), seated lateral leg flexibility, sit and reach flexibility, static balance, karate agility, punching speed and Wingate peak power compared to the novice group. With the two groups being similar with respect to mean age and basic anthropometry (stature and body mass), this indicates that the significant differences in general and karate-specific motor fitness variables are due to differences in the physical abilities of the groups.

Table 4. 1 Anthropometric and Motor Fitness Variables of Elite and Novice Karate Practitioners.

Measured Variables	**Elite (n=12)**	**Novice (n=12)**			
	$\bar{x}$ **± SD**	$\bar{x}$ **± SD**	***P Value***	**ES**	***95% C.I.*** **(Lower, upper)**
Age (years)	32.9 ± 13.5	30.1 ± 12.7	p=0.61	0.21	(-0.60, 1. 01)
Stature (cm)	179.1 ± 8.0	176.1 ± 10.3	p=0.44	0.33	(-0.49, 1.12)
Body mass (kg)	76.3 ± 8.7	76.6 ± 19.5	p=0.96	-0.02	(-0.82, 0.78)
Resting heart rate (bpm)	74.9 ± 11.9	76.4 ± 13.4	p=0.77	-0.12	(-0.92, 0.69)
Margaria-Kalamen test (watts)**	920.0 ± 134.5	749.0 ± 159.4	p=0.01	1.16	(0.26,1.98)
Standing long jump (cm)	212.3 ± 18.7	203.0 ± 25.1	p=0.36	0.42	(-0.40, 1.21)
Karate agility (s)*	7.5 ± 2.4	9.9 ± 2.5	p=0.03	-0.95	(-1.75, -0.07)
Power punch (AU)*	71.2 ± 7.3	63.5 ± 9.2	p=0.03	0.92	(0.05, 1.73)
Speed punch (s)**	0.33 ± 0.11	0.53 ± 0.18	p=0.001	-1.26	(-2.09, -0.35)
Punching Response time (s)	0.23 ± 0.05	0.25 ± 0.04	p=0.26	-0.44	(-1.24, 0.38)
Hand grip strength (kg)	50.4 ± 6.3	44.5 ± 12.9	p=0.17	0.58	(-0.25, 1.37)
Static balance (s)**	3.5 ± 1.3	1.7 ± 0.7	p=0.001	1.73	(0.74,1.60)
Sit and reach flexibility (cm)*	38.2 ± 8.9	29.7 ± 10.9	p=0.048	0.85	(-0.01, 1.66)
Seated lateral leg flexibility (cm)**	40.5 ± 7.7	27.9 ± 9.2	p=0.001	1.49	(0.54,1.33)
Arm ergometer cadence (peak rpm)**	230.2 ± 9.3	208.2 ± 18.2	p=0.001	1.52	(0.57,1.37)
$\dot{V}O_{2\,max}$ (ml.kg^{-1}. min^{-1})	48.2 ± 8.4	43.9 ± 12.5	p=0.33	0.40	(-0.42, 1.20)
Wingate peak power (watts)* #	1093.0 ± 119.5	976.2 ± 125.6	p=0.03	0.95	(0.06, 1.78)
Wingate Time to peak power (s)#	4.9 ± 1.3	5.4 ± 1.5	p=0.43	-0.36	(-1.15, 0.46)
Wingate mean power (watts)#	597.0 ± 39.3	547.0 ±85.9	p=0.09	0.76	(-0.11, 1.58)
Wingate mean power/ BM (watts/kg)#	7.8 ± 0.5	7.4 ± 1.6	p=0.43	0.33	(-0.49, 1.12)
Wingate peak power/BM (watts/kg)#	14.3 ± 1.9	13.4 ± 3.3	p=0.43	0.33	(-0.49, 1.12)
Wingate fatigue decrement (%)#	31.2 ± 8.5	28.8 ± 8.5	p=0.51	0.28	(-0.53, 1.80)

Comparison based on independent t-test group means ± standard deviations. *$P < 0.05$ and **$P < 0.01$. Effect size and 95% Confidence Interval (lower, upper): # N = 11 for Novice group in Wingate test.
Abbreviations: AU = arbitrary unit of measurement, ES = effect size (Cohen's d); BM = body mass.

The data in table 4.1 highlight that, in general, measures of peak/explosive power (i.e. Margaria-Kalamen power, punching power and speed, peak arm ergometer cadence, and Wingate peak power) and karate-specific parameters (punching power and speed, seated lateral leg flexibility and karate-specific agility) were better in the elite group compared with novice practitioners. Static balance and sit and reach flexibility were also better in the elite group.

4.1.2 Discriminant Analysis differentiating between Participants

Discriminant analysis was used to determine which motor fitness variables might best predict karate ability, by using the nine general and specific motor fitness tests indicated as significantly different between groups in Table 4.1. This statistical technique first ranked these nine variables in order of highest to lowest importance for predicting karate proficiency, given the data of the elite and novice athletes in this study. The results were:

1. Static balance
2. Seated lateral leg flexibility
3. Arm ergometry
4. Speed of punch
5. Margaria-Kalamen power test
6. Wingate test of anaerobic power
7. Karate agility
8. Punching power
9. Sit and reach flexibility

4.1.2.1 Discriminant Analysis Enter Method

The discriminant analysis enter method is a test where the statistical software (SPSS version 16) uses the variables that have been entered in the equation to determine their classification levels. The discriminant analysis enter method therefore used the nine variables that were statistically different between groups (listed above). This statistical technique showed that 95.8% of the cases (i.e. 23 of 24 participants) were correctly classified, as "elite" or "novice" with all the elite karate participants correctly classified in their group, and only one subject from the novice group misclassified. This indicates that this one novice participant displayed similar general and karate-specific abilities to the elite karate participants (refer to Appendix 16).

Using only the four karate-specific motor fitness tests that were significantly different between groups (i.e. seated lateral leg flexibility, karate agility, speed of punch, and power of the punch) in the discriminant analysis enter method, 91.7% of the cases were still correctly classified in their groups. It was also observed that all the elite karate participants were correctly classified in their group. There were only two participants from the novice group who were misclassified, having karate-specific motor fitness abilities similar to the elite karate participants.

Similarly, when using the discriminant analysis enter method with the five general motor fitness abilities identified in Table 4.1 (Margaria-Kalamen power test, arm ergometer cadence, sit and reach flexibility, static balance, and Wingate peak power), 95.8% of cases were correctly classified. Thus, using the five general motor fitness variables for discriminating novice and elite participants had the same classification accuracy as using the nine variable model. It can also be noted that all the elite participants were correctly classified in their groups and only one novice participant was misclassified.

4.1.2.2 Discriminant Analysis Stepwise Method

The discriminant analysis stepwise method is a test whereby the two most important variables that discriminate the ability of the two groups are identified. Of the nine significantly different variables identified above (and in Table 4.1), the two variables selected by this technique as being most statistically important were the Margaria-Kalamen power test and static balance. The degree of classification accuracy using these two variables was 87.5%, meaning that only 3 subjects of 24 were misclassified when using these two performance variables. One participant from the elite group was misclassified and two of the novice participants were misclassified. That these two general motor fitness variables were chosen by this statistical method suggests that using general motor fitness tests to discriminate karate abilities may be as effective as using karate-specific motor fitness tests.

However, when using the four karate-specific motor fitness test (seated lateral leg flexibility, karate agility, punching speed, and punching power) with the discriminant analysis stepwise method, the two variables chosen were the speed of the punch and seated lateral leg flexibility, resulting in 91.7% cases being correctly classified. This produced greater classification accuracy than when using the Margaria-Kalamen power test and static balance above and, specifically, only two of the novice karate participants were misclassified and all the elite participants were correctly classified.

Therefore, the discriminant analysis stepwise approach provided the greatest accuracy in classifying participants when using karate-specific motor fitness variables.

4.2 Energetic and Fatigue Characteristics of Karate Sparring

The following sections and their figures compare energy system and fatigue measures at pre and post-simulated sparring – specifically, punching speed, punching power, punching response time and blood lactate concentrations.

4.2.1 Punching Power

In figure 4.1, it can be observed that the scores at post-test for both elite and novice groups are significantly different from pre-test ($P < 0.001$), with both groups displaying a significant decrease in punching power following the simulated sparring. There was no interaction between the elite and novice karate participants following the simulated sparring bout ($F = 0.005$, $DF = 1.22$, $P = 0.947$). This means that the punching power of both novice and elite participants decreased to a similar degree. An independent t-test between elite and novice participants at pre-sparring showed a significant difference ($P < 0.01$) in the punching power, with the elite participants being more powerful. The elite group was still significantly more powerful than the novice group with fatigue (post-sparring).

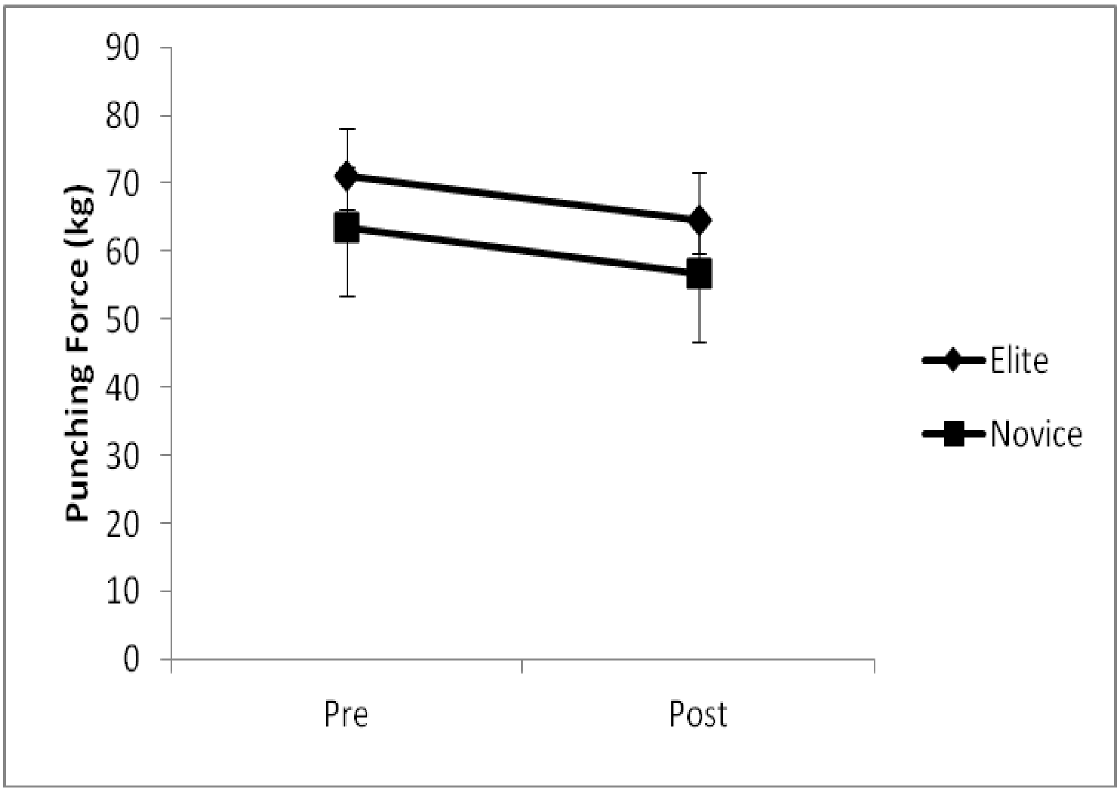

Figure 4.1 Punching Power Scores of Elite (N=12) and Novice (N=12) karate practitioners before (Pre) and following (Post) three minutes of simulated karate sparring.

4.2.2 Punching Speed

In figure 4.2, it can be observed that the scores from pre-test to post-test within both elite and novice groups are significantly different (P < 0.01), with both groups displaying a decrease in punching speed following simulated sparring. The elite karate participants displayed a greater reduction in speed than the novice group (interaction effect, F = 8.51, df = 1.22, P = 0.008). Despite this, the elite group was still significantly faster in their punching speed compared to the novice group post-sparring. Again, an independent t-test indicated pre and post-test differences (P < 0.01) between the two groups in punching speed.

