Physiological demands and time-motion analysis of simulated elite karate kumite matches

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DECLARATION

THESIS TITLE:

Physiological demands and time-motion analysis of simulated elite karate kumite matches

I, Elsabé le Roux, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgments indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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ABSTRACT

Introduction: Since competition has become the focal point of athletic training and the development of more tournament competitions on both national and international levels, the popularity of karate is ever increasing. No single performance characteristic dominates in combat sports and success requires a mixture of technique, strength, aerobic fitness, power and speed. Thus it has come to light that without proper investigation of the physiological demands imposed on an athlete during a competition situation, it would be unlikely that the athlete will develop to his or her full potential.

Objectives: The objectives of this study were:

- to identify the various physiological demands placed on the athlete during a simulated karate kumite competition situation;
- to conduct a time-motion analysis to determine the characteristics of the karate kumite matches;
- to determine the physiological demands imposed on the athlete during simulated competition with regards to the body's energy systems, heart rate response to the fight situation, breathing rates and core temperature.

Methods: For this study, twelve (n=12) elite male karate athletes were recruited from the Free State Karate High Performance Squad. Selected tests were performed, including, anthropometry, a graded maximal effort test (VO_{2max}) and a simulated kumite competition. The competition consisted of six rounds with progressively decreasing set recovery periods in between. During the simulated competition, the heart rate, breathing rate and estimated body core temperature were recorded by the Zephyr BioHarness$_{TM}$ 3 System. All of the kumite matches were video recorded and a time-motion analysis was conducted with the use of Dartfish Software 6, to determine the match characteristics. All physiological and time-motion data were then analysed separately, using a repeated measurements analysis of variance (ANOVA) model with "round" as fixed effect. This analysis excluded the data regarding the techniques scored, which was analysed by a generalized linear model with a Poisson error distribution and logarithmic link function.

Results: Athletes achieved a higher HR_{max} during the simulated kumite matches than during the graded maximal effort test (187.5 < 190.8 bpm). There was a 55.45% aerobic and 44.55% anaerobic energy system contribution during the respective kumite matches, with an effort-to-rest ratio of ~1.5:1. A statistical significant difference ($P < 0.05$) was found between rounds regarding the means calculated for the mean HR during the fight ($F= 7.05$; $P= 0.03$). Fifty-two percent (52%) of all the techniques scored were attributed to upper limb techniques and 48% to the lower limbs. The same values were recorded with regard to the scoring of offensive versus defensive techniques. There were no significant differences ($P > 0.05$) between rounds with respect to the mean counts of techniques used.

Conclusion: A karate kumite match can be characterized as a high-intensity activity with regards to physiological variables, where athletes are subjected to maximal cardiovascular responses. It is thus advisable that coaches remain focussed on the technical and tactical aspects of training and that conditioning specialists focus more on improving the athletes' ability to sustain high-intensity activities during conditioning sessions.

- Key words: Time-motion analysis, Karate kumite matches; Physiological demands of karate, Elite karate athletes

OPSOMMING

Inleiding: Sedert kompetisies die fokuspunt van oefening geword het en die ontwikkeling van meer toernooie op beide nasionale en internasionale vlak, het die gewildheid van karate toegeneem. Geen enkele prestasie eienskap oorheers in gevegskuns sporte nie, maar sukses vereis 'n mengsel van tegniek, krag, aerobiese fiksheid, eksplosiewe krag en spoed. Dit het ook aan die lig gekom dat sonder ‘n behoorlike ondersoek van die fisiologiese vereistes wat aan 'n atleet tydens 'n kompetisie situasie gestel word, dit onwaarskynlik sou wees om die atleet te ontwikkel tot sy of haar volle potensiaal.

Doel: Die doel van hierdie studie was om:

- die verskillende fisiologiese eise wat tydens 'n gesimuleerde karate kumite kompetisie situasie op die atleet geplaas word, te identifiseer;
- 'n tyds-bewegings analiese te doen om die eienskappe van die karate kumite gevegte te bepaal;
- die fisiologiese vereistes wat aan die atleet gestel word tydens gesimuleerde kompetisie te bepaal met betrekking tot die liggaam se energie-stelsels, hartklop reaksie op die geveg situasie, asemhalingstempo en geraamde liggaamskerntemperatuur.

Metode: Vir hierdie studie is twaalf (n = 12) elite manlike karate atlete gewerf uit die Vrystaat Karate Hoë Prestasie Groep. Verskeie toetse is uitgevoer, insluitend, antropometrie, 'n gegradeerde maksimale inspanning toets (VO_{2maks}) en 'n gesimuleerde kumite kompetisie. Die kompetisie het bestaan uit ses rondtes met vasgestelde progressiewe verminderde herstel periodes tussen elke rondte. Gedurende die gesimuleerde kompetisie is die hartklop, asemhaling en beraamde liggaamskerntemperatuur deur die Zephyr BioHarness$_{TM}$ 3 Sisteem gemoniteer. Al die kumite gevegte is per video opgeneem en 'n tyds-bewegings analise is uitgevoer met behulp van die Dartfish 6 sagteware sisteem, om die gevegs-eienskappe te bepaal. Alle fisiologiese en tyds-beweging data is afsonderlik ontleed met behulp van 'n herhaalde metings analise van variansie (ANOVA) model met "rondte" as vaste effek, met die uitsondering van die data ten opsigte van die gebruikte tegnieke wat deur 'n veralgemeende lineêre model met 'n Poisson fout verspreiding en logaritmiese skakel funksie ontleed is.

Resultate: Atlete het 'n hoër maksimale harttempo tydens die gesimuleerde kumite gevegte as gedurende die gegradeerde maksimale inspanning toets ($187.5<190.8$ bpm) bereik. Daar was 'n 55,45% aerobiese en 44,55% anaërobiese energiesisteem bydrae tydens die onderskeie kumite gevegte, met 'n inspannings tot rus verhouding van ~ 1.5:1. ‘n Statistiese beduidende verskil ($P < 0.05$) is gevind oor die gemiddeld tussen rondtes bereken vir die gemiddelde harttempo tydens die geveg ($F = 7.05$; $P = 0.03$). Twee en vyftig persent (52%) van al die tegnieke aangeteken is toegeskryf aan handtegnieke en 48% aan tegnieke soos skoppe en balansbrekings. Dieselfde waardes is aangeteken met betrekking tot aanvallende teenoor verdedigende tegnieke. Oor die algemeen, was daar geen beduidende verskille ($P > 0.05$) tussen rondtes met betrekking tot die gemiddelde aantal tegnieke gebruik tydens die gevegte nie.

Samevatting: Kenmerkend is ‘n Karate kumite geveg 'n hoë-intensiteit aktiwiteit met betrekking tot die fisiologiese veranderlikes, waar atlete onderhewig is aan maksimum kardiovaskulêre reaksies. Dit is dus raadsaam dat afrigters gefokus bly op die tegniese en taktiese aspekte van oefening en dat kondisionering spesialiste meer fokus op die verbetering van die atlete se vermoë om hoë-intensiteit aktiwiteite tydens kondisionering sessies te onderhou.

- Sleutelwoorde: Tyds-beweging analise, Karate kumite gevegte; Fisiologiese eise van karate, Elite karate atlete

LIST OF TABLES AND FIGURES:

CHAPTER 1: INTRODUCTION, PROBLEM STATEMENT AND SCOPE OF THE STUDY

1.1 INTRODUCTION

Both elite and recreational athletes continue to make strides in optimizing their performance and reducing the likelihood of injury and/or illness during either training or competition. Recent statistics indicate that, on a global scale, some 50 million participants from 187 registered national federations take part in the World Karate Federation (WKF) organization (WKF, 2014). During 2008, WKF karate was also selected for potential inclusion in the Olympic program and possibly the 2020 Olympic Games in Tokyo, Japan (WKF, 2014). Since competition has become the focal point of athletic training (Iide, Imamura, Yoshimura, Yamashita, Miyahara, Miyamoto & Moriwaki, 2008:839-844) and the development of more tournament competitions on both national and international levels, the popularity of karate is ever increasing (WKF, 2014). According to Chaabène, Hachana, Franchini, Mkaouer and Chamari (2012:829-843), karate-kumite is of an intermittent nature, requiring that both the aerobic and anaerobic alactic energy systems be developed. Aspects such as training, physiological, psychological and other variables are therefore constantly being investigated and identified. These could allow the athlete to maximize any measure of advantage over competitors, either by improving performance and/or reducing injury and illness.

The physiological characteristics of athletes are generally measured by testing their fitness components and skill (Chaabène *et al*., 2012:829-843). The fitness components tend to include cardiorespiratory endurance, muscular strength, muscular endurance, flexibility and body composition (Vanhees, Lefevre Philippaerts, Martens, Huygens, Troosters & Beunen, 2005:102-114). On the other hand, skill-related components include speed, agility, power, balance, coordination and reaction time (Vanhees *et al*., 2005:102-114). Most combat sports require a mixture of technique, strength, aerobic fitness, power and speed where no single performance characteristic dominates (Beekley, Abe, Kondo, Midorikawa & Yamauchi, 2006:13-20).

Karate athletes have to perform several high-intensity actions during a match. Top-level karatekas have high fitness levels and according to Baker and Bell (1990:69-74), karate "fighting" is considered a high-intensity event. However, one of the most important challenges confronting coaches and athletes is the understanding of the main physiological factors contributing to the professional success or failure of a karateka (Chaabène *et al*., 2012:829-843). By gathering the information about the different fitness components needed, skilled coaches and conditioning specialists will be able to develop optimal training programs according to the athlete's strengths and weaknesses.

In support of this notion, it has come to light that there is insufficient research regarding karate as a sport to assist coaches, athletes and conditioning specialists. This is grounded on the understanding of the physiological demands imposed during kumite matches and the subsequent specific conditioning interventions required to assist in the performance enhancement of karate athletes.

1.2 PROBLEM STATEMENT

In all sports, the emphasis placed on elite performance is overwhelming. This has led to ever increasing scientific investigations of sporting activities and their concomitant demands, in order to gain even the smallest edge over the opponent. Thus, without proper investigation of the physiological demands imposed on an athlete during a competition situation, it would be unlikely that the athlete will develop to his or her full potential.

1.3 AIM OF THE STUDY

The objective of this study was to identify the various physiological demands placed on the athlete during a simulated competition situation. By conducting a time-motion analysis to determine the characteristics of the karate-kumite matches and, in turn, outlining the physiological demands imposed on the athlete during competition with regards to the body's energy systems, heart rate response to the fight situation, breathing rates and core temperature regulation.

1.4 HYPOTHESIS

It is hypothesized that the majority of actions in the kumite matches will ensue from the oxidative glycolytic and anaerobic energy systems, with the maximum heart rate achieved during a fight emerging as similar to the maximum heart rate achieved during the graded exercise tests. In addition hereto, it is hypothesized that there will be dominance in upper-limb attack techniques.

1.5 SCOPE OF THE STUDY

Elite karateka requires months and years of intensive training and mental preparation to enable success in winning fights. Factors, especially the physiological and psychological attributes, which set this group apart from other athletes have not been clearly defined and analyzed.

In Chapter 2, a review of the literature exploring the history of karate and World of Karate Federation (WKF) Kumite, the characteristics and physiological profile as well as time-motion analyses of karate is presented.

Chapter 3 presents the methodology of testing, which includes a full description of all testing instruments and protocols. Chapter 4, presents the findings of this descriptive cross sectional study. In Chapter 5, a full discussion of the findings of this dissertation is provided. Chapter 6 concludes the study, and proposes possible applications and future directions in the conditioning of karateka in the field of Exercise and Sport Sciences.

CHAPTER 2: LITERATURE REVIEW

2.1 THE SPORT OF KARATE

The following paragraphs aim to provide essential information regarding the sport of karate.

2.1.1 History

The origin of martial arts can be traced back to the Chinese monasteries where the students practised martial arts as part of their physical training with the aim of building endurance and strength (Nakayama, 2012a:19-173). The population in Okinawa developed "empty-hand" fighting (karate) to defend themselves, during a time when the use of all weapons was prohibited. Karate was introduced to Japan in 1922 by Master Funakoshi. He then established the Shotokan style in 1936 and the Japan Karate Association in 1955 (Nakayama, 2012a:19-173).

Over time, various karate styles and techniques, which led to the establishment of new forms of karate, were developed (Noble, 1996:38-44). Different forms of karate were introduced to countries all over the world by Japanese masters of the various styles. However, competition fighting was never the focus of any of the original Japanese fighting masters. The French began a world organization and hosted the first international championships in 1963 (WKF, 2014). Recent statistics indicate that globally, some 50 million participants from 187 registered national federations take part in the World Karate Federation (WKF) competitions (WKF, 2014). During 2008, WKF karate was also selected for possible inclusion in the Olympic program (WKF, 2014).

Karate tournaments can be classified in two main divisions, namely: kata (set sequence of movements) and kumite (fighting). Competition kumite can be described as a semi-contact fighting event, which consists of the execution of defensive and offensive techniques while two athletes are freely moving around in the competition area (Imamura, Yoshimura, Nishimura, Nakawaza, Nishimura & Shirota, 1999:342-347). The kumite rules of karate competitions have changed dramatically over the years to make the sport more spectacular and attractive for spectators and the media.

2.1.2 World Karate Federation (WKF) Kumite

WKF kumite is a semi-contact fighting event during which two opponents move freely on an 8x8m WKF-approved mat. Athletes are required to wear WKF-approved protective gear (mitts, shin pads, foot protectors, body protectors, mouth guards and chest protectors for females). Attackers are supposed to control the impact of their contacts, hence no excessive contact is allowed during the fight (WKF, 2014). Participants receive a three-minute fighting period in the case of men and two minutes in the case of women, with the aim of scoring as many points as possible. In order to be declared the winner, the competitor needs to either lead by eight points or to have obtained the highest number of points at the full-time signal (WKF, 2014).

The total duration of fights are, however, usually much longer than the fixed two or three minutes (more or less 267 seconds on average) due to stoppages and referee decision-making while the fight is taking place. Each fight starts when the referee calls out "shobo hajime" (start fighting) and ends when the referee calls out "yame" (stop fighting). These stop and start intervals will vary according to the number of points awarded, the frequency of penalties given, or the time spent on referees' decision-making during the fight (WKF, 2014).

Competitors are awarded one, two or three points at a time, depending on the type of techniques used or the body part that was struck during the fight. Three points (Ippon) will be awarded in cases where the head or face (jodan) was "hit" by making use of a kick, or if the competitor executed a take-down technique and then made use of another scoring technique while the competitor was down. Two points (Wasa-ari) are granted in situations where the competitor has "hit" the opponent's back, abdominal or chest area (chudan) by making use of a kick. One point (Yuko) is awarded in cases where hand techniques were successfully performed to the head, face (jodan), back, abdominal or chest area (chudan) (WKF, 2014).

2.1.3 Characteristics of Karate

As stated by Evans (1997:7) karate is fundamentally the practice and development of blocking and striking techniques. Karate training consists mainly of three components: kihon (basics), kata (form) and kumite (sparring), each playing a crucial role in the development of karate skills (Yokota, 2010:91). According to Kato (2002:1), kihon is the aspect of training with which all beginners start. This aspect consists of the execution and repetition of the basic defensive and attacking techniques in a pre-arranged setup

As reviewed by Ross (2009:11), the different karate curricula expect all beginners to be first taught the different punch variations, which are then followed by the different kicking techniques. Nakayama (2012a:15) reveals that different techniques must be repeated in such a manner that the various body parts travel to the target across the correct path. It is also expected that the different techniques be developed to perfection as the karatekas attain higher levels and grades (Sforza, Turci, Grassi, Fragnito, Pizzini & Ferrario, 2000:957).

According to the literature the different punching and kicking techniques most commonly used during kumite are gyaku zuki and kizami zuki (punching techniques), and the front and back mawashi geri and ushuru geri (kicking techniques) (Nunan, 2006:47-53). The term “zuki” or “tsuki” in Japanese refers to a trust, punch or strike, whereas the term “geri” refers to a kick (Shotokankarate, 2014).

2.1.3.1 Punching Techniques

The hands are more agile than the feet and are more commonly used for attack and defence in order to protect the body against attacks (Lee & Uyehara, 1977:29). With punching techniques, the hand can reach a peak velocity of 10 to 14 $m.sec^{-1}$ if techniques are executed correctly (Feld, Mcnair & Wilk, 1979:150). As Lee and Uyehara (1977:45) explain, a well-executed punching technique should be performed effortlessly and muscle tightening should only occur a split second before impact.

As previously indicated, the different punching techniques most commonly used in karate are:

- Gyaku tsuki (Figure 2.1): A punch or blow that is performed with the hand that is on the opposite side of the front leg is referred to as a gyaku tsuki. For proper execution of the technique it is important to utilize the power generated through the hips. The punch should be coordinated with the rotation of the hips in such a manner to ensure maximum power and efficiency. The positioning of the fist is located at the side at about hip height, with the palm facing upwards and should travel in a straight, direct line to the respective target. A well executed gyaku tsuki will require the elbow to be brushed against the side during execution with the forearm turning 180 degrees inwards as the muscles contract at the correct moment of impact to create focus or “kime” as referred to by the Japanese. The range of the technique can be extended by reaching forward with the front foot in the direction of the opponent or focus of attack, while lowering and rotating the hips in a forward position towards the opponent (Nakayama, 2012a:91-119).

Figure 2.1: The Karateka on the right is demonstrating the final position of a chudan (abdominal) gyaku tsuki (Photo taken by researcher)

- Oi tsuki (Figure 2.2) refers to a stepping punch. The technique is executed with the same hand as the foot stepping forward. The same punching principles apply for oi tsuki as for gayku tsuki with regards to the elbow brushing against the side and the forearm turning 180 degrees inwards as muscles contract on impact. The range of the technique can also be increased by a forward reach by the front foot before stepping over with the back leg. However, as this is a long-range technique, opponents can easily anticipate or recognise the technique and perform a counter-attack. Thus it is important for the karateka to make use of quick foot movements, driving the hips forward and pushing hard off the rear leg (Nakayama, 2012a:91-119).

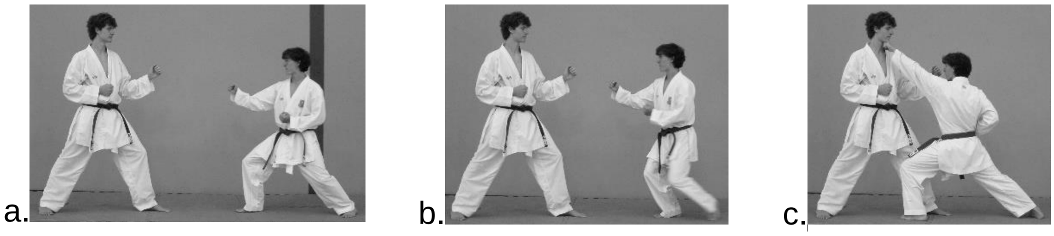

Figure 2.2: The karateka on the right is demonstrating;
a. the starting position of a oi tsuki;
b. the transition phase and
c. the final position of a jodan oi tsuki
(Photo taken by researcher)

- Kizami tsuki (Figure 2.3): This is a technique executed by the same hand as the front leg. A world renowned Jeet Kune Do (a style of martial arts) master, Bruce Lee, believed that the a leading straight punch or “kizami tsuki” is the most important punch as the lead hand has a shorter travelling distance to the target, in turn making it a very fast technique (Lee & Uyehara,1977:30). However, Lee and Uyehara (1977:30) believed that the fist should be positioned in a vertical rather than horizontal manner as in other karate styles. With regards to the technical aspects of the straight kizami zuki, it is imperative to have a forward-facing back foot, a well-loaded back leg, and good forward drive through the back leg and hips towards the target. The forward movement from the body will initiate the front-hand punch towards the face of the opponent. It is vital to have a good shoulder to strike from to ensure not only optimal power and speed, but also accuracy (Nakayama, 2012a:91-119). The punching principle with respect to the inward rotation of the forearm and muscle contraction again applies to this technique. The rotation of the hips and shoulders, however, is limited. The range can once again be extended with a forward reach by the front foot together with other movement techniques which will be discussed later in this chapter.

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Figure 2.3: The karateka on the left is demonstrating the final position of a jodan (head, face) kizami tsuki (Photo taken by researcher)

According to Nunan (2006:50) the gyaku tsuki is the most frequently used technique during competitions. However, Lee and Uyehara (1977:30) are of the opinion that the kizami zuki is a better punch technique with regards to situations where seven or more centimetres in reach can be obtained. Researchers at Harvard University also concluded that the speed of techniques is more important in achieving success than the amount of strength applied (Harverd University, 2006:1-3). Furthermore, the efficiency of the techniques is determined by the position of the body and its stability rather than by anything else (Cesari & Bertucco 2008:355).

2.1.3.2 Kicking Techniques

According to Nakayama (2012a: 136-173), kicking techniques are technically more difficult than most of the punching techniques and therefore require more time and effort during training. The legs and feet, respectively, play an important role in attacking and scoring points during kumite. An obvious observation would be that the legs are longer than the arms and this fact makes it possible to score points over a longer distance. Lee and Uyahara (1977:58) confirm this by stating that kicking techniques are especially important in situations where the karateka wants to keep his/her distance from the opponent.