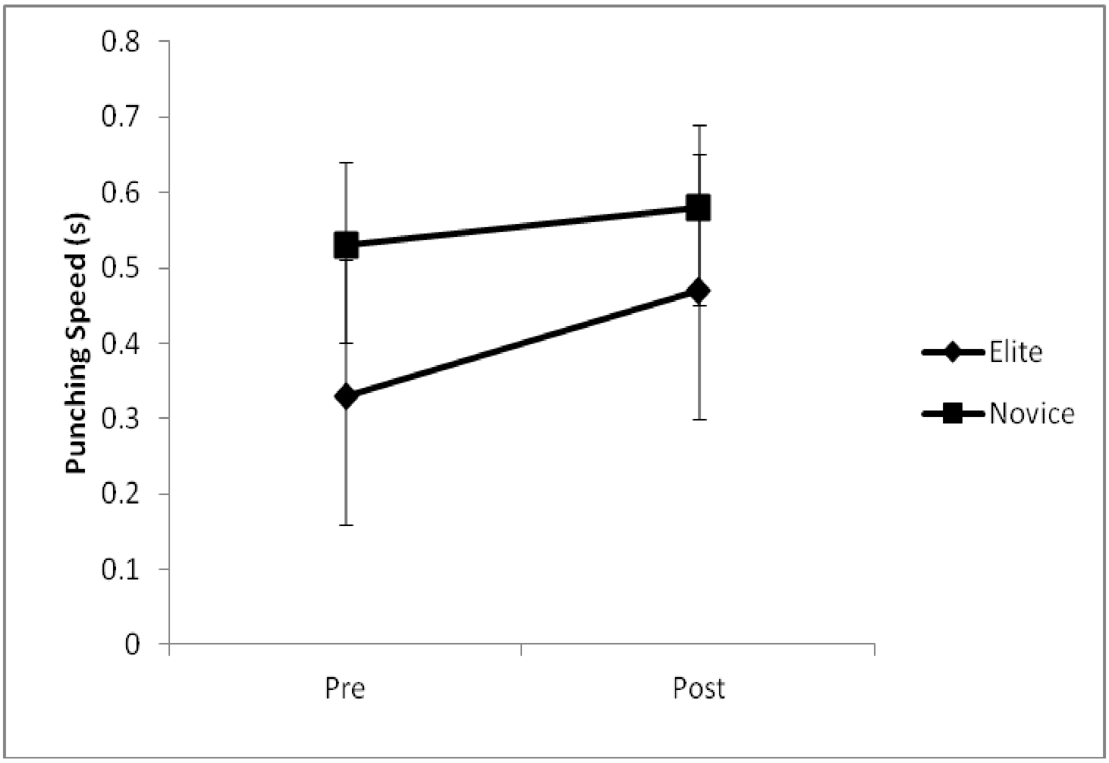

Figure 4.2 Punching Speed Scores of Elite (N=12) and Novice (N=12) karate practitioners before (Pre) and following (Post) three minutes of simulated karate sparring.

4.2.3 Punching Response Time

In figure 4.3, it can be observed that the punching response times from pre to post-test within both elite and novice groups were significantly slowed (P < 0.001) following simulated sparring. There was no interaction effect between the elite and novice karate participants following sparring (F = 0.55, df = 1.22, P = 0.817) and, thus, both groups showed a similar degree (slope) of slowing in their response time with fatigue.

The mean score for the reaction time from the novice karate athletes was subtracted from the elite karate player score and then divided to the standard deviation score (0.225 - 0.246/0.36 = 0.7). A score less than 0.2 is considered a smaller effect size, a score of 0.5 is medium and a score around 0.8 is a larger effect size. Therefore, the higher probability of a practical difference between the two groups has been shown below (Baumgartner & Hesley, 2006).

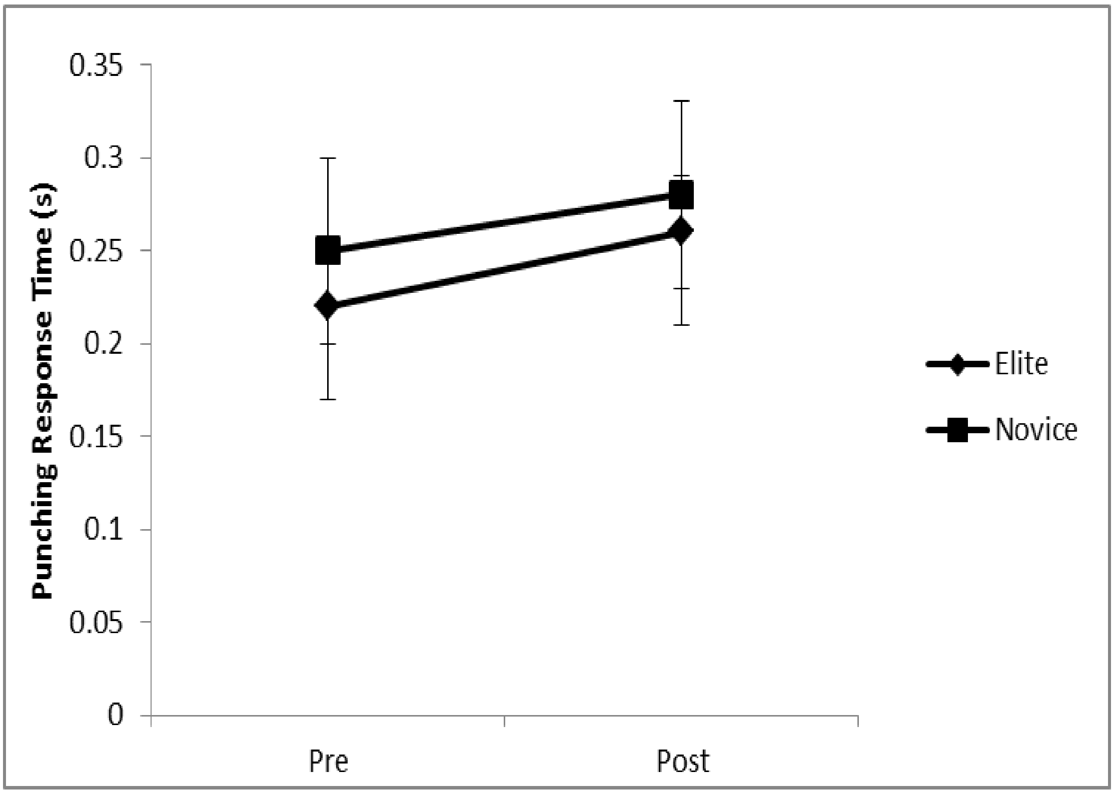

Figure 4.3 Punching Response Time Scores of Elite (N=12) and Novice (N=12) karate practitioners before (Pre) and following (Post) three minutes of simulated karate sparring.

4.2.4 Blood Lactate Concentration during Simulated Sparring

Figure 4.4 shows that changes in blood lactate concentrations following simulated sparring were similar between groups. Both elite and novice participants displayed significant increases in blood lactate concentrations following simulated sparring ($P < 0.001$), with no interaction effect between groups ($F = 0.809$, $df = 1.22$, $P = 0.379$).

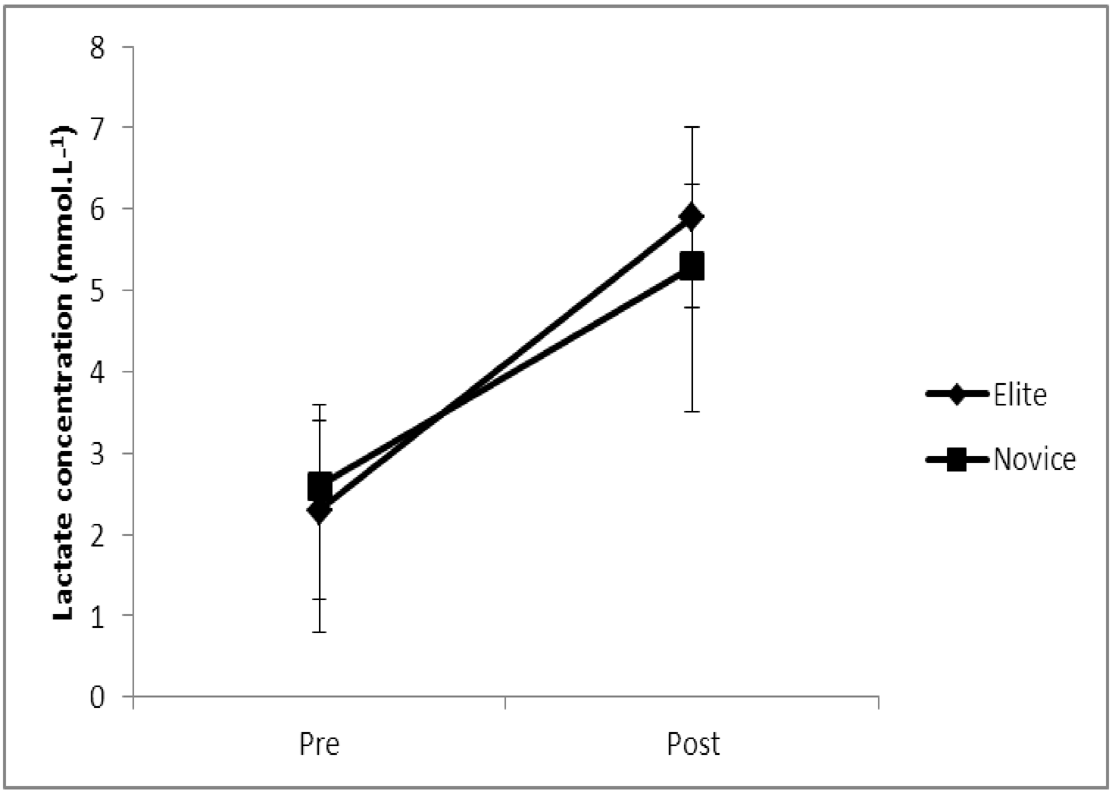

Figure 4.4 Changes in Blood Lactate Concentration Pre and Post-Sparring of Elite (N=12) and Novice (N=12) karate practitioners following three minutes of simulated karate sparring.

4.3 Aerobic Demands of Karate Sparring

The aerobic demands of simulated karate sparring for elite and novice karate participants are shown Table 4.2, including the average and peak $\dot{V}O_2$ values (as ml.kg^{-1}. min^{-1} and %$\dot{V}O_{2\,max}$), with the group mean for $\dot{V}O_{2\,max}$ (from the graded treadmill test) also provided. There was no difference in the average or peak $\dot{V}O_2$ (ml.kg^{-1}. min^{-1}) between the two groups for the simulated sparring bout. When values are reported as relative $\dot{V}O_{2\,max}$ (%), the average $\dot{V}O_2$ scores for the three minutes of sparring are similar, suggesting that there is a moderate aerobic requirement during sparring. Importantly, these data indicate that both groups worked at a similar relative intensity throughout the test. In contrast, when peak $\dot{V}O_2$ during sparring is expressed as relative $\dot{V}O_{2\,max}$ (%), the peak exertion of the elite group (68% $\dot{V}O_{2\,max}$) was lower (P = 0.07) than that of the novice group (81% $\dot{V}O_{2\,max}$) with a large effect size.

Table 4. 2 Aerobic Demands of the Simulated Karate Sparring

Variables	**Elite (N = 11)** $\bar{x}$ **± SD**	**Novice (N = 9)** $\bar{x}$ **± SD**	***P Value***	***ES***	***95% C.I. (lower, upper)***
$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1})	46.97 ± 7.7	42.74 ± 12.7	p=0.33	0.41	(-0.51, 1.28)
Peak $\dot{V}O_2$ Sparring (ml.kg^{-1}. min^{-1})	31.58 ± 8.3	35.19 ± 13.7	p=0.40	-0.33	(-1.20, 0.57)
Peak $\dot{V}O_2$ Sparring $\dot{V}O_{2\,max}$ **(%)**	67.72 ± 16.5	80.71 ± 12.1	p=0.07	-0.88	(-1.77, 0.07)
Average $\dot{V}O_2$ Sparring (ml.kg^{-1}. min^{-1})	29.70 ± 7.9	28.90 ± 11.6	p=0.88	0.08	(-0.94, 1.09)
Average $\dot{V}O_2$ Sparring $\dot{V}O_{2\,max}$ (%)	61.90 ± 13.3	63.90 ± 14.9	p=0.79	0.14	(-1.18, 0.92)

CHAPTER FIVE

5.0 Discussion

5.1 Motor Fitness Characteristics

In part one of this research, the motor fitness abilities of twelve elite male karate participants were compared to twelve novice karate participants, in order to determine whether general and karate-specific motor fitness characteristics could discriminate karate sparring abilities between the two groups. Results showed that there were significant differences in nine motor fitness variables, some of which relate to general motor fitness and others relate to karate-specific performance. Thus, the hypothesis that a combination of general and karate-specific motor fitness tests could discriminate the karate sparring ability of elite versus novice karate participants was supported. Specifically, the data showed elite karate participants had significantly greater power, speed, flexibility and balance compared to the novice karate participants.