The four kicking techniques most commonly used in kumite are:

- Mawashi geri (Figure 2.4): Also referred to as a “roundhouse” kick, it can be executed either using the front foot (front foot mawashi geri) or the back foot (back foot mawashi geri). With the rotation by the hips, the foot moves in a large circle around the body, hence the foot is moving from outside, inward towards the target (Nakayama, 2012a:136-173). Acording to Lee and Uyehara (1977:56) the mawashi geri may not be as powerful as some of the other kicks, but it remains very deceptive and effective due to the quick recovery associated with the execution of this kick.

a. b. c.


Figure 2.4: The karateka on the right is demonstrating;
a. the starting position;
b. back foot knee pick up and
c. final position of the jodan back foot mawashi geri (Photo taken by researcher)

With regards to the front foot mawashi geri (Figure 2.5), it is imperative that the foot position of the supporting leg is more outward bound, in order to ensure good penetration as well as stability, during the execution of the kick. The front hip and knee should be pushed forward towards the target without an excessive backward lean of the upper body. An early front knee lift is essential to ensure a good kick height. When observing from a frontal plane, the head, front shoulder, hip, knee and foot should be in a singular straight line at the contact point. A straight vertical knee lift is required to ensure an effective technique and reduce the occurrence of injuries (De Bremaeker, 2010: 205).

a. b. c.

Figure 2.5: The karateka on the left is demonstrating;

a. the starting position;

b. initial back foot slip-step with front foot knee pick-up and

c. final position of the jodan front foot mawashi geri

(Photo taken by researcher)

- Ushiro mawashi geri (Figure 2.6): This is also known as a reverse roundhouse kick and can either be performed by the front or back foot. The kick starts in front of the body and moves in a half-circle outwards, striking the opponent with the sole or heel of the foot (Nakayama, 2012a:136-173).

Figure 2.6: The karateka on the left is demonstrating the final position of a jodan ushiro mawashi geri (Photo taken by researcher)

- Mae geri (Figure 2.7): This kick is classified as a front kick with the ball of the foot making contact (Nakayama, 2012a:136-173).

a. b. c.

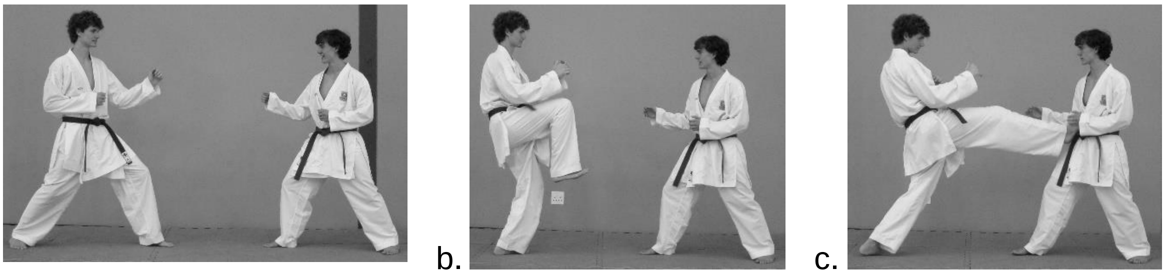

Figure 2.7: The karateka on the left is demonstrating
a. the starting position of a mae geri;
b. the knee pick up and
c. the final position of the mae geri
(Photo taken by researcher)

- Yoko geri (Figure 2.8): This kick refers to a side kick directed to the side or front. When performing this kick the hips are utilized to thrust the kicking leg into full extension when contact is made with the target. As this technique is the most powerfull kick in karate it is often used to knock the opponent off balance or to stop the attacker in his/her tracks (Beasley, 2003:75).

Figure 2.8: The karateka is demonstrating the final position of a yoko geri
(Photo taken by researcher)

In other research pertaining to kicking techniques, the power of a kick can be determined by the amount of "whiplash" generated by the foot due to the coordinated contraction of the leg muscles (Nakayama, 2012a: 136-173). A kinetic analysis of the kicking action reveals that as the thigh decelerates, the lower leg simultaneously accelerates, which results in the “whiplash” kicking action (Sorensen, Zacho, Simonsen, Dyhre-Poulsen & Klausen, 1996:483).

According to Evans (1997:29), the initial movement during which the knee is raised and bent to its maximum is the most important facet of all kicks. Through training, karatekas will be taught to lift the knee to the front for mae geri and to the side for mawashi geri. However, for competition kumite, karatekas should try to use the same knee position for all kicks in order to confuse the opponents and limit the threat of anticipation (Evans, 1997:29).

The importance of the knee lift at the start of the kicking actions is imperative to the activation of the hip muscle needed to initiate the kicking action, after which the thigh muscles are activated to execute the remainder of the movement. It is also essential that the hips and ankles of the non-kicking (bottom) leg should be stable while the kick is being performed. This stability will ensure greater difficulty for the opponent to succeed with a leg sweep, throw or take-down (Nakayama, 2012b:25-38). According to Hickey (1997:137) most elite opponents will try to use a sweep technique the moment the karateka shifts his/her weight to a particular leg.

Furthermore, elite karatekas should be able to quickly alternate between kicks by judging the distance from the target, and timing their actions correctly (Hickey, 1997:139). In addition, Evans (1997:29) also concluded that karatekas need a high degree of flexibility to effectively perform jodan (head) kicks.

2.1.3.3 Additional Techniques

Additional techniques such as leg sweeps and take-downs are often used in order to position the opponent in a vulnerable way and subsequently, to score higher points (three points). Nevertheless, points can only be awarded when these techniques are combined with another scoring technique such as a punch or a kick.

Grabbing, on the other hand, is used as a defensive strategy, due to the fact that a karateka is more susceptible to be scored upon when he/she is moving backwards (Ross, 2009:16).

- Leg sweep (Figure 2.9): The sweep action is executed with the medial part of the foot that makes contact with the opponent's lower leg, preferably the lower half of the leg. The opponent's balance is then disturbed by the leg shifting from underneath the body, which in turn leads to an unstable position and a potential fall (Nakayama, 2012b:25-38).

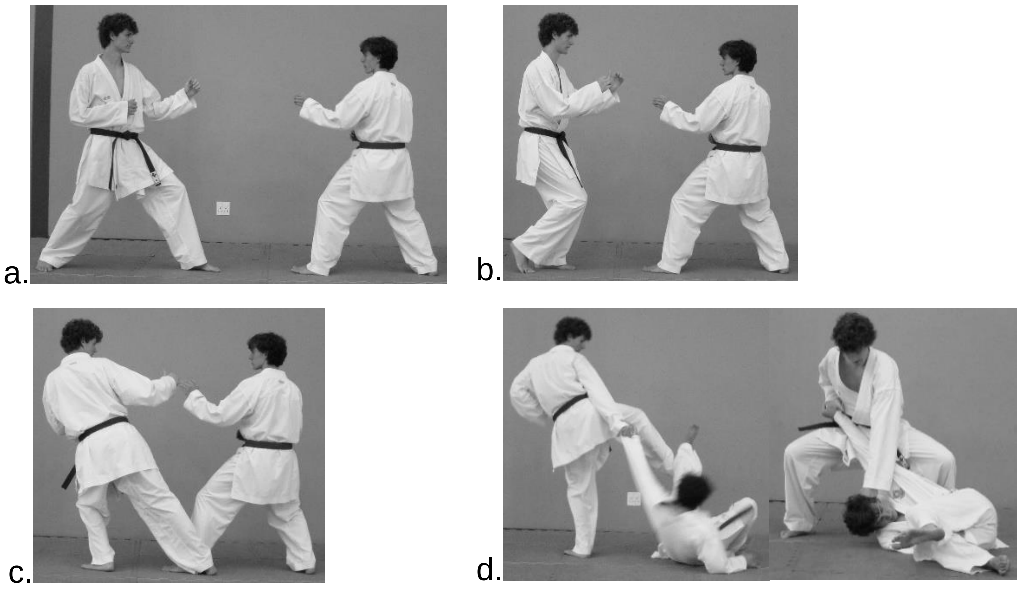

Figure 2.9: The karateka on the left is demonstrating;
a. the starting position of a foot sweep (ashi barai);
b. the karateka on the left is demonstrating the initial "take off";
c. foot contact with the lower leg and
d. final position after which a scoring technique will follow
(Photo taken by researcher)

- Take down (Figure 2.10): There are various take-down techniques that can be used. However, most of these techniques are often combined with a leg sweep to increase the effectiveness of the technique. A take-down can be executed with the rotation of the hips, while the knees are bent and the hips are lowered below the opponent's hips. The use of total body strength and the understanding of body dynamics will increase the technique's effectiveness (Nakayama, 2012b:25-38).

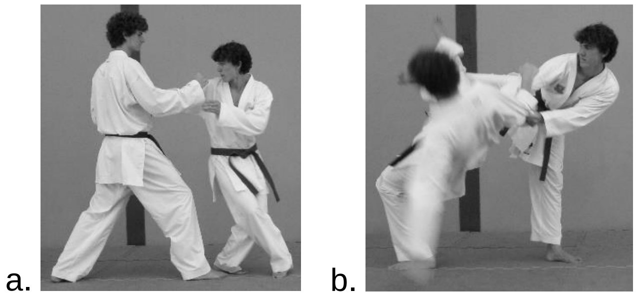

Figure 2.10: a. The karateka on the right is demonstrating the preparation phase of the take down and
b. the use of body dynamics and strength to throw the opponent to the ground after which a scoring technique will follow

(Photo taken by researcher)

- Grabbing: This action is illegal, but is still used to prevent the opponent from scoring a point (WKF, 2014).

2.1.3.4 Movement Skills

The different movement skills which karatekas utilize together with the above-mentioned techniques are subsequently discussed below. These skills have been pointed out by coaches as an important part of kumite, as movement skills determine the timing and manner in which karatekas attempt to score their points.

According to Jung and Lawler (2000:1) the exact fighting distance and reach during kumite competitions can be controlled by the use of movement skills. During a kumite match, karatekas will usually maintain a safe non-reachable fighting distance while they evaluate the opponent's abilities and start to strategize against them. Evans (1997:45) observed that karatekas often initiate an attack with half or double steps, shifts or a forward lunge to decrease the fighting distance as quickly as possible to surprise the opponent, creating a compressed space.

The side-stepping technique is mainly used as a defensive tactic but in some instances it can also be used as an initiating movement for an attack or counterattack (Lee & Uyehara, 1977:21). However, side-stepping must be explosively executed in these situations (Evans, 1997:44).