Elite karate participants displayed greater punching speed and power than novice participants, indicating that these punching abilities were major contributors to karate sparring proficiency. This supports the experiential-based evidence of Nakayama (1983) who states that the basic techniques of karate are influenced by speed and power. The research by Ravier, Grappe and Rouillon (2004) demonstrated that international competitors were characterised by considerably better values for cycle sprint velocity (+13%) and squat jump power (+14%) in contrast to the national level karate athletes. Roschel et al. (2009) also found that there were significant differences in the power abilities (bench press and squat power) between a winning group and a defeated group of the Brazilian national karate team. Taken together, these data indicate that explosive power is an important characteristic of karate proficiency, with success in karate performance, in part, dependent on maximal velocity and explosive strength.

Better karate-specific agility was observed for the elite participants in the present study, as well as for karate-specific seated lateral leg flexibility and the standard sit and reach test. The types of exercises performed more regularly by the elite participants are likely to have enabled them to perform better on these tests. During sparring competitions, competitors receive more points for scores to the head of the opponents and, to achieve this, karate athletes undertake karate-specific flexibility training. Improvements in flexibility due to karate training have been reported previously by Douris et al. (2004), who observed Soo-Bahk-Do practitioners to have significantly greater flexibility when compared to sedentary participants. Similarly, Violan et al. (1997) found that six months of karate training increased flexibility and balance in junior beginners when compared to a control group, with the most significant increases found in quadriceps and hamstring flexibility.

The present study suggests that the static balance test can discriminate karate ability, with elite karate participants demonstrating greater balance than the novice group. Fredrick and Hobusch (1990) and Schmidth (1988) believe a properly balanced position is important for the effectiveness of the karate kick and also affords protection against a possible counterattack to the groin area. For techniques to be powerful, fast, accurate and smoothly executed, they must commence from strong and well-balanced stances (Nakayama, 1983). The refereeing rule book for sparring in all styles of karate states that points are only given to those correct striking techniques that are accompanied by well-balanced stances. The competitor that loses balance during striking is considered to be ineffective in achieving the sparring objectives (AKF, 2012). Therefore, in order to win karate sparring matches, karate participants are encouraged to improve their balance.

The nine general and karate-specific motor fitness variables identified by independent t-tests as being different between groups underwent different methods of discriminant analysis. These techniques showed that both general and karate-specific motor fitness variables can accurately discriminate karate abilities between the elite and novice karate participants, and that they can correctly classify participants as either elite or novice. When all nine variables were used in these analyses, the classification accuracy was 95.8%, with all elite karate participants correctly classified and only one subject from the novice group misclassified (i.e. this novice participant had similar motor fitness abilities as the elite participants). However, using only the four (statistically different) karate-specific tests (i.e. punching speed, punching power, karate agility and seated lateral leg flexibility) in the discriminant analysis enter method still delivered classification accuracy of 91.7%, with only two participants from the novice group being misclassified.

To further refine the efficiency of using these tests in practice, the discriminant analysis stepwise method was performed, where less discriminatory variables were disregarded by determining the contribution that each variable makes towards the sensitivity of classification. The two variables that provided the greatest classification accuracy were the karate-specific motor fitness variables of punching speed and seated lateral leg flexibility. The classification accuracy was still 91.7%, with only two novice participants being misclassified and the entire elite group being correctly classified. These two karate-specific variables provided greater classification accuracy than that of the two general fitness variables (i.e. static balance and Margaria-Kalamen power test) selected by the discriminant analysis stepwise method which was 87.5%. Overall, the tests of punch speed and seated lateral leg flexibility were just as accurate in classifying elite participants as when using all nine variables that were identified as significantly different between elite and novice groups, while the accuracy of these two tests only differed from using the nine tests by one misclassification in the group of 12 novice participants. Thus, in practice, the use of these two karate-specific tests may be a time and resource efficient approach to gaining insights into the performance standards and/or performance progression of karate practitioners.

5.2 Energy System Characteristics

5.2.1 Anaerobic Power

A significantly faster time, as a measure of power, was demonstrated by the elite practitioners compared to novice karate participants in the Margaria-Kalamen power test. Peak arm ergometer cadence, as a measure of anaerobic ability of the upper body, was also found to be significantly better in the elite karate participants. In this test, the action of the arm pushing forward may resemble the upper body punching technique in karate, and is supported by the superior punching speed and power of the elite compared to the novice group. The results for the Wingate cycle test also indicated there to be a significant difference between the elite and novice participants in peak anaerobic power. The elite karate athletes also performed 8% better than the novice group on the Wingate mean power test, 5% better for mean power body-weight, 6% better in peak power-body weight, and 9% better for time to peak power. However, these differences were not statistically significant and suggest that glycolytic energy requirements for success in karate performance are less important (and less discriminatory) than alactic energy contributions. The elite practitioners also fatigued more rapidly (by 8% but not statistically significant) compared to the novice group, as indicated by the fatigue decrement measure in the Wingate cycling test. This might again be due to the more alactic nature of karate sparring, where the average time engaged in fighting is 2 seconds, compared to 30 seconds in the Wingate cycling test.

These outcomes likely reflect the way in which karate techniques are practiced. The cycling action used in Wingate cycling is not specific to karate sparring movements. However, the use by elite karate athletes of very fast steps during sparring for successful attacking and defending, as well as kicking the punching bags to improve speed, may have contributed to the more powerful leg action (i.e. greater peak power) during the Wingate test. In support of the present study's findings, Ravier et al. (2004) examined force-velocity relationships in two groups of karate athletes – 10 international level karate competitors and 12 national level competitors – by performing squat jumps, maximal counter-movement jumps, and three sets of 8 seconds sprints on a friction-braked cycle ergometer. The results showed that the international competitors had significantly greater values for sprint velocity (+13%) and squat jump power (+14%).

There were no significant differences between the elite and novice karate participants in the punching response test. This result differs from other research (Hughes, Bhundell & Waken, 2009) that found significant differences between elite, intermediate and novice performers with respect to response time in table tennis. It is noted that nine participants from the elite group had a faster punching response time (0.03 s) compared to the novice group. This suggests there is a practical difference between the elite and novice karate participants' punching response time even if not statistically significant. This practical difference could be large enough to be meaningful in a karate sparring match because, in karate sparring, the time to react to an attacking move is very small. This smaller punching response time increment could mean the difference between winning or losing a match (Williams & Wragg, 2006). A larger sample size may increase the likelihood of establishing a significant difference if it truly exists. Moreover, the effect size for the data was 0.7. This larger effect size therefore supports the greater probability that a practical difference exists between the novice and elite karate player's punching response time (Baumgartner & Hesley, 2006).

Interestingly, there were no significant differences between the elite and novice karate participants for grip strength. Similarly, Roschel et al. (2009) showed there were no significant differences between winners and defeated participants in strength (maximum dynamic strength 1RM upper and lower limbs), bench press and squat power using 60% 1RM. These data could support the proposition that power generation and not absolute strength is more important to proficiency in karate performance. However, it is also possible that grip strength itself and/or its less dynamic nature is not specific to karate performance. In fact, Imamura et al. (1998) did report significant differences between elite and novice karate participants in bench press strength and half squat strength.

5.2.2 Aerobic Power

Elite and novice karate participants displayed similar aerobic characteristics with respect to mean $\dot{V}O_{2\,max}$. One limitation is that a treadmill run was used to assess aerobic power, while it is usually better to use an ergometer or test protocol that simulates movement patterns specific to those for which the subject has been trained (Adams, 1994). Future work might seek to develop a karate-specific aerobic test, where participants undertake a protocol of simulated sparring which includes graded increases in the delivery of punches and kicks as the test progresses. However, the mean $\dot{V}O_{2\,max}$ value (48.2 ± 8.3 ml.kg^{-1}.min^{-1}) for the elite group may be a reflection of the way in which sparring activity is performed. During sparring, participants use relatively few of the high intensity movements of kicking, striking and blocking throughout a bout. This was supported by video analysis from AKF Championship bouts during pilot work (see Appendix 8), where competitors engaged in actual fighting for an average of 14.1% of the bout time. Similarly, Beneke et al. (2004) demonstrated that during simulated karate sparring matches with male karate athletes of national and internationally rank, the high intensity actions (punches, kicks and blocks) were 1 to 3 seconds in duration, with a total of 3.4 high intensity actions per minute. Therefore, karate sparring appears to only require a moderate degree of aerobic fitness.

In agreement with the present study, Imamura et al. (1998) reported a lack of difference in aerobic fitness between the elite and novice karate participants, although their elite group had a substantially greater aerobic fitness than the elite participants in the present work. Similarly, Ravier et al. (2006) reported no differences in aerobic fitness between national and international karate athletes but, again, their maximal oxygen uptake scores (57.6 and 59.4 $ml.kg^{-1}min^{-1}$, respectively) were greater than those in this study. A study by Keshishian (1998) using a field testing measure (i.e. 20 m multistage shuttle run test) also showed that elite karate athletes were not significantly different in aerobic fitness to novice practitioners.

In contrast, the study by Jui-Chia, Lin and Esposito (2003) showed that experienced Tae-Kwon-Do players produced significantly higher peak heart rates and $\dot{V}O_{2\,max}$ scores than novices during training. This may be due to Tae-Kwon-Do and its particular rules and regulations of sparring, where the competitors are engaged in sparring continuously for the duration of the bout. During this continuous three minutes of activity, greater energy will be supplied from aerobic metabolism (Stull & Bahram 1988). In contrast, in All Styles of Karate, the referee stops the match when a competitor wins a point, puts one foot out of the court, or commits a foul. This short engagement in sparring of 11-17% of bout duration places a lesser aerobic demand on karate players when compared to the Tae-Kwon-Do competitors (Markovic, Vucetic & Cardinale 2008).

With respect to the aerobic demands of karate sparring, it was hypothesised that simulated karate sparring involves a high relative aerobic demand for both elite and novice karate participants and this was partially supported by this work. Specifically, the average $\dot{V}O_2$ across the three minutes of simulated sparring for the elite and novice groups was 62% and 64%$\dot{V}O_{2\,max}$, respectively

Importantly, these average $\dot{V}O_2$ scores for the simulated sparring protocol provide evidence that the elite and novice participants performed the test at a very similar relative exercise intensity. Meanwhile, peak $\dot{V}O_2$ values during sparring showed that novice participants exhibited a high relative aerobic demand (80%$\dot{V}O_{2\,max}$) at a point during sparring, while elite practitioners maintained a moderate aerobic demand (68%$\dot{V}O_{2\,max}$) when at peak sparring exertion. This indicates that the relative intensity of sparring was greater for the novice group at times of peak exertion, likely reflecting their lack of experience in competition sparring and/or their lower efficiency of movement during periods of greater sparring intensity. In contrast, the moderate aerobic demand experienced by the elite group throughout the entire three minutes, and during the periods of greatest intensity, of actual karate sparring supports a lesser reliance on developing aerobic power for success in karate and is consistent with the lack of difference in $\dot{V}O_{2\,max}$ between groups with differing levels of karate proficiency reported here and in the published literature.

5.3 Energetic and Fatigue Characteristics of Karate Sparring

The hypothesis that three minutes of simulated karate sparring reduces the performance of punching speed, punching response time and punching power in elite and novice karate participants was supported by the results of this research. Conversely, the hypothesis that simulated karate sparring would have minimal effect on the blood lactate concentrations of karate participants was not supported. Specifically, three minutes of simulated karate sparring had a detrimental effect on punching speed, punching power and punching response time, as well as producing increases in blood lactate concentrations for both groups.