It remains an important fact that every human being is unique, and that every individual has a different body type and limb lengths (Jung & Lawler, 2000:1). This will in turn determine the karatekas' fighting and reaching distance that will be most desirable for scoring points or avoiding attacks (Jung & Lawler, 2000:1). Those karatekas who have technical flaws in their attacking techniques will also be able to compensate for these through effective movement (Evans, 1997:43). Movement skills are not only used to add momentum and the element of surprise to a technique, but are mainly utilized to manipulate the opponent's position and to force him/her to make positional errors. In this instance the forward, backward and side-way hopping movements are primarily used to gain a positional advantage over the opponent (Beneke, Beyer, Jachner, Erasmus & Hütler, 2004:518). Kato (2002:3) revealed that the body weight needs to be transferred in a wide range of directions and be followed by hip actions and limb extensions in order to perform these hopping movements effectively. The body must also, at all times, be properly aligned in order to facilitate the correct muscle actions and offer stability by lowering the centre of gravity (Nakayama, 2012a:19-88).

A discussion on the ways in which karatekas use the above-mentioned techniques during competitions follows:

2.1.3.5 Competition Tactics

The term "tactics" is a commonly used term among elite athletes pertaining to any mode of procedure for gaining advantage or success (Dictionary.com, 2014a). A common tactic is to attack in threes (Hickey, 1997:134). Usually the first two attacks are directed jodan (head), which will likely force the opponent to lift his hands and in turn create an opening for the attacker to score points on the chudan (abdominal, chest or back) area with a third technique (Beasley, 2003:117). Another tactic often used is “faking”, where the karateka attempts to draw the opponent forward and analyse his/her intentions. However, the fake technique, must be executed in such a manner that it looks legitimate and forces the opponent to react in a certain way (Hickey, 1997:139). According to Nishimura, (1995:3) elite karatekas have the ability to swiftly analyse and evaluate their opponents’ tactics and apply their own tactics to counter attack those of the opponent.

Furthermore Nishimura (1995:3) also states that it is crucial that karatekas transition smoothly and directly into their attacks without providing the opponent with indications of the planned attacks. It remains a primary aim to surprise the opponent and prevent him/her anticipating the next move. Karatekas who want to launch surprise attacks can only execute them when the hands and feet are continually being positioned in such a manner that techniques can be performed from any position at any time, thus the body should be appropriately positioned (Nakayama, 2012a:19-88). The surprise element will also be affected by the timing of the attack (Hickey, 1995:1). In this instance it would be most beneficial to attack when the opponent is preparing him/herself for an attack, at the start of his/her attack, or directly after the opponent has completed his/her attack (Hickey, 1997:130). Another benefit would be to counter immediately after the opponent has struck. It remains imperative not to block, retreat and then attempt to counter, but rather to block and counter simultaneously (Nishimura, 1995:2). In the cases where immediate counter actions are not performed, the opponent will be in a better position to move out of range or even to score a point.

According to Lee and Uyehara (1977:119) bobbing and weaving, consisting of side-to-side and in-and-out movements, are often used as defensive tactics. Nevertheless, the drawbacks of these tactics is that they can be quite time consuming to perform and allow the opponent the opportunity to adapt and make the necessary changes to his/her attacking sequence. For example, Kato (2002:3) revealed that, in order to weave to the inside of a right kizami tsuki, one should move to the outside by dropping the head and body with more or less 22-30 centimetres, which may take approximately 0.25 sec.

It is essential that karatekas select tactics that suit their competitive levels and abilities, are easily mastered during training, and can be combined with previously learned skills (Hickey, 1997:135). Success is not guaranteed by tactics alone. The karateka's ability to evaluate and analyse his/her opponent remains a crucial contributing factor to a successful karateka (Beasley, 2003:117).

2.2 PREVIOUS RESEARCH STUDIES ON TIME-MOTION ANALYSIS

The following section pertains to previous research done with regards to the time-motion analysis and physiological characteristics and demands within the martial arts sporting community as well as the various methods utilized to conduct them.

2.2.1 Video and Time-Motion Analysis

Time-motion analysis (TMA) has been implemented for over 35 years, with research published for many different sports (Reilly & Thomas, 1976:87-89; Hughes & Knight, 1995:257-259; Heller, Peric, Dlouha, Kohlikova, Melichna & Novakova, 1998:243-249; Deutsch, Kearney & Rehrer, 2002:160-166; Sforza and Nakayama, 2000:948; Kellick, 2005:1; Cabello & Gonzalez-Badillo, 2003:62-66; Liebermann & Franks, 2004:57; McDonald, 2006:1; Buse & Santana, 2008:42-48; Iide *et al*. 2008:839-844; Roberts, Trewartha, Higgitt, El-Abd & Stokes, 2008:825-833; Matsushigue, Hartman & Franchini, 2009:1112- 1117, Vaz, Van Rooyen & Sampaio, 2010:51-55; Santos, Franchini & Limasilva 2011:1743-1751; Hughes, Hughes, Williams, James, Vučković & Locke, 2012:383-401; Quarrie, Hopkins, Anthony & Gill, 2012:353-359). According to Dobson and Keogh (2007:48-55), TMA can be defined as the quantifiable observation of the change in an object's movement pattern over a given time period. Many of the aims of this research have been to increase the knowledge and understanding of the physiological demands of the specific sport to assist with the development of training regimes (McLean, 1992:285-296).

The demands of competition in sport have been primarily reported with the use of TMA and more recently global positioning systems. According to Deutsch, Maw, Jenkins and Reaburn (1998:160-166), TMA may be defined as an objective non-invasive method for quantifying work rate, and provides information that can be used in the design of physical conditioning programmes and testing protocols (Deutsch *et al*., 1998:160-166).

The use of video technology enables athletes and coaches to receive "instant visual feedback" of their performances (Dartfish, 2009) and is a very effective way to get practical concepts across from the coach or analyser to the athlete (Bray, 2012:6). According to Schmidt and Lee, the learning process of the participants can be improved and accelerated by this type of feedback, however only, if it is applied appropriately (quoted by Liebermann & Franks, 2004:40).

McKenzie, Holmyard and Docherty (1989:101-113), conversely, argued that TMA is a time-consuming process inherently prone to measurement error. This is due to the fact that observations are influenced by an observer's knowledge, perceived importance of competition, focus of attention, state of arousal and preparing for anticipated events. Hopkins (2000:1-15) also stated in this regard that although researchers using TMA have reported the reliability of their methods, none have reported the Typical Error of Measurement (TEM) which is a requirement in other physiological tests.

Lames and McGarry (2007:62-79) reported that the reliability of measurements or assessments made during TMA research is considered as vital. According to Lames and McGarry (2007:62-79) the results must be considered with caution if the reliability of the testing method was not established, either within the study or in previous literature. Due to the similarities between some movement patterns during match-play, e.g. jogging and running, it is understandable that in the majority of video-based TMA studies, some form of subjective judgement regarding the categorisation of each individual movement is applied (Tenga & Larsen, 2003:90-

102). Lames and McGarry (2007:62-79) also emphasizes in this regard that the decision of accurately coding each movement is solely placed on the interpretation of the observers or analysts.

Athletes will not always have the ability to regulate the feedback derived from the video material, hence communication between the coach and athlete is crucial in the feedback process and the implementation of the various interventions (Lieberman & Franks, 2004:40-41). It has also emerged that although coaches value the scientific information gained from the use of video analysis and other technology in sport, they often still prefer their simple and traditional methods of analysis and evaluation of training goals (Liebermann & Franks, 2004:57).

Despite the preferences of coaches, it cannot be ignored that immediate and detailed kinematic analysis, which is dependent on complex technologies due to its capability of tracking and recording motion events in real time, may be highly beneficial (Liebermann & Franks, 2004:57). It would therefore be inevitable that this type of technology will be used to analyse the detail of very quick and complex movements which often occur during elite sport and cannot be tracked or processed by the human eye and brain (Andrzejewski & Elbaum, 2005:1). The processing of detail is especially important in the sense that the slightest error or flaw in the execution of movements may be unfavourable to optimal performances. Thus, with video analysis, the coaches will be able to highlight certain faults in the execution of techniques and movements as well as compare them with various reference clips. The exact nature of a specific sport can also be analysed with the use of video analysis. This could assist with the development of sport-specific profiles. These profiles are said to be more accurately developed when real-time analysis is utilized rather than with simulated actions and movements. It is with this notion that the literature review also focus on the use of video analysis among martial art sports. Roberts *et al*. (2008:825-833) stated further that for the analysis of complex movement patterns, video recording is optimal, as it can be slowed down or repeated when necessary. Players are normally filmed throughout an entire match, providing a continuous recording of the frequencies, mean and total durations in each activity. This allows for work rate and percentage-game calculations.

Roberts *et al*. (2008:825-833) concluded that in addition to using time-motion data to improve training specificity, there is also a need to accurately quantify match demands for the purposes of designing more specific exercise protocols that allow the investigation of issues specific to the sport.

2.2.1.1 Video analysis of kumite and other related sports

Knowing the opponent's strengths and weaknesses can allow karatekas to prepare properly for competitions. Video analysis can assist the coaches in obtaining this information about the karateka's various opponents. Sevostyanov and Kholodov (2005:15) conducted a video analysis study in which they determined which techniques are most commonly used to score points in full contact karate. In another study the Polish national judo coach analysed the frequency together with the efficiency index of all the techniques during several judo fights. He discovered that 78% of all the points scored were through basic and auxiliary techniques. The other techniques were only subsequent to situations where the opponents made errors (Adam, 2007:217).

Furthermore, authors such as McDonald (2006:1) and Kellick (2005:1) emphasized the practical significance and importance of video analysis within sport. These authors both mentioned that the use of video analysis directly contributed to the success of the England and USA Taekwondo teams, respectively. With the information obtained through the recordings, both teams could develop various tactics and strategies in order to achieve success (McDonald, 2006:2).

Sforza and Nakayama (2000:948) made use of video analysis during the early 1960's, with the aim of maximizing the effectiveness of two different punches, namely choku tsuki (straight punch) and oi tsuki (stepping punch), by utilizing a special stroboscopic camera and electromyography. The acceleration and velocity of the hands together with the electrical activity within the involved muscles were also determined for the different levels of karatekas. Nakayama concluded that the speed of both of the techniques was faster for the more experienced karatekas than for beginners (as quoted by Sforza *et al*, 2000:948). In 2000, Sforza also conducted a study of the same two punches, where he made use of an Italian computerized system, namely "*ELITE*" and eight infrared cameras. During the repetitive executions of the punches, the patterns of the different body movements were analysed and it was discovered that the execution of the oi tsuki was faster than the choku tsuki. It was also concluded that the effectiveness and success of any technique was dependent on the karateka's ability to keep his/her centre of gravity parallel to the ground while moving (Sforza *et al.*, 2000:948).