Post-sparring, the punching speed of the elite group reduced significantly more than observed in the novice group, with an interaction effect between groups. In the elite group, punching speed was reduced to 70.3% of pre-sparring punching speed, while the post-sparring punching speed of the novice group was 90.4% of pre-sparring punching speed. However, elite participants had greater punching speed pre-sparring and they were still faster than the novice group post-sparring, despite their greater relative fatigue decrement. In contrast, the relative changes in punching power and punching response time following simulated sparring were similar between groups.

In the present study, blood lactate concentrations following three minutes of simulated sparring were not different between groups. The increases in blood lactate concentrations in the elite participants (mean 5.7 ± 2.4 mmol.L^{-1}) are similar to those reported by Roschel et al. (2009) in winners and defeated athletes of Brazilian elite karate teams, with 5.1 ± 1.2 and 5.2 ± 2.2 mmol.L^{-1}, respectively. In contrast, Imamura et al. (1999) reported blood lactate responses for the five types of karate exercises (S-Basics for 15 minutes, M-Basics for 10 minutes, TECH I for 10 minutes, TECH II for 15 minutes and kata for 20 minutes) to be 1.4 to 3.0 mmol.L^{-1}. These concentrations are lower than those reported for simulated sparring, and these differences are likely due to the higher intensity movements (attacks, blocks and sliding movements) used during karate sparring. Blood lactate increases in the present study were also different, and significantly less, than those reported by Markovic et al. (2008). However, their mean post-sparring blood lactate concentration of 14.1 ± 1.1 mmol.L^{-1} was observed in seven elite female Tae-Kwon-Do athletes and is likely due to Tae-Kwon-Do sparring competitions being more continuous than the sparring in karate competitions.

With respect to the aerobic demands of karate sparring (as discussed above in section 5.2.2), the peak aerobic contribution during simulated sparring was 68%$\dot{V}O_{2\,max}$ for the elite group, representing 31.6 ± 8.3 ml.kg^{-1}.min^{-1}. The aerobic nature of three minutes of sparring for elite participants is supported by the lactate responses, with a mean of 5.7 ± 2.4 mmol. L^{-1} post-sparring. These findings are supported by Beneke et al. (2004) who selected ten male karate athletes (nationally and internationally ranked) to perform four sparring matches, where each was judged like a championship. The proportional contributions of aerobic, anaerobic alactic, and anaerobic glycolitc energy were calculated as 77.8%, 16.0%, and 6.2%, respectively. The results suggest that the activity profile of sparring results in aerobic metabolism being the primary energetic pathway, but that this system is not heavily stressed.

However, there are differences in the literature concerning the aerobic demands of the three minutes of simulated sparring. In the present study, the peak $\dot{V}O_2$ of the elite group during simulated sparring is substantially lower than that reported by Iide et al. (2008) of 47.8 ± 8.0 ml.kg^{-1}.min^{-1} and representing 84.9 ± 8.1% $\dot{V}O_{2\,max}$. This relative value is closer to that of the novice group (81% $\dot{V}O_{2\,max}$) in the present study, and this similarity may be due to the fact that participants in Iide et al. (2008) were young male participants and likely to be less experienced than the elite participants in the present study. In contrast, Imamura et al. (1999) reported peak $\dot{V}O_{2\,max}$ during karate training, where elite karate participants practiced S-Basics for 15 minutes, M-Basics for 10 minutes, TECH I for 10 minutes, TECH II for 15 minutes and kata for 20 minutes, to be 47.4 ± 5.9% $\dot{V}O_{2\,max}$. This is lower than the values achieved in the present work where the elite participants utilized a peak 68% $\dot{V}O_{2\,max}$ and may be due to the higher intensity attacks, blocks and sliding movements in simulated free sparring.

Taken together, during three minutes of simulated karate sparring, elite karate participants had a moderate aerobic demand placed on them. The reason for the moderate aerobic demand may well be due to elite karate competitors carrying out minimal high intensity actions during sparring [1.4% to 2.4% of the total sparring match (Beneke et al. (2004)]. In contrast, the novice karate group had a significantly higher peak aerobic demand during the three minutes of simulated sparring and this likely reflects the lack of familiarity with competition sparring and less efficiency in high intensity actions in comparison to elite participants.

In summary, the data suggest that there is a high demand for power, speed, agility and flexibility in karate sparring. Elite karate competitors carried out minimal high intensity actions during the simulated sparring which yielded a moderate aerobic demand. Therefore, training to improve karate sparring proficiency should focus on these sport-specific fitness characteristics, while ensuring that aerobic conditioning does not occur at the expense of alactic energy system development. This study had a high degree of external validity given that the participants were representative of elite and novice karate groups from a variety of karate schools. However, it is important to note that while these evidence-based data on physical and skill attributes may guide approaches to talent identification, other perceptual-cognitive and technical skills specific to karate will be important in accurately selecting participants for talent development (Vaeyans et al., 2008).

5.4 Limitations of the Study

1. The researcher was not blinded to the sample groups or assessment procedures during the physical fitness testing of the karate participants.

2. The measurement of times for the Margaria-Kalamen Anaerobic Power Test, static balance test and karate agility tests with an electronic timer system, instead of hand-held stopwatch timing, would provide greater assurance of timing accuracy.

3. The sample size was a total of 24 participants. Larger sample sizes for both groups would increase the chance of finding other differences if they indeed exist, as well as increasing the ability to generalise the concepts derived from the research to a larger group of karate athletes.

4. The internal validity may have been threatened due to the multiple treatment interferences. In this study, there was more than one experimental variable and, thus, there were risks of the performance of one task either enhancing or inhibiting the performance of a different task. This included the completion of all tests on a given day, with the potential of accumulated fatigue in the participants as they progressed through the testing battery. Rest and recovery periods were included between testing protocols in an attempt to reduce any amount of fatigue that could compromise the accuracy of test results.

5. Video notational analysis during the simulated sparring test would have provided greater insight into the movement patterns of the elite and novice karate participants during this activity. These data would have thus assisted the interpretation of the aerobic demand differences observed between the two groups during the three minutes of sparring However, the average $\dot{V}O_2$ values recorded for each group for the three minutes of sparring (elite: 62%$\dot{V}O_{2\,max}$; novice: 64%$\dot{V}O_{2\,max}$) provides strong evidence that both groups performed the simulation test at a similar relative intensity. Moreover, given that there was no video recording of the testing bouts, the number of punches and kicks performed by participants in each group cannot be compared. These data could have provided further comparative measures of exercise intensity or work rate to explain the

similarities in average $\dot{V}O_2$ and differences in peak $\dot{V}O_2$ between the two groups for the simulated sparring.

5.5 Recommendations for Future Research

1. Future research should include female karate participants because of the large female population of karate practitioners in Australia. Their inclusion would increase the generalisability of the findings.

2. The inclusion of junior karate participants would be beneficial given that this population makes up the majority of the karate students in almost all karate schools. It is important to include them to ensure appropriate training programs based on current scientific research findings, as well as assisting with talent identification. Ultimately, this could increase their success in karate championships as adult competitors.

3. A study design that includes an experimental (specific training) group and a control (standard karate training) group could indicate whether a program, designed to improve the motor fitness characteristic identified in this study as being important to karate success, has a significant effect on future competition successes.

4. Increasing the number of karate-specific tests, such as those involving eye and hand coordination or sport-specific skill/anticipation tests, could add further strength to characterising elite karate performance.

CHAPTER SIX

Conclusions

Many factors contribute to success in karate. While years of basic training are required to enhance the skills necessary in sparring, being faster or more powerful alone does not inevitably make one better at karate sparring. The results of this investigation demonstrate that competitors at higher skill levels can be classified correctly based on several general and karate-specific motor fitness variables. In particular, the findings of this research suggest that successful competitors are faster and more powerful, with better balance, flexibility and agility. In contrast, aerobic fitness was not a discriminating characteristic of karate proficiency between elite and novice participants. Consistent with this, the peak aerobic and glycolytic demands of karate sparring were relatively moderate in elite practitioners. Therefore, training the capacities of speed, power, agility, flexibility and balance rather than aerobic fitness may be more important for success in karate. The findings also suggest that karate athletes should spend less time developing aerobic energy systems and focus instead on sports-specific performance factors such as limb speed, punching power, balance, lower limb flexibility and karate agility.

The discriminating general and karate-specific motor fitness tests, in conjunction with karate skill testing, may provide coaches with a means of measuring karate proficiency and training progress by using a more objective testing battery that is related to karate success. The coach should observe a positive relationship between improvements in these motor fitness abilities and success in sparring. Moreover, the grading system could become more reliable if these motor fitness abilities were assessed in conjunction with normal karate grading protocols. Furthermore, the effectiveness of training programs could be monitored, in part, by observing improvements (or lack thereof) in these motor fitness abilities.

The motor fitness profiling of elite and novice practitioners in this work may provide data useful for talent identification in the sport of karate. In karate, students who do not have black belts are not permitted to spar in elite level competitions. Thus, if a karate student has similar motor fitness abilities to the elite karate practitioners, consideration could be given to placing them in an elite group in order to fast track their development in sparring. However, as Vaeyens et al. (2008) highlight, excellence in a sport is not simply based on achieving set physical or skill attributes; therefore, fast-tracking of novice practitioners should only occur after assessment of other key karate-specific attributes (not measured in this study) considered important to success. However, these empirical data provide guidance for developing appropriate performance characteristics in future talent and guiding the underpinning training regimens. For their part, students can enhance their performance and, perhaps, have longer, more satisfying careers in karate.

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APPENDICES

Appendix 1: Ethics Approval Letter

ACU National

Brisbane Sydney Canberra Ballarat Melbourne Human Research Ethics Committee

Committee Approval Form

PrincipalInvestigatorlSupervisor: Dr Tim Heazlewood Sydney Campus Brisbane Sydney Canberra Ballarat Melbourne Human Research Ethics Committee

Committee Approval Form

Co-Investigators: Dr Janet Currie Sydney Campus

Student Researcher: Mr Hovik Keshishian Sydney Campus

Ethics approval has been granted for the following project:
Utilisation of Energy Systems in Karate

for the period: 25 September 2006 to 30 December 2007

Human Research Ethics Committee (HREC) Register Number: N200607 12

The following standard conditions as stipulated in the *National Statement on Ethical Conduct in Research Involving Humans* (1999) apply:

(i) that Principal Investigators *1* Supervisors provide, on the form supplied by the Human Research Ethics Committee, annual reports on matters such as: ,
- security of records
- compliance with approved consent procedures and documentation
- compliance with special conditions, and

(ii) that researchers report to the HREC immediately any matter that might affect the ethical acceptability of the protocol, such as:
- proposed changes to the protocol
- unforeseen circumstances or events
- adverse effects on participants

The HREC will conduct an audit each year of all projects deemed to be of more than minimum risk. There will also be random audits of a sample of projects considered to be of minimum risk on all campuses each year.

Within one month of the conclusion of the project, researchers are required to complete a *Final Report Form* and submit it to the local Research Services Officer.

If the project continues for more than one year, researchers are required to complete an *Annual Progress Report Form* and submit it to the local Research Services Officer within one month of the anniversary date of the ethics approval.

Signed: Date: 25 September 2006
(Research Services Officer, McAuley Campus)

(Committee Approval.dot @ *15/10104)*

Appendix 2: Information Letter to Participants

ACU National

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

INFORMATION LETTER TO PARTICIPANTS

TITLE OF PROJECT: Motor Fitness Profiling of Elite and Novice Karate Practitioners

NAME OF PRINCIPAL SUPERVISOR: Dr Tim Heazlewood

NAME OF STUDENT RESEARCHER: Mr Hovik Keshishian

PROGRAMME IN WHICH STUDENT ENROLLED: MASTER OF EXERCISE SCIENCE (RESEARCH)

Dear Participant,

You are invited to participate in this study. The purpose of the study is to determine the differences in training type and years of karate experience on anthropometrics (height and weight) and motor fitness (speed, strength, power, agility and work) of karate athletes of different abilities. You will be asked to complete a questionnaire related to your training history and type. In addition, to assess the exercise physiological demands of undertaking a simulated karate sparring by assessing changes in heart rate, oxygen consumption and blood lactate production and how fatigue occurs following the simulated competition. A drop of blood from your finger will be collected at the completion of simulated competition round, which means two samples will be collected in this test.