Buse and Santana (2008:42-48) concluded that one of the possibilities of improving the training organization is the knowledge of the combat time structure, with special attention to the effort-to-pause relationship. In accordance with previous research regarding the TMA of simulated karate kumite matches, it was established by Iide *et al*. (2008:839-844) that the duration of the shortest and longest offensive and defensive techniques during the simulated kumite matches were 0.3s and 1.8s, respectively. A study by Beneke *et al*. (2004:518-523) reported that the average effort periods during karate match simulation were ~18s, while the recovery interval was ~9s, with an effort-to-rest ratio of 2:1. However, a more recent study by Chaabène, Hachana, Franchini, Mkaouer and Chamari (2014:302-308) regarding the physiological and time-motion variables during kumite fighting, revealed an action-to-rest ratio of ~1:1.5 and a high-intensity action-to-rest ratio of ~1:11.

It has been reported by Matsushigue *et al*. (2009:1112-1117), that during official taekwondo combat, which is also a striking combat sport much like karate, the mean effort time of 8 ± 2s did not differ from the break time of 8 ± 3s, resulting in an effort-pause ratio of 1:1. Bridge, Jones and Drust (2011:344-357), also reported that during the 2005 World Taekwondo Championships, the fighting time was 17 ± 0.3s, the preparatory time was 6.4 ± 2.1s, the non-preparatory time was 3.0 ± 0.6s, and the referee stoppage time was 2.8 ± 0.9s, resulting in an average fighting-to-non-fighting ratio of 1:6.

A study by Santos *et al*. (2011:1743-1751), showed that the mean attack times were 1.3 ± 0.4s, stepping periods were 9.2 ± 3.9s and the pause periods were 6.0 ± 3.9s during the 2007 World Twaekwondo Championships and the 2008 Olympic twaekwondo competition matches, which resulted in a 2:1 effort-pause ratio and a 1:15 attack-total time ratio. However, modern karate consists of numerous repetitions of high-intensity actions per fight lasting 1-3s each, which is separated by low-intensity, hopping-stepping movements lasting 18 ± 6s and short referees' breaks of 9 ± 6s, with single defensive or offensive techniques lasting 0.3 ± 0.1 to 1.8 ± 0.4s for the shortest and longest duration actions, respectively (Beneke, 2004:518-523). Thus, it has been reported that high-intensity intermittent sports rely mostly on anaerobic energy sources with determinant actions being a function of explosive movement (Glaister, 2005:757-777).

As previously mentioned in this chapter, Beneke *et al*. (2004:514) utilized video analysis to determine the physiological requirements and energy contributions of different energy systems during kumite competitions. All the fights were recorded and the various activities that occurred were analysed and characterised according to the level of intensity of each. The maximum oxygen consumption and blood lactate results were also catalogued to determine the energy contributions during kumite matches and competitions. These findings and statements highlight the importance of identifying the various kumite characteristics by means of video analysis as well as determining the physiological demands of the kumite event.

2.2.2 Physiological Profile

Chaabène *et al*. (2012:829-843) stated that one of the most important factors governing an athlete's performance is their level of cardiorespiratory endurance. This involves the athlete's ability to sustain prolonged activities involving both the cardiovascular and respiratory system. The body's oxygen demand during strenuous exercise or activity is dependent on the efficiency and the ability of these systems to function together. Thus, the maximum oxygen uptake (VO_{2max}) is considered to be a key determinant of current cardiorespiratory fitness levels and can be defined as the largest amount of oxygen that an individual can utilize during an exercise of increasing intensity per kg of body weight (American College of Sports Medicine, 2006:1).

2.2.2.1 Related Research

Referring to the study by Iide *et al*. (2008:839-844), the researchers mention that it is also important, especially for sport nutritionists, to know the energy expenditure during competition in order to advise athletes to consume adequate energy from a variety of foods to avoid injuries and problems that may arise due to nutritional deficiencies. In most studies it has been recommended only to make use of heart rate (HR) responses (Stricevic, Okazaki, Tanner, Mazzarella & Merola, 1980:57-67) or both oxygen uptake (VO_2) and HR responses of karatekas performing kata (Zehr & Sale, 1993:269-274). In light of this, a study conducted by Toyoshima, Inoshita, Ueda, Mori and Nakano (2003:31-38), made use of HR responses, without measuring VO_2 during a 3-minute bout of simulated karate matches. They estimated the percentage of maximum VO_2 (%VO_{2max}) of a 3-minute bout of sparring from the HR obtained during the bout, and HR-VO_2 curve obtained from an incremental test to volitional exhaustion on a bicycle ergometer. However, according to Imamura *et al*. (1999:342-347), the results collected by the Toyoshima should be cautiously approached because higher HR responses were elicited for a given %VO_{2max} during five types of karate exercises when compared to those for a cycle ergometer or treadmill.

In a more recent study conducted during an international karate competition, Tabben, Sioud, Haddad, Franchini, Chaouachi, Conquart, Chaabène and Chamari (2013:263-271), a mean HR of 183 ± 8 bpm was revealed, which corresponded to approximately 91 ± 3% of the competitors' HR_{max}. This suggests that high demands were placed upon the aerobic metabolism during competiton. In comparison, cardiovascular strains of 93% HR_{max} have been reported by Iide *et al*. (2008:839-844) during simulated karate sparring matches. These findings would suggest that the physiological demands placed on the body are similar, irrespective of the karate modes, style of combat or level of competition. In contrast, HR values for simulated taekwondo matches have been reported to vary from 148 ± 2 to 197 ± 2 bpm, while less variation has been observed during competition from 176 ± 10 to 187 ± 8 bpm (Chiodo, Tessitore, Cortis, Lupo, Ammendolia, Iona & Capranica, 2011:334-339). However, Tabben *et al*. (2013:263-271) also observed that there was no increase of HR over the course of the three phases of international karate competition and this suggested that the cardiovascular demands remained stable throughout every match.

As stated by Bouhlel, Jouini, Gmada, Nefzi, Abdullah and Tabka (2006:285-290), in a study of taekwondo, a sequence of three simulated matches of 3-minutes each, with a 1-minute rest period (RP), was found to result in a constant increase of HR and blood lactate concentration during the sequence, demonstrating the high-intensity of the exercise. They suggested that the anaerobic metabolism is important during the attacks, whereas the aerobic metabolism predominates during the intervals between attacks. This however, suggests that the characteristics of the alternating periods of exercise and rest and the frequency of high-intensity movements and the total duration of the activity are determining factors for a better understanding of the meaning of blood lactate and HR.

According to Matsushigue *et al*. (2009:1112-1117), during a power action, there is a marked contribution of phosphagens to the energy supply expected for technique execution. However, the frequency of these techniques throughout the match determines the metabolic cost of the specific techniques executed. During match simulations by the Czech national taekwondo team, Heller *et al*. (1998:243-249) observed that a 6-times longer RP compared with the intense exercise period (EP) might be sufficient for important recovery of phosphocreatine (PCr) which is degraded during explosive movement. This statement is supported by the study conducted by Gaitanos, Williams, Boobis and Brooks (1993:712-719), in which a RP 5-times higher than the 6-second exercise bout resulted in adequate recovery of PCr, allowing for the predominant contribution of phosphagens until the end of 10 repetitions of maximum power cycle ergometer exercise. The predominance of the alactic (anaerobic) metabolism during fighting agrees with the small increase in blood lactate concentrations observed by Matsushigue *et al*. (2009:1112-1117).

Also Impellizzeri and Marcora (2007:59-71) stated that "VO_{2max} is considered to be a valid indicator of respiratory, cardiovascular and muscular system cooperative function". For activities where body mass is used to classify athletes in weight categories, such as karate, the oxygen uptake is measured relative to body mass in ml/kg/min. Thus VO_{2max} measurements ranging from 47.8 ± 4.4 to 61.4 ± 2.6 ml/kg/min has been reported for national and international male karate athletes (Ravier, Dugué, Grappe & Rouillon, 2009:687-694).

Doria, Veicsteinas, Limonta, Maggioni, Aschieri, Eusebi, Fano and Pietrangelo (2009:603-610), found that after a few minutes of resting, VO_2 values of about 0.3L min^{-1}, the O_2 consumption oscillated with time according to the warming up procedure used by each individual athlete, as characterized by personalized tasks and short recovery intervals. A sharp increase in VO_2 during the actual competition phase almost reached a steady-state value after about one minute, followed by an exponential decline in recovery. During the recovery period, the time constraints of the fast component of oxygen uptake were 31.5 ± 9.5 seconds for kumite athletes ($p<0.05$). This study also revealed that compared to the HRmax measured during the cycle ergometer tests, the maximal HR of the simulated competition were 92 ± 2 and 97 ± 6% in kumite.

The results collected during a study by Imamura, Yoshimura, Nishimura, Nishimura and Sakamoto (2003:111-114), showed the respective mean values of VO_2 and $\%VO_{2max}$, HR and $\%HR_{max}$, during the performance of 1000 punches and 1000 kicks as 406 ± 39 ml/min, 17.1 ± 4.1%, 108.2 ± 13.0 bpm, and 57.1 ± 6.2% for 1000 punches, respectively and 941 ± 173 ml/min, 41.1 ± 8.8%, 156.6 ± 12.0 beats/min, and 82.7 ± 5.8% for 1000 kicks, respectively. According to de Vries (1980:120) the more physically fit or athletically trained an individual is, the lower the respective HR for a given submaximal workload.

In accordance to the maximum HR calculated, it has also been reported that the rate of recovery is an important factor in determining the fitness level of an individual (Edwards & Robinson, 2004:36). The authors also stated that a good recovery heart rate within one minute of exercise cessation would be a drop in HR of 25 to 30 bpm although a rate of 50 to 60 bpm can be considered ideal. In contrast however, a study by Vicente-Campos, López, Nuñez & Chicharro (2014:1123-1128), revealed a mean $HR_{recovery}$ of 15.24 ± 8.36 bpm resulting in 8.60 ± 4.70% of the participants HR_{max} after completion of a maximal stress test on a treadmill. A significant correlation was also noted between the Peak VO_2 and $HR_{recovery}$ after three minutes of exercise cessation ($r = 0.36$; $p < 0.001$).

In comparison to other top-level athletes in various sports, the VO_{2max} of top-level karate athletes was similar to those of established taekwondo athletes, and wrestlers, but it was lower than those values reported in boxers (Butios & Tasika, 2007:179-185). It has also been reported that karate requires a much higher percentage contribution of aerobic metabolism when compared with taekwondo with a 66 ± 6%, 30 ± 6% and 4 ± 2%, respectively, for aerobic, anaerobic alactic and anaerobic lactic systems. This difference may be due to the different kumite match durations or the use of more upper limb techniques in karate compared with taekwondo (Campos, Bertuzzi, Dourado, Santos and Franchini, 2012:1221-1228).