A risk is involved with the use of the Lactate Pro blood lactate analyser to test the blood lactate concentration produced by exercise. The lancet and the lactate strips will only be used once and will be disposed of appropriately in a sharps container. This will result in minimal risk to the participant. The researcher will also wear gloves for the blood and temperature testing that will only be used once before disposal.

The total time to test all the variables will take approximately one hour of your time and the testing will occur at the Exercise Physiology Laboratory-Edward Clancy Building, Australian Catholic University, Albert Road, Strathfield Campus. As a result, no additional time is required from the participants.

The potential benefit of this study to the participants comes through improved performance due to a greater understanding of the differences between different ability levels. As well as what factors influencing performance can trained and how the athlete responds physiologically to a simulated competition, which will enable modifications and improvements to training programs. The potential benefit of this study in general comes through a greater understanding of the effects of competition exercise on athletes across different ability levels. This hopefully will result in improved coaching and karate athlete training.

Participants are free to refuse consent altogether without having to justify their decision, or to withdraw consent and discontinue participation in the study at any time without giving a reason. The research data collected for the study may be published or may be provided to other researchers in a form that does not identify you in any way.

Confidentiality will be ensured during the study through the use of numbers to indicate the participants rather than the use of their names.

Any questions regarding this project should be directed to the Principal Supervisor or to the Student Researcher.

Dr Tim Heazlewood or Mr Hovik Keshishian

02 9701 4378

School of Exercise Science

25A Barker Rd, Strathfield NSW 2135

Participants will be kept informed about their individual results.

This study has been approved by the Human Research Ethics Committee at the Australian Catholic University.

In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Supervisor and Student Researcher have not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Unit.

NSW/ACT: Chair, HREC
C/o Research Services
Australian Catholic University
Strathfield Campus
Locked Bag 2002
STRATHFIELD NSW 2135
Tel: 02 9701 4093
Fax: 02 9701 4350

Any complaint or concern will be treated in confidence and fully investigated. The participant will be informed of the outcome.

If you agree to participate in this project, you should sign both copies of the Consent Form, retain one copy for your records and return the other copy to the Supervisor or Student Researcher.

Principal Supervisor Student Researcher

Appendix 3: Consent Form: Participants' and Researcher's Copies

CONSENT FORM

PARTICIPANT'S COPY

TITLE OF PROJECT: Utilisation of Energy Systems in Karate

NAME OF PRINCIPAL SUPERVISOR: Dr Tim Heazlewood

NAME OF STUDENT RESEARCHER: Mr Hovik Keshishian

I... *(The participant)* have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this research, which consists of the questionnaire on training, blood lactate (3 samples), aerobic fitness, heart rate and motor fitness testing realising that I can withdraw at any time. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE:

DATE:

SIGNATURE OF PRINCIPAL SUPERVISOR:

DATE:

SIGNATURE OF STUDENT RESEARCHER:

DATE:

CONSENT FORM
RESEARCHER'S COPY

TITLE OF PROJECT: Utilisation of Energy Systems in Karate

NAME OF PRINCIPAL SUPERVISOR: Dr Tim Heazlewood

NAME OF STUDENT RESEARCHER: Mr Hovik Keshishian

I .... *(the participant)* have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this research, which consists of the questionnaire on training, blood lactate (3 samples), aerobic fitness, heart rate and motor fitness testing realising that I can withdraw at any time. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE:

DATE:

SIGNATURE OF PRINCIPAL SUPERVISOR:

DATE:

SIGNATURE OF STUDENT RESEARCHER:

DATE:

Appendix 4: Exercise Safety Questionnaire

Exercise Safety Questionnaire

Name: ___________________________________ Age: ____ Sex:___
Address:____ P'Code____
Home Phone: _________________ Mobile:_____________________ Email Address:
____

Person to be contacted in case of accident

____

Have you ever had or do you have?

A Hernia______
Arthritis _______
Asthma _______
Diabetes ______
Epilepsy ______
Dizziness ______
Heart Murmur ______
Stroke _______
Ulcer _______
Any heart condition ______
High Blood Pressure ______
Any Chronic Illnesses ______
Raised Cholesterol/Triglycerides _____
Are you on any prescribed medication ____
Do you have any infections or infectious Diseases? _____
Anyone in your family under 60 with Heart Disease, Stroke? _____
Are you dieting or fasting? _____

Any pain or major injuries, particularly in the following areas:

Neck____Back____Knees____Ankles____Hips____.

This information is used as a guideline to the limitations of my ability to exercise. I have answered the questions to the best of my ability.

Signed: _________________________________ Date: ____________

Appendix 5: Data for the Calibration of the Harley Stretch Machine

The table of data for the Harley stretch stretching machine, angular displacement and distance measured (cm) between the two levers of the Harley stretching machine. Note that the number 1 = elite and number 2 = novice karate participants.

Participants	1=Elite, 2=Novice	Harley Stretch (AU)	Angular Displacement (°)	Distance (cm)
1	1	36	140	144
2	1	49	153	153
3	1	38	145	147
4	1	38	145	147
5	1	47	150	151
6	1	37	143	145
7	1	41	147	147
8	1	53	160	157
9	1	32	129	141
10	1	30	127	139
11	1	34	130	143
12	1	51	158	155
13	2	26	116	133
14	2	38	145	147
15	2	51	158	155
16	2	26	116	133
17	2	25	115	131
18	2	26	116	133
19	2	30	125	139
20	2	30	125	139
21	2	17	100	115
22	2	21	108	126
23	2	18	102	117
24	2	27	118	135

This table shows the correlation for the Harley stretch machine and the distance measured between the two levers on the Harley stretch machine. The correlation between the two measurements is r = 0.961.

Correlations

[DataSet1] E:\Harley Flexibility Correlation.sav

Descriptive Statistics

	Mean	Std. Deviation	N
HarleyStretch	34.2083	10.48800	24
Distance	140.5000	11.18228	24

Correlations

		HarleyStretch	Distance
HarleyStretch	Pearson Correlation	1.000	.961**
	Sig. (2-tailed)		.000
	N	24	24
Distance	Pearson Correlation	.961**	1.000
	Sig. (2-tailed)	.000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

This is the table of correlation for the Harley stretch machine and the angular displacement. The correlation between the two measurements is r = 0.980.

Correlations

[DataSet1] E:\Harley Flexibility Correlation.sav

Descriptive Statistics

	Mean	Std. Deviation	N
AngleDisplacement	132.1250	18.30494	24
HarleyStretch	34.2083	10.48800	24

Correlations

		Angle Displacement	HarleyStretch
AngleDisplacement	Pearson Correlation	1.000	.980**
	Sig. (2-tailed)		.000
	N	24	24
HarleyStretch	Pearson Correlation	.980**	1.000
	Sig. (2-tailed)	.000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 6: Data for the Calibration of the Mega-Strike Punching Bag

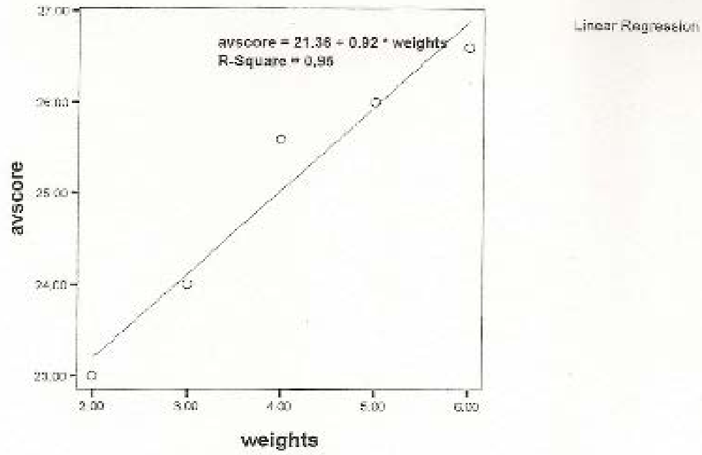
Data for the calibration of the Mega-Strike punching bag and dropping weights while the bag is placed on a soft surface.

	Weight (kg)	Score 1	Score 2	Score 3	Av/score
1	2	23	23	23	23
2	3	24	24	24	24
3	4	25	26	26	25.6
4	5	26	26	26	26
5	6	26	27	27	26.6

Correlation between scores from the punching bag and weights releasing on the bag (soft surface).

Interactive Graph

[DataSet0]



Correlations

[DataSet0]

Descriptive Statistics

	Mean	Std. Deviation	N
avscore	25.0400	1.49265	5
weights	4.0000	1.58114	5

Correlations

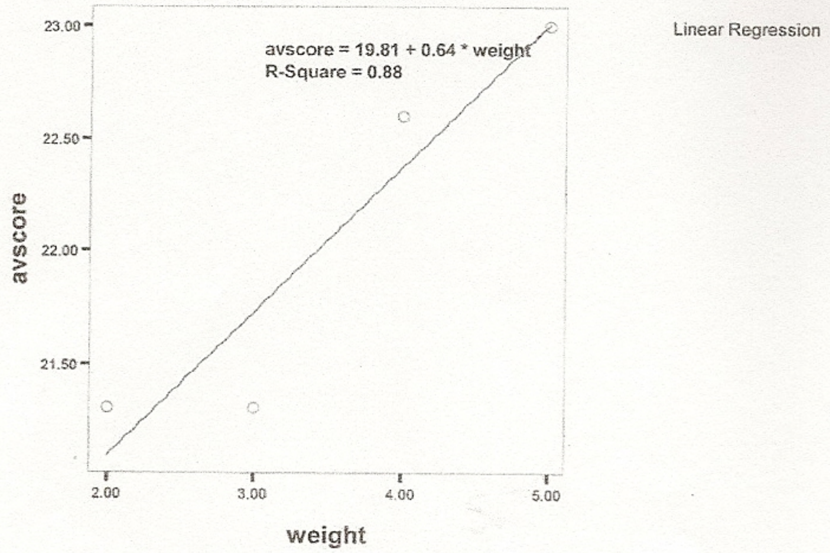
		avscore	weights
avscore	Pearson Correlation	1	.975**
	Sig. (2-tailed)		.005
	N	5	5
weights	Pearson Correlation	.975**	1
	Sig. (2-tailed)	.005	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

Data for the calibration of the Mega-Strike punching bag and dropping weights while the bag is on a hard surface.

N	Weight (kg)	Score 1	Score 2	Score 3	Score 4
1	2.00	22.00	21.00	21.00	21.30
2	3.00	22.00	22.00	20.00	21.30
3	4.00	23.00	23.00	23.00	22.60
4	5.00	23.00	23.00	23.00	23.00

Correlation between scores from the punching bag and weights released on the bag (hard surface).



Descriptives

[DataSet0]

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
avscore	4	21.30	23.00	22.0500	.88129
weight	4	2.00	5.00	3.5000	1.29099
Valid N (listwise)	4				

Correlations

[DataSet0]

Correlations

		avscore	weight
avscore	Pearson Correlation	1	.938
	Sig. (2-tailed)		.062
	N	4	4
weight	Pearson Correlation	.938	1
	Sig. (2-tailed)	.062	
	N	4	4

CORRELATION BETWEEN THE TWO METHODS OF CALIBRATION

Descriptives

Descriptive Statistics

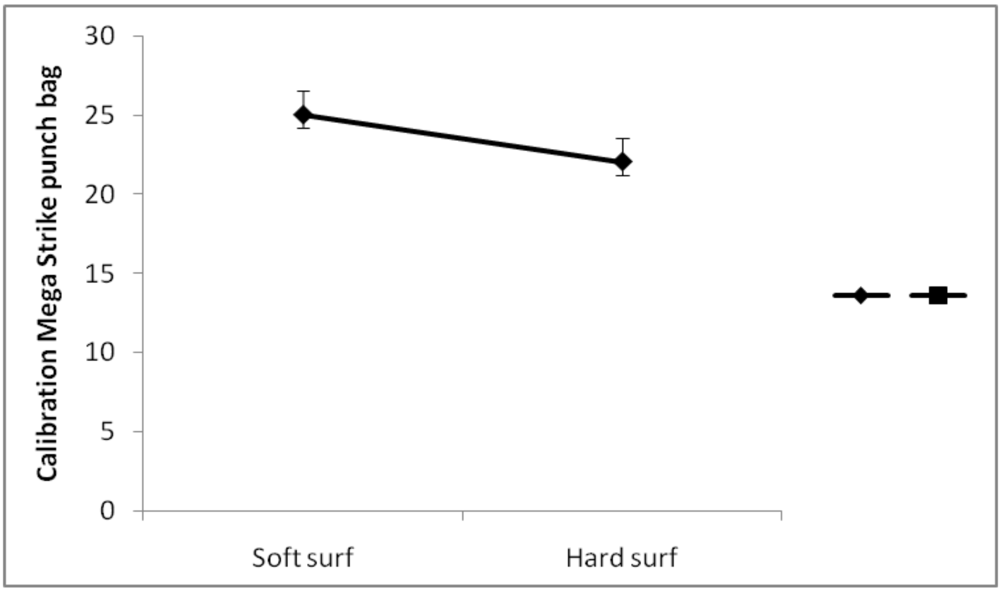
	N	Minimum	Maximum	Mean	Std. Deviation
Cal.Soft.Surface	5	23.00	26.60	25.0400	1.49265
Cal.Hard.Surface	4	21.30	23.00	22.0500	0.88129
Valid N (listwise)	4				

Correlations

Correlations

		Cal.Soft.Surface	Cal.Hard.Surface
Cal.Soft.Surface	**Pearson Correlation**	1	0.955*
	Sig. (2-tailed)		0.045
	N	5	4
Cal.Hard.Surface	**Pearson Correlation**	0.955*	1
	Sig. (2-tailed)	0.045	
	N	4	4

***. Correlation is significant at the 0.05 level (2-tailed).**



Appendix 7: Reliability tests for Static Balance, Karate Agility, Punching Response Time and Punching Speed

The table below shows the Dependent T-test, correlation and Coefficient of Variations for the static balance, karate agility, response time and punching speed.

	N	Dependent T-values	Correlation R Values	Correlation P Values	CV%
Static balance	5	P=0.07	R=0.99	P=0.001	0.21
Karate agility	5	P=0.18	R=0.99	P=0.001	0.06
Response time	5	P=0.21	R=0.96	P=0.008	0.08
Punching speed	5	P=1.00	R=0.79	P=0.11	0.21

Reliability tests procedures for static balance, karate agility, response time and punching speed

To validate the accuracy and reliability scores of the agility, static balance and the karate punching speed and punching response time tests. One group of five adult males aged 18 and over from the North Ryde karate school was randomly selected.

The participants in the study they all did these tests twice with a three minute rest given between each test. Statistical analysis dependent t-test and correlation were conducted on their scores.

The following results were derived from these tests.

Dependent t-test for all the three tests showed there were no significant ($P < 0.05$) differences between their first and the second test scores. The correlation coefficient for the static balance test was very high ($r = 0.99$). The correlation coefficient for the punching response time was ($r = 0.96$). The correlation coefficient for the punching speed was (r = 0.79). The statistical analysis indicates that these tests are accurate and reliable.

Test-retest reliability was conducted for ‘karate agility’, where participants (n = 5) performed the test twice, separated by three minutes. A dependent t-test showed significant difference between times for the two trials (P = 0.04), with a Pearson’s r = 0.90 (P = 0.05) and a typical error of 0.086%. The statistical analysis indicates that this test is accurate and reliable.

Appendix 8: Karate Agility Notational Analysis

The karate agility test used in this study was designed by the researcher. It was based on notational analysis of video footage of sparring movements of elite male athletes at AKF karate championship bouts. Total body shifting actions were cactegorised into 44% forward (step-slide), 45.4% backward and 10.6% sideways.

The Notational Analysis of Karate Sparring AKF Championships in Sydney

Number of fights	Duration (minutes)	High Intensity actions	Total time engaged in fight (Sec)	Percentage of time engaged in fighting (%)	Forward movement (%)	Backward movements (%)	Sideways movements (%)
1	3	51	27	15	55	40	5
2	3	47	23	13	40	45	15
3	3	58	31	17	30	50	20
4	3	50	26	14.5	45	47	8
5	3	46	20	11	50	45	5
Average		50.4	25.4	14.1	44	45.4	10.6
Min		46	20	11	30	40	5
Max		58	31	17	55	50	20

A total of five karate sparring matches were analysed. The subsequent information was recorded.

1. Sparring duration. Three minutes
2. Average number of high intensity actions (punches, kicks and blocks) in the 3 minute sparring. 50.4

3. Average time engaged in actual fighting. 25.4 (sec)
4. Percentage of time competitors engaged in actual fighting during the match. 14.1%
5. Percentage of time athletes moving forward (stepping and sliding). 44%
6. Percentage of time athletes moving backward (stepping and sliding). 45.4%
7. Percentage of time athletes moving sideways (stepping and sliding).10%

Appendix 9: Descriptive Statistics for the Elite and Novice Participants

In table below, the descriptive statistics analyzed were: number of cases, range, minimum, maximum, mean, standard error, variance, skewness, kurtosis.

	N	Range	Minim	Maxim	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
Independent Variables	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Age (years)	24	39	17	56	31.5	2.6	12.8	165.9	0.48	0.4	-1.2	0.9
Height (cm)	24	35	156	191	177.5	1.8	9.2	83.9	-0.5	0.4	-0.1	0.9
Body Mass (kg)	24	57	58	115	76.4	3	14.7	218.5	1.1	0.4	0.9	0.9
Margaria power test (kgm.s^{-1})	24	65.8	59.7	125.6	85	3.5	17.2	295.3	0.4	0.4	0.1	0.9
Margaria power test (watts)	24	646.1	586.1	1232.3	834	34.4	168.5	28424.5	0.4	0.4	0.1	0.9
Long jump (cm)	24	94	150	244	208	4.5	22.1	488.3	-0.88	0.4	1	0.9
Karate agility (sec)	24	10.4	4.25	14.7	8.7	0.5	2.6	7.1	0.2	0.4	-0.5	0.9
Punching speed (sec)	24	32	49	81	67.3	1.8	9	81.4	-0.3	0.4	-1	0.9
Punching power (AU)	24	0.7	0.2	.9	0.4	0.03	0.2	0.03	0.7	0.4	0.2	0.9
Punching response time (sec)	24	0.1	0.2	.3	0.2	.001	0.04	0.002	-0.3	0.4	-1.3	0.9
Strength (kg)	24	41	30	71	47.4	2.1	10.3	107.6	0.2	0.4	-0.4	0.9
Static balance (sec)	24	4.9	1.1	6	2.5	0.3	1.3	1.9	0.9	0.4	0.1	0.9
Sit and reach flex (cm)	24	41	12	53	33.9	2.2	10.6	113.2	-0.2	0.4	-0.3	0.9
Lateral leg flex (cm)	24	36	17	53	34.2	2.1	10.4	109.9	0.3	0.4	-0.7	0.9
Arm ergometer cadence (rpm)	24	90	16	250	219.1	3.7	18.1	327.1	-1.4	0.4	4.1	0.9
Resting heat rate (bpm)	24	54	54	108	75.6	2.5	12.3	153.4	0.6	0.4	0.7	0.9
$\dot{V}O_{2\ max}$ **(ml.kg^{-1}min^{-1})**	24	44.2	17.8	62	46.1	2.2	10.6	112.8	-0.5	0.4	1	0.9
Wingate peak power (watts)	23	625	719	1344	1036.8	27.8	133.5	17845.3	-0.1	0.4	0.7	0.9
Wingate time to peak power (watts)	23	5	3.8	8.8	5.1	.3	1.3	1.8	1.6	0.4	2.1	0.9
Wingate mean power (watts)	23	328	350	678	573.3	14.3	69	4761.4	-1.6	0.4	4.4	0.9
Wingate mean power: Body mass (watts/kg)	23	4.3	5.1	9.4	7.5	0.2	1.14	1.3	-0.5	0.4	-.003	0.9
Wingate peak power: Body mass (watts/kg)	23	9.7	8.4	18.1	13.8	0.5	2.6	6.9	-0.6	0.4	-0.2	0.9
Wingate rate to fatigue (sec)	23	32	17.1	49.1	30	1.7	8.4	70.7	0.1	0.4	-0.4	0.9
Blood lactate at rest (mmol.L^{-1})	24	4	0.9	4.9	2.5	0.2	1.1	1.1	0.5	0.4	-0.5	0.9

Appendix 10: Tests for Normality of Baseline Data

Tests for Normality on Baseline Data

Parametric variables at baseline level were tested for normality using one criterion. The baseline data were considered normally distributed if doubled standard deviation values were smaller than the means (Peat & Barton, 2009).

Comparison between the Elite and Novice Karate Participant's Abilities

The standard deviation values for the elite and novice participants' measured independent variables were doubled. It indicates that the values are smaller than their means for the 23 measured variables for the elite and novice participants in this study. This increases the validity of this research.

In the table below the Standard deviation values for the fitness tests are multiplied by two

Variables	Particip	Mean	Std Deviation	SD *2
Age (years)	Elite	33	13.5	27
	Novice	30	12.7	25.4
Height (cm)	Elite	179	8.04	16.1
	Novice	176	10.3	20.6
Body Mass (cm)	Elite	76.3	8.7	17.4
	Novice	76.6	19.5	39
Margaria Power test (W)	Elite	919.9	134.5	269
	Novice	745	159.3	318.7
Standing Long Jump(cm)	Elite	212	18.7	37.5
	Novice	204	25.1	50.2
Karate agility (sec)	Elite	7.5	2.3	4.7
	Novice	9.8	2.5	5.1
Punching power (AU)	Elite	71	7.2	14.5
	Novice	64	9.2	18.5
Punching speed (sec)	Elite	0.3	0.1	0.2
	Novice	0.5	0.2	0.4
Punching response time (sec)	Elite	0.225	0.05	0.1
	Novice	0.246	0.04	0.08
Hand grip strength (kg.wt)	Elite	50.4	6.3	12.6
	Novice	44.5	12.9	25.5
Static balance (sec)	Elite	3.5	1.3	2.6
	Novice	1.7	0.7	1.4
Sit and reach flexibility (cm)	Elite	38.2	8.9	17.8
	Novice	29.7	10.8	21.6
Lateral leg flexibility (cm)	Elite	40.5	7.7	15.4
	Novice	27.9	9.1	18.2
Arm ergometer cadence (peak rpm)	Elite	230.1	9.3	18.6
	Novice	208.2	18.2	36.4
Resting heart rate (bpm)	Elite	74.9	11.9	23.7
	Novice	76.4	13.4	26.7
$\dot{V}O_{2\ max}$ **(ml.kg^{-1}min^{-1})**	Elite	48.2	8.4	16.7
	Novice	43.9	12.5	25
Wingate peak power (watts)	Elite	10926	119.5	238.1
	Novice	976	125.6	251.2
Wingate time to peak power (w)	Elite	4.9	1.3	2.6
	Novice	5.4	1.5	2.9
Wingate mean power (w)	Elite	597	39	78.6
	Novice	548	85.9	171.7
Wingate mean power: Body mass (watts/kg)	Elite	7.8	0.5	1
	Novice	7.4	1.6	3
Wingate peak power: Body mass (watts/kg)	Elite	14.2	1.9	3.8
	Novice	13.4	3.3	6.6
Wingate rate to fatigue (sec)	Elite	31.2	8.6	17.2
	Novice	28.8	8.5	17
Blood lactate at rest (mmol.L^{-1})	Elite	2.4	1.17	2.34
	Novice	2.6	1	2

Abbreviations: Particip=participants

Effects of Simulated Sparring

In the following table the standard deviation values for the independent variables were doubled. It indicates that these values are smaller than their means. This increases the validity of this research.