Campos *et al*. (2012:1221-1228) also observed an increase in the total absolute energy expenditure over the course of combat. This indicated that there was a greater energy demand for the completion of high-intensity actions, as the match progressed, even though there was no increase in the number of technical actions, as observed during the TMA. These findings can be attributed to an increase in the aerobic contribution, because this system is responsible for the restoration of homeostasis during periods of low-intensity efforts (Glaister, 2005:757-777). Thus, as concluded by Beneke *et al*. (2004:518-523), aerobic capacity is necessary to prevent fatigue during training, and breaks between subsequent bouts of fighting activity within a fight, and to improve the recovery process between consecutive matches.

When considering the importance of measuring core temperature, it is imperative that the complete and proper functioning of the body is dependent on the maintenance of a body core temperature (Tc) of between 36.5 to 38.5ºC. The systems of the body malfunction when the Tc increases or decreases from these values. Thus, the greater the variance, the greater the malfunction (Moran & Mendal, 2002:879-885). Tc above 41.5ºC or below 33.5ºC causes a fast decline in the proper functioning of the body, which may result in injury and eventually death (Hensel, 1981:1). A more recent study by Sessler (2014:25-31) confirmed that a normal body core temperature can be considered to be 37 ± 1°C, despite widely varying environmental temperatures.

According to Moran and Mendal (2002:879-885), there are two different mechanisms that cause a rise in Tc. Firstly, the malfunctioning of one or more of the internal systems of the body, possibly accompanied by infection, resulting in fever. Secondly, malfunction can be caused by an upset in the delicate balance between the amount of heat absorbed from the environment, metabolic heat production, and the amount of heat emitted from the body, mainly by sweating. A significant contribution to the amount of heat accumulated in the body during exercise is due to the duration and intensity of the exercise, which in turn drives metabolic heat production. For example, the average gastrointestinal temperature increased from 37.6ºC before exercise to 39.3ºC after running for 45 minutes (Hughson, Green, Houston, Thomson, Maclean & Sutton, 1980:1141-1144.).

The results from a study regarding the running performance during intermittent-sprint exercise competition in warm conditions, showed that peak Tc was achieved during the final quarter at 39.3 ± 0.7°C, and that several players reached values near 40.0°C. Furthermore, the largest proportion of the total rise in Tc (2.1 ± 0.7°C) occurred during the first quarter of the match, with only small increases during the remainder of the game. These findings indicated that the plateau in Tc may be regulated by the reduction in low-intensity activity, and that pacing strategies may be employed during competitive team sports in the heat to ensure control of the internal heat load (Duffield, Coutts & Quinn, 2009:1238-1244).

As concluded in a review by Lim, Byrne and Lee (2008:347-353), heat is not only the end-product of metabolism but it also has therapeutic properties in the event of an infection, and may serve as a self-limiting signal that triggers central inhibition of exercise performance. Thus, athletes and coaches should continue to be vigilant about heat injury.

In accordance with the above-mentioned literature, Campos *et al*. (2012:1221-1228) suggested three factors that could be related to the increase in physiological demand during combat. Firstly, the athletes may be under thermal stress due to protective garments, climate or illness. Secondly, an increase in the physiological demand may be due to insufficient recovery between rounds, and lastly, the match strategy may lead to increased demand during each round.

2.2.3 Measurement Instruments

The following sections pertain to the additional testing techniques and equipment utilized in other research studies.

2.2.3.1 Anthropometrical Assessments

The term "anthropometry" refers to the scientific study of the measurements and proportions of the human body (Dictionary.com, 2014b). According to the International Society of the Advancement of Kinanthropometry (*ISAK)*, anthropometry is a longstanding science and the most recent standards have been assembled by international experts (Stewart, Marfell-Jones, Olds & de Ridder, 2011:3). These standardized methods provide the basis for the ISAK accreditation system that has been operating since 1996 (Stewart *et al.*, 2011:3).

Various techniques are required to obtain a comprehensive anthropometric profile on a person. These measurement sites are routinely taken to provide information for monitoring athletes, growth tracking, development, aging and performance, and linking physical activity and nutritional interventions to changes in the body size, shape and composition (Stewart *et al.*, 2011:4). The most common anthropometrical measurements include, height, weight, skinfolds (body fat percentage) and girths (Topend Sport, 2014). Once these measurements are completed, the practitioner can use various methods and computations to analyse the data (Stewart *et al.*, 2011:4).

Over the years, various skinfold measurement sites have been identified. However, the most regularly applied sites include the following: the triceps, subscapular, biceps, suprailiac, supraspinale, abdomen, quadriceps and medial calf (Topend Sport, 2014). In addition to the various measurement sites, countless body fat percentage calculation methods have also been developed, with the most commonly applied techniques being the method of Jackson and Pollock (7 skinfold sites) as well as the Yuhasz method using 6 skinfold sites (Topend Sport, 2014).

The Harpenden Skinfold Caliper is the self- administrated apparatus used to take the skinfold measurements. According to Topend Sports (2014), it is the most prestigious caliper available. The Harpenden Skinfold Caliper is also the only Caliper CE that is marked under the Medical Devices Directive 93/42/EEC for a Class 1 Device with Measuring Function and is calibrated using masters traceable to National Standards (Topend Sports, 2014).

It has been established, that the adoption of standard profiling and methodology allows for comparisons to be made locally, nationally and internationally between sample groups. For example, a review article by Chaabène *et al*. (2012:829-843), aiming to create a physical and physiological profile of elite karate athletes, revealed various anthropometrical characteristics recorded through several different studies, and the similarities among them. Their main findings were that the percentage body fat ranged from 7.5% for top-level Japanese karatekas (Imamura *et al*., 1997:9-13) to 16.8% for elite- level Polish karatekas (Sterkowicz-Przybycien, 2010:195-201). However, the French international-level team revealed a 13.7% body fat (Ravier *et al*., 2005:810-817).

2.2.3.2 Ergometers (VO_{2max})

An ergometer can be defined as an apparatus for measuring the work performed by a person exercising (Merriam-Webster, 2014). This piece of equipment can in turn be connected to other monitoring equipment such as the Cortex Metamax 3B gas analysis system, measuring: oxygen economy, lactate thresholds, oxygen consumption at lactate threshold, maximal lactate steady state and peak-power output, according to peak performances (Macfarlane & Wong, 2012:2543). Thus, exercise physiologists and specialists use these types of assessments to design training programs and as indicators for future evaluations (Livestrong, 2014).

According to a study by Rivera-Brown and Frontera, all the respective ergometers; treadmill, cycle and rowing, obtained a high reliability for efficient VO_{2max} testing among 20 trained adolescents (1998:164). Another study also concluded that there was no significant difference between the results produced by both the cycle and treadmill ergometers during the testing of twenty-one severely overweight youth (Loftin, Sothern, Warren & Udall, 2004:5).

The review article by Chaabène (2012:829-843), once again revealed that researchers over the years utilized various types of ergometers to determine the testing subjects' VO_{2max} results. It may thus be concluded that every researcher has an ergometer preference, or may be subject to the type of ergometer at his/her disposal.

2.2.3.3 Zephyr$_{TM}$ BioHarness$_{TM}$

The Zephyr$_{TM}$ BioHarness$_{TM}$ is a wireless physiological monitoring system that has the ability to measure heart rate, heart rate recovery, breathing rate, acceleration, intensity & load and estimated core temperature (Zephyr Technology, 2014). Recently, wireless portable technologies, such as global positioning systems, accelerometers and heart rate monitors, are becoming more and more popular in the health, sport and occupational settings associated with human physical activity (Hailstone & Kilding, 2011:293). For instance, the LifeShirt© successfully monitored healthy (Kent, O'Neill, Davison, Nevill, Elborn & Bradley, 2009:1) and clinical populations (Clarenbach, Senn, Brack, Kohler & Bloch., 2005:1282–1290; Witt, Fisher, Guenette, Cheong, Wilson & Sheel, 2006:389–395; Heilman & Porges, 2007:300–305) through simultaneously measuring breathing frequency, heart rate and physical activity.

The validity and reliability of the LifeShirt© measurements have previously been determined to its application in the field (Brack, Thuer, Clarenbach, Senn, Noll, Russi & Bloch, 2007:1). The Zephyr$_{TM}$ Bioharness$_{TM}$, however, functions on a similar wireless ambulatory physiological monitoring system, capable of measuring breathing rate, also known as respiratory rate, without the need for expensive metabolic systems (Zephyr Technology, 2014). This device also has wide-reaching applications. The system comprises a single chest strap, incorporating Smart Fabric sensors to measure chest expansion and retraction, making it possible to take measurements in a non-invasive manner and avoid obstruction of physical activity (Hailstone & Kilding, 2011:294).

The aim of the study by Hailstone and Kilding (2011:294) was to determine the reliability and validity of the BioHarness$_{TM}$ to measure respiratory rate. They measured twelve physically active participants on two separate occasions where they performed a maximal incremental treadmill test. Breathing rate measurements were taken continuously during both trials and both with a Metamax 3B gas-analyser (Cortex, 2014) and the BioHarness$_{TM}$. They concluded that there were no significant differences between the results recorded by the different devices (Hailstone & Kilding, 2011:294). Thus, the BioHarness$_{TM}$ can be said to be a valid and reliable device for determining heart rate and respiratory rate as well as the respiratory breakpoint during exercises of varying intensities (Johnstone, Ford, Hughes, Watson & Garrett, 2012:407, Johnstone *et al.*, 2012:415).

2.2.3.4 Dartfish Software 6 video analytical program

As previously established in this chapter, the utilization of video analysis is vital in order to improve training specificity and designing more specific exercise protocols that allow the investigation of issues specific to the sport (Roberts *et al*., 2008:825-833). Dartfish stated that they make the power of video accessible across industries such as sports, education and healthcare (2009).