Table below displays standard deviation times by two for the simulated sparring

	N	Mean	Std. Deviation	SD * 2
Punching Power pre-sparring (AU)	24	67.3	9.	18
Punching Power post-sparring (AU)	24	60.7	8.7	17.4
Punching Speed pre-sparring (s)	24	0.4	0.2	0.4
Punching Speed post-sparring (s)	24	0.5	0.2	0.4
Punching Response time pre-sparing (s)	24	0.235	0.04	0.1
Punching Response time post-sparing (s)	24	0.271	0.05	0.1
Blood lactate pre-sparing ($mmolL^{-1}$)	23	2.4	1.1	2.2
Blood lactate post-sparing ($mmolL^{-1}$)	23	5.6	2.4	4.8

The $\dot{V}O_{2\,max}$ Compared to the Peak $\dot{V}O_2$ Post Simulated Sparring

In the following table the standard deviation scores were doubled. It indicates that the values are smaller than their means. This increases the validity of this research.

The table below displays standard deviation values times by two for $\dot{V}O_{2\,max}$ and peak $\dot{V}O_{2\,max}$ for simulated sparring

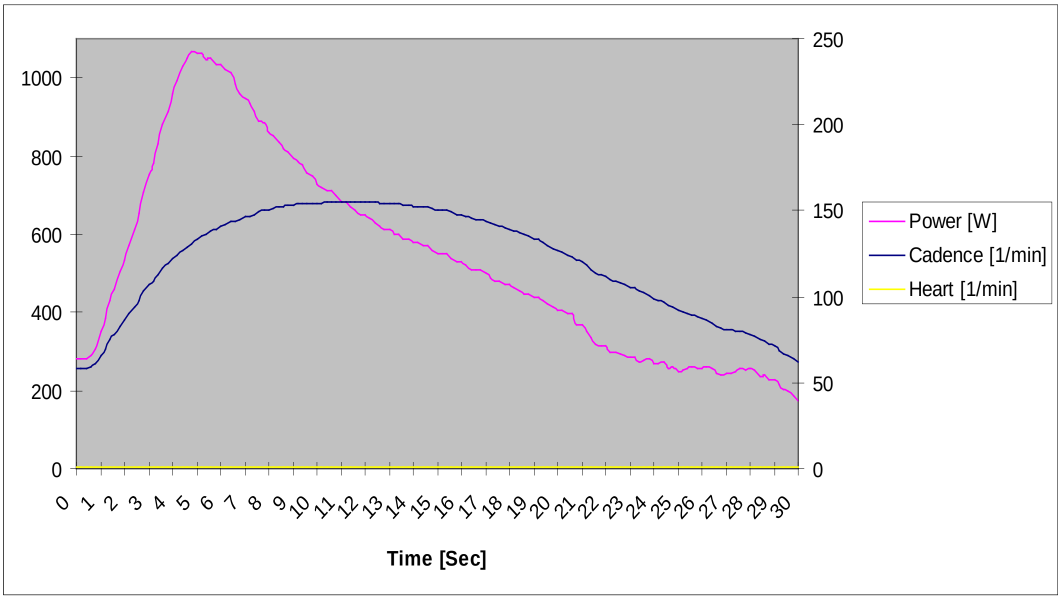
	Participants	N	Mean	Std. Deviation	SD * 2
1	**Elite**	11	67.7	16.5	33
2	**Novice**	9	80.7	12	24

Appendix 11: Wingate Test of Anaerobic Power a Pilot Study

The table and the graph below display the lactic anaerobic capacity for a period of thirty seconds using the Wingate Test of anaerobic power.

Wingate Test of Anaerobic Power

Patient Name	X	
Weight	66	(kg)
Torque	46.2	(Nm)
Protocol Name	Wingate 60	
date	12/06/2007	
Time	2:27:00 PM	
Mean Power	538	(W)
Peak Power	1066	(W)
Minimum Power	185	(W)
Time to Peak Power	4.8	(S)
Mean Power body/mass	8.2	(W/Kg)
Peak Power body/mass	16.2	(W/Kg)
Rate to Fatigue	35	(W/Sec)



Wingate Test of Anaerobic Power

Appendix 12: Example of $\dot{V}O_{2\ max}$ data

Subject Data

F1	F2	Barometer (mmHg):	760
Subject Name:	X	Temperature (C):	20.0
Subjects age:	22	Relative Humidity:	45
Subject Sex:	M		
Subject Height (cm):	190		
Subject Weight (kg):	71.4		
Subject BSA:	1.97		
FiO_2:	20.93		
$FiCO_2$:	0.04		

Metabolic Data during the treadmill test

Time	Freq	Vt	VO2	VCO2	RER	VO_2/kg
(min)	(br/min)	(ml)	(ml/min)	(ml/min)		(ml/kg)
00:30	20	1144	754	625	0.83	10.6
01:00	16	1182	775	563	1.73	10.9
01:30	13	1745	1009	739	0.73	14.2
02:00	20	1774	1307	1063	0.81	18.4
02:30	22	1283	1020	826	0.81	14.3
03:00	24	1191	1094	860	0.79	15.4
03:30	16	1781	1084	885	0.82	15.2
04:00	21	1693	1345	1151	0.86	18.9
04:30	23	1650	1480	1247	0.84	20.8
05:00	22	1844	1622	1370	0.84	22.8
05:30	21	1968	1593	1387	0.87	22.4
06:00	23	1893	1625	1442	0.89	22.8
06:30	25	2179	1937	1819	0.94	27.2
07:00	28	1956	2085	1908	0.92	29.3
07:30	21	2479	2242	2002	0.89	31.5
08:00	23	2699	2318	2263	0.98	32.6
08:30	24	2597	2329	2269	0.97	32.7
09:00	27	2545	2479	2507	1.01	34.8
09:30	29	2667	2541	2667	1.05	35.7
10:00	28	2644	2478	2553	1.03	34.8
10:30	32	2307	2451	2503	1.02	34.4
11:00	31	2324	2352	2445	1.04	33.0
11:30	30	2574	2377	2523	1.06	33.4
12:00	32	2468	2441	2512	1.03	34.3
12:30	31	2853	2830	2858	1.01	39.7
13:00	32	2748	2907	2900	1.00	40.8
13:30	31	3079	3041	3176	1.04	42.7
14:00	32	3153	3211	3363	1.05	45.1
14:30	31	3138	3106	3252	1.05	43.6
15:00	34	3023	3290	3398	1.03	46.2
15:30	35	2961	3403	3521	1.03	47.8
Mean	26	2242	2081	2019	0.93	29.2
Peak	35	3138	3403	3521	1.06	47.8

Appendix 13: Example of metabolic data during karate sparring

Subject Data

F1	F2
Subject Name:	X
Subject Age:	46
Subject Sex:	M
Subject Height (cm):	165
Subject Weight (kg):	65
Subject BSA:	1.74
Barometer (mmHg):	760
Temperature (C):	20
Relative Humidity:	45
FiO_2:	20.93
$FiCO_2$:	0.04

Metabolic Data for the simulate karate sparring

Time	Freq	Vt	VO2	VCO2	RER	VO_2/kg
(min)	(br/min)	(ml)	(ml/min)	(ml/min)		(ml/kg)
00:15	32.9	959	644	728	0.97	12.5
00:30	56.9	1161	1125	1223	1.10	19.9
00:45	33.8	1391	1476	1217	0.83	22.3
00:60	39.3	1664	1994	1658	0.83	30.1
01:15	42.7	1542	2060	1695	0.84	31.1
01:30	42.3	1450	2065	1729	0.84	31.2
01:45	45.0	1623	2081	1880	0.90	31.4
02:00	45.9	1537	2090	1913	0.92	31.6
02:15	43.7	1528	1980	1844	0.93	29.9
02:30	49.2	1585	2147	2014	0.94	32.4
02:45	46.2	1633	2161	2026	0.94	32.6
03:00	44.8	1683	2132	2063	0.97	32.2
Mean	43.6	1480	1830	1666	0.92	28.1
Peak	56.9	1683	2161	2063	1.10	32.6

Appendix 14: Discriminant Analysis Enter Method and Stepwise Analysis

Discriminant Analysis Enter Method general and specific motor fitness test results

All the variables that were statistically significant between the elite and the novice karate participants were utilised in the Discriminant Analysis Enter method. This includes general and specific tests (nine variables). The statistical analysis shows 95.7% of the cases were correctly classified. Discriminant Analysis was used to verify which variables can best predict karate ability based on general motor fitness and karate-specific motor fitness constructs.

Table of Discriminate Analysis Enter Method.
Classification Results 95.7% of the cases were correctly classified

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	12	0	12
		Novice	1	11	12
	%	Elite	100.0	0.0	100.0
		Novice	9.1	90.9	100.0

Discriminant Analysis Enter Method Karate-specific Tests Results

In this table, four karate fitness tests were entered in the equation. The result shows 91.7% of the cases were correctly classified in their groups. This is 4.1% less accurate than using the nine variable models.

Table of Discriminant Analysis Enter Method
Classification Results 91.7% of the cases were correctly classified.

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	12	0	12
		Novice	2	10	12
	%	Elite	100.0	0.0	100.0
		Novice	16.7	83.3	100.0

Discriminant Analysis Enter Method General Fitness Tests Results

In the following table the variables entered were the five general motor fitness tests. The result shows 95.7% of the cases were correctly classified in their groups.

Table of. Discriminant Analysis Enter method
Classification Results 95.7% of original grouped cases correctly classified.

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	12	0	12
		Novice	1	11	12
	%	Elite	100.0	0.0	100.0
		Novice	9.1	90.9	100.0

Discriminant Analysis Stepwise all the Significant Variables Test Results

In the following table there were only two of the nine significant variables used by the computer software for the statistical analysis. These were Margaria-Kalamen power test and static balance. The level of classification using these two variables was 87.5%.

Table of Discriminant Analysis Stepwise Method
Classification Results 87.5% of original grouped cases correctly classified.

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	10	2	12
		Novice	1	11	12
	%	Elite	83.3	16.7	100.0
		Novice	8.3	91.7	100.0

Discriminant Analysis Stepwise Karate-specific Variables Test Results

In the following table using karate-specific tests the only variables chosen for the analysis by the computer were the speed of the punch and seated lateral leg flexibility. There were 91.7 % cases correctly classified.

Table of Discriminant Analysis Stepwise Method
Classification Results 91.7% of original grouped cases correctly classified.

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	10	2	12
		Novice	1	11	12
	%	Elite	83.3	16.7	100.0
		Novice	8.3	91.7	100.0

Discriminant Analysis Stepwise General Fitness Variables Test Results

In the following table using general motor fitness tests the variables chosen for analysis were static balance and Margaria-Kalamen power test. The classification was 87.5%.

Table of Discriminant Analysis Stepwise Method
Classification Results 87.5 % of original grouped cases correctly classified.

			Predicted Group Membership		Total
		Participants	Elite	Novice	1.00
Original	Count	Elite	12	0	12
		Novice	2	10	12
	%	Elite	100.0	0.0	100.0
		Novice	16.7	83.3	100.0

Appendix 15: Pre-test to Post-test Fatigue Analysis Using Mixed Model ANOVA

It can be observed that for the scores at the pre-test to post- test, both elite and novice participants displayed a significant decrease in punching speed and punching power and increase in punching response time and blood lactate concentration ($P < 0.05$) following the simulated sparring. There is an interaction effect for punching speed.

Pre-test to Post-test Fatigue Analysis Using Mixed Model ANOVA

Variables	P-Value	Interaction
Power punch (AU) Pre to post sparring	P<0.001	No
Power punch (AU) Elite/Novice	P <0.01	No
Speed punch (AU) Pre to post sparring	P<0.01	Yes
Speed punch (AU) Elite/Novice	P<0.01	Yes
Response time (sec) Pre to post sparring	P<0.001	No
Response time (sec) Elite/Novice	Ns	No
Lactate concentration ($mmol.L^{-1}$) Pre to post sparring	P<0.001	No
Lactate concentration ($mmol.L^{-1}$) Elite/Novice	Ns	No

Abbreviation: AU = arbitrary unit of measurement; Ns = not significant

The Scores for Pre to Post-Sparring Means and Standard Deviation

Variables	**Elite (N = 12)**	**Novice (N = 12)**
	$\bar{x}$ ± SD	$\bar{x}$ ± SD
Response time Pre/spar (sec)	0.22 ± 0.05	0.24 ± 0.36
Response time Post/spar (sec)	0.26 ± 0.05	0.28 ± 0.05
Speed Pre/spar (sec)	0.33 ± 0.11	0.53 ± 0.18
Speed Post/spar (sec)	0.47 ± 0.13	0.58 ± 0.17
Power Pre/spar (sec)	71.16 ± 7.27	63.50 ± 9.23
Power Post/spar (sec)	64.66 ± 5.38	56.83 ± 9.82
Blood lactate Pre/spar ($mmol.L^{-1}$)	2.25 ± 1.18	2.6 ± 1.00
Blood lactate Post/spar ($mmol.L^{-1}$)	5.94 ± 2.92	5.38 ± 1.88

Abbreviation: spar = sparring

Appendix 16: Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices

The statistical assumptions have not been violated since the values derived through the Tests of Equality of Covariance Matrices are greater than 0.05. The following tables display the values for the statistical analysis performed throughout this study.
This part of statistical analysis (Box’s Test) illustrates the comparisons between the elite and novice karate participants’ motor fitness abilities
Discriminant Analysis Enter Method - nine significant variables.
Variables = Margaria power test, karate agility, punching power, punching speed, static balance, sit and reach flexibility, lateral leg flexibility, arm ergometer cadence, Wingate peak power tests.

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		76.5
F	Approx.	0.8
	df1	45
	df2	1422.4
	Sig.	0.7

Discriminant Analysis Enter Method five general motor fitness variables
Variables = Margaria power test, static balance, sit and reach flexibility, arm ergometer cadence, Wingate peak power tests.

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		18.9
F	Approx.	0.9
	df1	15
	df2	1741.6
	Sig.	0.5

Discriminant Analysis Enter Method specific motor fitness variables
Variables = karate agility test, punching power, punch speed, lateral leg flexibility

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		11.8
F	Approx.	0.9
	df1	10
	df2	2313.9
	Sig.	0.5

Discriminant Analysis Stepwise method specific motor fitness variables

Variables = karate agility test, punching power, punch speed, lateral leg flexibility

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		3.6
F	Approx.	
	df1	3
	df2	87120
	Sig.	0.4

Discriminant Analysis Stepwise method general motor fitness variables

Variables = Margaria-Kalamen power test, static balance, sit and reach flexibility, arm ergometer cadence, Wingate peak power tests.

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		4.8
F	Approx.	1.4
	df1	3
	df2	111064.4
	Sig.	0.2

Discriminant Analysis Stepwise method general and specific motor fitness variables

Variables = Margaria-Kalamen power test, static balance test, sit and reach flexibility, arm ergometer cadence, Wingate peak power, karate agility test, lateral leg flexibility, punching power and punching speed test.

Box's Test of Equality of Covariance Matrices

Test Results

Box's M		4.8
F	Approx.	1.4
	df1	3
	df2	111064.4
	Sig.	0.2

This part of the statistical analysis illustrates the comparisons between the elite and novice karate participants' simulated sparring and $\dot{V}O_{2\,max}$.

Punching speed

Box's Test of Equality of Covariance Matrices

Box's M	8
F	2.4
df1	3
df2	87120
Sig.	0.06

Punching response time

Box's Test of Equality of Covariance Matrices

Box's M	2.5
F	0.760
df1	3
df2	87120
Sig.	0.5

Blood lactate concentrations

Box's Test of Equality of Covariance Matrices

Box's M	7.1
F	2.1
df1	3
df2	111064
Sig.	0.096

Punching power

Box's Test of Equality of Covariance Matrices

Box's M	3.8
F	1.1
df1	3
df2	87120
Sig.	0.3

Appendix 17: Researcher's Karate Experience

Hovik Keshishian has been training and teaching karate for 39 years, achieving his 7th degree black belt in Australia in 2010. He has competed successfully in state, national and international competitions in the Shotokan and All Styles of Karate organizations. He has successfully coached a karate athlete who won gold medal in the world karate championships. He has held judging and refereeing licenses in karate for 27 years and has been involved in numerous judging and referring seminars to ensure that simulated sparring is a better representation of an actual competition sparring.

He is currently the NSW Shotokan karate technical and development delegate. He has attended state and national karate competitions and recorded the matches for analysis. This was to ensure that the participants chosen for the present study were a good representative group to be used for research, as well as to observe the similarities of the two events. The researcher has had the technical support of number of high ranking black belts including world champions and 7th and 8th degree karate masters.

Appendix 18: Martial arts not considered Karate

Martial arts not considered Karate according the Australian All Styles Rules:

- Boxing
- Wrestling
- Street fighting
- Unarmed combat
- Judo
- Jui-Jutsu
- Ninjutsu
- Tai Jatsu
- Aikido
- Hapkido
- Tae-Kwon-Do
- Silat, Bando
- Thai Boxing
- Kick Boxing
- Savate, Kung Fu
- Wushu, Tai Chi
- Chuan, stick fighting
- Arnis
- Kendo
- Laido
- Kyudo (AKF, 2012).

Appendix 19: Scoring Criteria and Illegal Scoring Techniques

Scoring Criteria in Sparring

A score is registered when the majority of officials identify an effective, legal technique delivered with good control to a legal target area. The scoring distance required is 10-15 centimetres.

Three points are awarded for spinning and jumping kicks to the upper target area (being defined as the face, head and the neck area).

Two points are awarded for upper kicks (being defined as kicks to the face, head and behind the neck and/or kicks coming in a downward motion to the head). Two points are awarded for take-downs (dropping an opponent to the floor) followed up with a legal hand technique (male and female black belt divisions only).

One point is awarded for punches above the torso area including the face, side and back of the shoulders, forehead, neck and back of the head. A single point will also be awarded for kicks directed above the waist and below shoulder height. A single point is awarded for foot sweep techniques followed up with a valid hand technique.
Note: It is not required that punches and kicks make contact with an opponent in order for the judges to consider them effective. Under (NAS) rules an effective technique demonstrates superior control because it does not make contact.

Contact often results from a deficiency in one of the elements of an "effective technique". "Effective" refers to the ability of the technique to cause serious injury, to disable and/or to stun an opponent if delivered with full force. Hence, for example, a punch delivered at an opponent who is "back-pedalling" is unlikely to be effective because the timing and distance are changing, thereby negating the landing/impact potential of the technique. In the same manner even a small deflection, block or sidestep may be sufficient to dissipate the power of an opponent's attack. An effective technique relies on concentrated effort.

The main aspects of an effective technique are power, timing, distance, and balance. These aspects of the attack should all come together at the focus point. Techniques delivered to the biceps or arm region will not score. (These are sometimes referred to as a body block.)

“Control” in this context, comprises

a) Power and speed such that, although evident, the full force of attack is held in reserve.

b) Correct technique delivered with spirited intent (not malicious or “wild”) and within a range or distance considered close having regard to the skill level of the division.

c) Awareness of the combat circumstances and potential to continue the attack or defend the counter attack. The contestant must maintain guard and remain involved in the contest until the referee says, “stop”.

d) Execution of the technique must be completed within the ring. That is, at least one foot must remain inside the ring perimeter and the technique must be delivered three seconds before the referee calls "stop" due to the travelling rule. In the instance of aerial techniques the competitor may land outside the ring but the technique itself must be completed inside the ring. (Once a competitor with one foot in the ring and the other outside of the ring lifts his front foot he is declared out.)

6.2 One competitor must be declared the winner when

a) At the expiration of time she/he has accumulated a majority of points.

b) One competitor gains a clear majority lead of eight points or reaches a maximum fifteen points.

c) One competitor is disqualified.

d) One competitor fails to attend, withdraws or is declared unfit.

e) In a draw situation, during the extension bout the first person to score is declared the winner.

6.3 When a judge observes a scoring technique he/she shall communicate using the whistle and at the same time extending the appropriate flag to indicate the scoring competitor (WKF, 2012).

Illegal Scoring Techniques and Actions

During sparring the following must be noted:

a) Point sparring is a non-contact event, target area 10 – 15 centimetres

b) Techniques that make contact and or may cause injury to head/ body

c) Excessive uncontrolled attacks directed to the head, arms & body.

d) Attacks directed below the belt (including fake groin kicks).

e) Wrestling, grappling, uncontrolled take downs.

g) Stomping on a fallen opponent.

h) Other dangerous or uncontrolled techniques, such as an uncontrolled spinning back fist, elbow and knee attacks, head butts, uncontrolled hook and uncontrolled spinning hook kick, uncontrolled spinning sweep using the heel or uncontrolled axe kick (WKF, 2012).

Appendix 20: The Karate Sparring Ring and Weight Divisions

The Sparring Ring

The ring should be either:

a) A padded surface, or

b) Outlined with adhesive tape or other marking around the perimeter.

c) The dimensions of the sparring area is 8 metres square (WKF, 2012).

Individual competitions may be categorised according to:

a) Gender (male and/or female)

b) Age

c) Grade/experience (WKF, 2012).

Weight divisions

The following are the female weight divisions in karate (kumite) sparring:

Female Kumite (under 53 Kg)

Female Kumite (under 60 Kg)

Female Kumite (over 60 Kg)

Female Kumite Open

Following are the male weight divisions in karate (kumite) sparring:

Male kumite (under 60 Kg)

Male Kumite (under 65 Kg)

Male Kumite (under 70 Kg)

Male Kumite (under 75 Kg)

Male Kumite (under 80 Kg)

Male Kumite (over 85 Kg)

(WKF, 2012).

Appendix 21: Different Categories of Sparring

As the word suggests, sparring (kumite) in karate is a method of practicing the various techniques while facing an actual opponent.

In 1920's, under the leadership of Gichin Funakoshi, a system of elementary sparring was devised. This was gradually developed and refined into the present day free-style sparring, which can be performed as a competitive match.

Because karate in its early days was used in fighting actual armed enemies and was itself perfected into a dangerous weapon, it was not until it became associated with the other Japanese martial arts that the concept of focusing the techniques just short of contact with the opponent was developed, making sparring possible.

There are two types of sparring: one in which the mode of attack is determined and agreed upon in advance; and the other free style, in which nothing is predetermined. Within the former are basic sparring and semi free sparring (Nishyama & Brown, 1983).

1. Basic Sparring (Kihon Kumite)

In basic sparring, the two participants face each other from a fixed distance and take turns attacking and defending. In every case, the mode of attack and target are predetermined. It could appropriately be called a formal exercise (kata) in sparring. The purpose of basic sparring is to train beginners in the principles of applying techniques (Nishyama & Brown, 1983) and learn the different stances while executing basic techniques (Kanazawa, 1986). In Shotokan Karate there are four basic sparring types.

- **Gohon Kumite**

In this type of sparring the movements should be performed swiftly and five times in succession.

- **Sanbon Kumite**

This is similar to Gohon Kumite; it is a fundamental training to acquire correct breathing techniques and physical power. The attacks are performed consecutively with a different technique at a different level, that is, three times to the upper, middle and lower sections of the body.

- **Kihon Ippon Kumite**

In this type of sparring each partner takes a turn in attacking with a predetermined level and technique of attack. The aim is to learn correctly a group of exercises of stepping, dodging and different positions and basic techniques of attack and defence.

- **Kaishi Ippon Kumite**

When facing an attack, the defender blocking as in Kinhon Ippon Kumite, then attacks stepping forward. The defender stepping back or sideways, executes a block and counter-attacks (Kanazawa, 1986).

2. Semi-Free Sparring (Jiyu-Ippon Kumite)

As in basic sparring, in this practice technique the mode of attack and the vital point to be attacked are prearranged. However, both attacker and defender assume relaxed ready positions and move about. The attacker must find an opening and create the proper distance from his opponent before attacking. The defender must watch for the attack and be ready to defend himself. As soon as the attack comes he must block or dodge, then counterattack. This type of sparring approaches the more advanced free style sparring. The student should apply dynamically the examples given in basic sparring. This is a midway step between basic and free style sparring. It gives excellent training in distancing, finding an opening and correct use of techniques in action (Nishyama & Brown, 1983).

Free Style Sparring (Jiyu-Kumite)

This is a completely free form of sparring in which neither the form of attack nor the attacker is prearranged. The attacks are pulled just short of contact with the target (Nishyama & Brown, 1983).