The Dartfish software permits analysis of technical performance during and after training. The Dartfish Software 6 video analytical program allows for the import of video clips from a variety of sources, video and clip management, instant feedback during play and comparison to previous projects (Dartfish, 2009). Features of the program include:

- Dual camera support, replay at different speeds and image by image.
- Zoom; Magnify; Mirror video horizontal and vertical, picture-in-picture
- Simultaneous view of up to 4 videos - split-screen mode in multiple formats
- Overlay and advanced drawings such as shape and trajectories
- Multiple stopwatches
- Save key-positions as still pictures

The use of the Dartfish video analytical programs have been widely reported in numerous studies (Bobo & Andrews, 2010:1-11; Melton, Mullineaux, Mattacola, Mair & Uhl, 2011:393-405; Stanescu, Stoicescu & Ciolca, 2011:1-6; Goetz, Piallat, Thibaudier, Montigon, David & Chabardès, 2012:306-317; Chan-Roper, Hunter, Myrer, Eggett & Seeley, 2012:77-82; González, 2013:68-89;; James, Mackenzie & Capra, 2013:419-427; Stadtmueller, 2013:1-37; Lussiana, Fabre, Hébert-Losier & Mourot, 2013:1-8; Dysterheft, Lewinski, Seefeldt, & Pettitt, 2013:320-327) and are therefore considered as a valid and reliable system of measurement and investigation.

2.3 VALUE OF RESEARCH

Since Beekley *et al*. (2006:13-20) pointed out that no single performance characteristic dominates in combat sports and success requires a mixture of technique, strength, aerobic fitness, power and speed. Thus it has come to light that without proper investigation of the physiological demands imposed on an athlete during a competition situation, it would be unlikely that the athlete will develop to his or her full potential. This study, however, will provide data for interpretation by coaching and fitness professionals when prescribing appropriate and specific training activities in preparing competitive karate athletes, as well as a better understanding as to why an ancient art such as karate is such a great exercise method for the promotion of full body fitness.

2.4 CONCLUSION

Conventional training methods may not always be sufficient to provide the required edge over the opponents. By regarding all the above mentioned factors, the sport and conditioning coaches will be able to design applicable training programs to promote optimal performance by having a complete knowledge of a particular sport.

Chapter 3 will focus on the methodology of the testing, which includes a full description of all testing instruments and protocols.

CHAPTER 3: RESEARCH DESIGN

3.1 INTRODUCTION

This chapter describes the protocol that was designed to investigate the objectives stated in Chapter 1. A description of the subjects, instruments and methods that were used as well the technique for every measurement will be discussed. In preparation for this study, literature was collected from electronic databases such as Kovsiekat, Pubmed, EbscoHost (Academic Search Elite and Medline), academic journals, and textbooks.

3.2 RESEARCH PARTICIPANTS

Before the study commenced and before the participants were recruited, the study was approved by the Ethics Committee of the University of The Free State (**UFS-HUM-2014-43**) (See Appendix A). A meeting with the head coach of Karate and the Deputy Director of Free State Sport Science Institute was arranged in order to obtain full permission for execution of the investigation as well as to explain the procedures that followed (See Appendix B & C).

For the purpose of this study, twelve (n=12) elite karate participants were recruited from the Free State Karate High Performance Squad based on the following inclusion criteria: (1) age between 15 and 30 years; (2) male; (3) practised karate regularly for at least five years; (4) compete on national level (5) able to understand instructions in English. Any information that was obtained in connection with this study and that could be identified as pertaining to the participant remained confidential and was disclosed only with the permission of the participant, or as required by law. Confidentiality was maintained by means of allocating numbers to karate athletes. Information was stored with the investigator and raw data held under lock and key. All processing of data was governed by a PC password protector.

Informed- and parental consent forms approved by the Ethics Committee of the University of The Free State were handed out and had to be signed by the participants or their parents (see Appendix D). The form contained all necessary information on and basic elements of the study as specified in the *Research Quarterly for Exercise and Sport* (Thomas, 1983) and as recommended for use by Thomas, Nelson and Silverman (2011). All athletes who volunteered to participate in this study could withdraw from the study at any time without prejudice. Furthermore, participants could refuse to answer any questions they did not wish to answer and still remain in the study. The athlete's position in the Free State Karate High Performance Squad was not affected by his decision to participate or refuse participation in this study.

3.3 STUDY DESIGN

This study made use of a convenience sample with a qualitative, descriptive, cross-sectional research design.

3.3.1 Research Participant Information

Before participation in the study each participant was asked to complete a consent form from the Free State Sport Science Institute, University of the Free State, as well as a questionnaire in order to create a basic athlete profile. The profile required the participant to state his name and surname, age, gender, race, level of experience, recent injuries, left or right dominance, and contact details (See Appendix E).

3.3.2 Anthropometrical Assessment

Measurements of body mass, height and skinfolds provide an appraisal of the structural status of an athlete at any given time (Ross & Marfell-Jones, 1991). Detailed athletic profiles are also valuable in describing the characteristics of elite athletes across sports and at various stages throughout a yearly training periodization cycle.

A standard anthropometrical assessment was conducted, measuring height, weight and percentage body fat with a Harpenden Skinfold Caliper. Selected skinfolds included triceps, sub-scapula, supra-iliac, umbilicus, thigh and medial calf. The first measurement that was taken was height in centimetres. Each participant's mass was measured using a Tanita BF-350 Body Composition Analyzer scale. This scales' ability to accurately determine body composition was validated by Beam and Szymanski (2010: 3455).

Body fat percentage was calculated using the Yuhasz method (Yuhasz, 1977). Fat percentage measurements were taken prior to the testing session before the participants completed the test and started sweating. This method measures the following six sites:

- **Tricep**: Vertical fold
  Midway between elbow and shoulder joint.
- **Sub-scapula**: Diagonal fold
  One inch below the inferior border of the scapula.
- **Supra-iliac**: Diagonal fold
  Directly above the iliac crest.
- **Umbilicus**: Vertical fold
  One inch to the right of navel.
- **Thigh**: Vertical fold
  Midway between supra-patella and hip joint.
- **Medial Calf**: Vertical fold
  Maximum circumference of calf on the midline of medial border

The sum of the six sites was calculated and converted into a percentage, using the equation below for males:

> ***Body fat percentage** = (0.1051 x sum of triceps, subscapular, supra-iliac, abdominal, thigh, calf) + 2.585.*

3.3.3 Graded Exercise Testing Maximal Effort VO_{2max}

An incremental VO_{2max} protocol was used to determine maximal exertion levels of each participant. The test was conducted in a fasting condition of four hours. No training was done the day prior to testing. The protocol started with an initial warm-up period of 90 seconds at 4 km/h and then increased in speed up to 8 km/h. Thereafter the treadmill speed automatically increased by 1 km/h every 1 minute until maximal exertion was achieved. The time point of maximal exertion was determined either by the participant, when he voluntarily stopped the exercise test due to fatigue, or by the researcher, when she stopped the test to ensure the safety of the participant with regards to the physiological responses observed and the behaviour of the athlete. Upon maximal exertion, the participant jumped to the side of the treadmill. Thereafter the recovery phase of three minutes, at a constant speed of 5km/h, was initiated.

The following thresholds were established during the graded maximal effort test:

- **Fatty acid threshold**: Allocated where the highest fat value (g/day) was measured.
- **Carbohydrate threshold**: Established at an R value of 1.00. This is also the threshold between the aerobic and anaerobic zones with all R values higher than 1.0 being indicative of the anaerobic zone and all R values less than 1.00 being indicative of the aerobic zone.
- **Lactate threshold**: Established through an indirect method as no blood lactate testing was done. This specific threshold was found between the carbohydrate threshold and the end of the test. It was estimated as the point where the R value increased substantially in value as opposed to preceding values (Jansen van Rensburg, 2010:80).

3.3.4 Simulated Kumite Testing

The simulated kumite bouts took place on a closed-cell mono-density polyethylene mat called a tatami. The surface of the mat has rice-straw embossing which helps with grip and traction so that the desired movements may be performed. This surface is the same as that used in all WKF karate competitions (Tatami- Sport, 2013).

Athletes participated in a fasting state of at least four hours prior to the simulated kumite bouts in order to achieve testing conditions similar to those under which the graded maximal effort testing was performed. This specification was also implemented to ensure that the physiological responses observed were not influenced by the intake of various foodstuffs. Each participant was fitted with a Zephyr BioHarness 3 System which included the BioHarness together with its module fitted to the participant's chest, underneath the body protector and karate gi (suit). Thereafter the participants proceeded to warm up for five minutes at low to medium intensity, after which the first pair of contestants participated in a simulated kumite bout of three minute duration. All matches were conducted in accordance with the official WKF (World Karate Federation) rules and guidelines.

At the start of the match, the referee stood 2 meters from the centre of the competition area. The contestants faced and stood 3 meters away from each other, at right angles to the referee. Each bout of sparring was started or stopped when the referee called "hajime", which means to start, or "yame", which means to stop (WKF, 2014).

Attacks were to be limited to the following areas: head, face, neck, abdomen, chest, back, and side. In order to score, a technique must be applied to a scoring area. Only controlled contact was allowed on the head and face, with no contact to the neck and full contact to the abdomen. A score was awarded when a technique was performed according to the following criteria: good form, sporting attitude, vigorous application, good timing, and correct distance (WKF, 2014).

During the match, the referee positioned himself a few meters away from the players to minimize interference. However, every time a player scored, the referee stopped the fight and made the contestants move back to the starting position. The referee then awarded three, two, or one point according to the area scored on and the techniques used; usually points were awarded within a few seconds of a score to minimize any interference. The fight could thus be stopped as many times as the contestants scored during the match, which is consistent with the official rules set by the World Karate Federation (WKF, 2014).

Each pair of contestants had at least four bouts to simulate a competition environment. After each of the simulated matches was completed, the participants were asked to sit flat on the ground for one minute to determine the recovery rate (or heart rate reserve) of the participants. The Zephyr BioHarness was removed four minutes after the last match as the participants finished their cool-down regime involving static stretching and foam rolling. Table 3.1 indicates the set durations of the various recovery and resting periods in between the respective rounds.

Table 3.1: Duration of recovery and rest periods in between rounds

Rounds	Recovery period (seated position)	Set rest periods	Total rest duration
1-2	1 minute	21 minutes	22 minutes
2-3	1 minute	16 minutes	17 minutes
3-4	1 minute	11 minutes	12 minutes
4-5	1 minute	6 minutes	7 minutes
5-6	1 minute	11 minutes	12 minutes
6+	1 minute	3 minutes	4 minutes

During the match the Zephyr system recorded the following data, which were analysed: [1]Heart rate (HR), [2]breathing rate (BR), and [3]estimated core temperature (T_c). All fights were recorded on four high-speed cameras set at an elevated position one meter behind each of the far corner judges, outside the competition area. The recorded fights were later analysed by the Dartfish Software 6 Video Analytical program, according to certain kumite characteristics. The kumite characteristics included:

Fighting activities:

- Low intensity or bouncing activities (no contact with the opponent)
- High intensity or techniques (from initiating action to technique retraction)
- Active contact (follow through after attack, clinching, and attempting to throw, tugging and pulling)
- Passive contact (being thrown, standing chest to chest- no attempt to work the clinch)

Stoppages:

- Referee (awarding of points, warnings and penalties)
- Medical
- Attire (fixing the protective gear, karate gi or belt)

Techniques Scored:

- Offensive and Defensive (Jodan and Chudan)
  - Punches (all tsukis)
  - Kicks (all geris)
  - Combinations (all double punches and kicks, as well as punches in combination with a kick)
  - Balance Breakings (all take downs and leg sweeps)

3.4 MEASURING INSTRUMENTS

The following section describes the measurement instruments utilized for the research study.

3.4.1 Performance Analysis Measurements

The use of the Dartfish video analytical program allowed the researcher to view and analyse video clips, capture skills and compare content (Dartfish, 2009). As previously stated in Chapter 2, the use of the Dartfish video analytical programs have been reported in numerous studies and therefore the progams are considered a valid and reliable system of measurement and investigation (Bobo & Andrews, 2010:1-11; Melton *et al.*, 2011: 393-405; Stanescu *et al.*, 2011:1-6; Goetz *et al.,* 2012:306-317; Chan-Roper *et al.*, 2012:77-82; González, 2013:68-89; James *et al.*, 2013:419-427; Stadtmueller, 2013:1-37; Lussiana *et al.*, 2013:1-8; Dysterheft *et al.*, 2013:320-327). The programs thus assisted the researcher in the TMA of the kumite fights and pinpointed primary movements and trajectories, calculated speeds and demonstrated key techniques and positions which are critical for karate performance at top level.

3.4.2 Physiological Measurements

In order to establish the basic athletic profile of the participants, a standard anthropometrical assessment was conducted, measuring, height, weight and percentage body fat with a Harpen Skinfold Calliper. To establish baseline values for maximum heart rate, breath-by-breath oxygen consumption, metabolic activity zones, recovery rates, and indirect muscle fibre type estimation, an incremental maximum effort test was done on a Cortex VO_{2max} machine performed on a Woodway Treadmill. This particular Woodway treadmill model is the top commercial model treadmill. It features a shock-absorption system which reduces impact to lower body muscles, joints and bones, yielding a more comfortable workout (Personal Power Training, 2012).

The utilization of Zephyr Technology's BioHarness 3 (Model BH3) which enables the capture and transmission of comprehensive physiological data on the wearer via mobile data and fixed data networks, enabled genuine remote monitoring of athletic performance as well as actual conditions in the athlete's real world (Zephyr$_{TM}$, 2014).

Characteristics measured by the Zephyr System that were to be utilized during this study included:

- Heart Rate: Recorded at 1sec intervals. The resting heart rate prior to activity was recorded, starting heart rate directly prior to the kumite bout, mean heart rate (HR_{mean}) calculated as the average of the heart rate during the entire kumite match and maximum heart rate (HR_{max}) as the highest value throughout the match, were recorded.
- Breathing rate: Recorded throughout the match.
- Core temperature (estimated): Measured prior to and immediately after each kumite match.

The technical equipment that was required for this study included: 4 x high speed cameras (1080/50p at 36Mbits/sec), 4 x Zephyr Bioharness systems, Dartfish Software 6 video analytical program, the BioHarness Log Downloader (V1.0.29.0) and the BioHarness MATLAB Script Files. The validity and reliability of the above mentioned measurement instruments has been discussed previously in chapter 2, subdivision 2.2.3.

3.5 METHODOLOGICAL AND MEASUREMENT ERRORS

Errors were minimised by training the research assistants and utilising the same assistant for all measurements taking. In order to minimise errors, each participant was weighed with the same calibrated Tanita BF-350 Body Composition Analyzer scale. In addition, the Cortex VO_{2max} machine and Zephyr BioHarness system were calibrated as per manufacturer's specifications and by the qualified personnel of the FSSSI.

3.6 PILOT STUDY

A pilot study with four participants was conducted during May 2014. The pilot study consisted of testing with no interventions. The aim was to ensure the effectiveness of the data sheets, equipment, and protocols. Moreover, the duration of testing per participant as well as the continuity of testing was examined for the proper planning of testing days. Data sheets, equipment, and protocols were found to be effective in testing the proposed objectives.

3.7 DATA MANAGEMENT

Data was captured electronically by the researcher in Microsoft Excel (Microsoft Office 2007).

After testing, a video analysis of each fight was conducted, and activities were categorised as follows: [1]offensive and defensive techniques; [2]upper and lower limb techniques; [3]fighting and preparatory activities, as well as [4]stoppages. This assisted in the TMA. In addition, the data from the Zephyr Systems were analysed according to: [1]resting, starting, mean, peak and recovery heart rate; [2]time to recovery

($HR_{reserve}$); [3]breathing rate and [4]estimated core temperature prior, during and after matches.

The data gathered from both the TMA, the data from the Zephyr Systems, together with the initial VO_{2max} data of each participant, was integrated to determine the physiological aspects of the various kumite characteristics. The data collected from the Zephyr System thus assisted in determining the physiological demands of a kumite competition. The different rounds of the simulated competition were also compared.

Data will be presented in chapter 4 in the following order: anthropometrical data, physiological variables, followed by the TMA. Furthermore, all of the data will firstly be discussed in group format followed by individual variances.

3.8 STATISTICAL ANALYSIS

The statistical analysis described below was undertaken by a biostatistician, using the SAS statistical software package (version 9.22) (see SAS, 2009). Descriptive statistics, namely means, standard deviations, as well as minimum and maximum values were calculated for all variables.

3.8.1 Zephyr Data

The following measurements were taken by the Zephyr system at a rate of every second over time:

1. Heart rate (HR)
2. Breathing (Respiration) rate (BR)
3. Estimated Core temperature (T_c)

From the profiles of these measurements over time, the following characteristics were calculated:

Value at start of fight, end of fight, minimum value during fight, maximum value during fight, difference maximum and minimum values, average value during the fight, value at start of 1 minute recovery period, at end of 1 minute recovery period, average value during 1 minute recovery period, value at end of set rest period, average value during set rest period.

Each characteristic of every specific measurement was analysed separately using a repeated measurement analysis of variance (ANOVA) model with “round” as fixed effect. Since each athlete participated in six rounds, the data was modelled as repeated measurements with “round” as a within-athlete (repeated) factor. An unstructured covariance matrix was fitted for the 6-variate repeated measures.

In order to accommodate correlation of the data within each match, the model initially included a random effect for “match”. Similarly, in order to accommodate correlation of the data across matches where different athletes fight the same opponent, the model initially also included a random effect “opponent”. However, in general the variance components associated with these additional random effects were either estimates to be zero, or the mixed model fit did not converge. Therefore, the final model excluded the random effects due to “match” and “opponent”.

From the repeated measures ANOVA, estimates of the mean response (least squares means) for each round were obtained, as well as P-values associated with the null-hypothesis of no difference between rounds.

3.8.2 Techniques Data

For each athlete and round, the following counts of techniques scored were available:

- Offensive jodan punches
- Offensive chudan punches
- Offensive jodan kicks
- Offensive chudan kicks
- Offensive balance breakings
- Defensive jodan punches
- Defensive chudan punches

- Defensive jodan kicks
- Defensive chudan kicks
- Defensive balance breakings

From these counts, the total counts of offensive and defensive techniques were calculated, as well as the total number of techniques (offensive plus defensive).

The counts of offensive, defensive and total techniques were analysed separately using a generalized linear model with Poisson error distribution and logarithmic link function. In each case, “round” and “athlete” were fitted as fixed effects. With this model, no significant over-dispersion was noted in any of the three-count variables.

Based on the generalized linear model, likelihood ratio (LR) chi-square statistics for the athlete and round effects were obtained. Furthermore, from the generalized linear model, estimates of the mean count for each round were obtained.

Similarly, estimates of the mean count for each athlete were also obtained, together with the standard errors.

3.8.3 Time-Motion Data

The following measurements of times were taken for each fight and athlete:

1. low intensity (bouncing/low intensity)
2. high intensity (techniques/high intensity)
3. active contact
4. passive contact

From these measurements, the following characteristics were calculated:

a. total=low intensity + high intensity + active contact + passive contact
b. total high intensity=high intensity + active contact
c. percentage low intensity=100*low intensity/total
d. percentage high intensity=100*high intensity/total
e. percentage total high intensity=100*total high intensity/total

f. percentage active contact=100*active contact/total
g. percentage passive contact=100*passive contact/total
h. percentage high low=100*high intensity/low intensity
i. percentage total high low=100*total high intensity/low intensity

Each measurement and each calculated characteristic were analysed separately using a repeated measurements analysis of variance (ANOVA) model with “round” as fixed effect. Since each athlete participated in six rounds, the data was modelled as repeated measurements with “round” as within-athlete (repeated) factor. An unstructured covariance matrix was fitted for the 6-variate repeated measures.

From the repeated measures ANOVA, estimates of the mean (least squares means) for each round were obtained, together with the standard errors of the mean.

Similarly, the overall average mean was obtained, together with the standard errors of the mean.

CHAPTER 4: RESULTS

4.1. INTRODUCTION

This chapter sets out the findings of the study and comprises a brief discussion of the respective data presentations. Firstly, the demographical and anthropometrical data of the study participants will be displayed followed by the data collected during the graded maximal effort test (VO_{2max}) and lastly the findings during the simulated kumite testing.

4.2 ATHLETE CHARACTERISTICS

Twelve (n=12) elite male karate athletes from the Free State Karate High Performance Squad took part in this study. Demographical data of the participants indicated that the age of the athletes ranged from 17 to 28 years, and the mean years of practice was about 10 years. The mean (± SD) weight, height and body fat percentage of the participants were 68.6 ± 11.1 kg, 177 ± 9.4 cm and 8.5 ± 1.7 %, respectively, with the weight ranging from 54 to 93.5 kg, height from 169 to 197 cm and body fat percentage from 6.41 to 12.84 %.

4.3 GRADED MAXIMAL EFFORT TEST (VO_{2MAX})

According to the graded maximal effort VO_{2max} test, the following energy systems were utilized by the athletes, namely the oxidative lipolytic, oxidative glycolytic, anaerobic and the lactate zone. Table 4.1 shows each athlete's target heart rate (HR) for each respective energy system as calculated during the maximal effort testing. During this testing procedure a maximum heart rate ranging from 172 to 209 bpm, with a mean maximum heart rate of 187.5 bpm, were recorded.VO_{2max} values ranged from 48.3 to 60.7 ml/kg/min, with a mean value of 54.78 ± 1.1 ml/kg/min.

Table 4.1: Athlete energy systems derived from heart rate data of VO_{2max} test						
Athlete	ENERGY SYSTEM HEART RATE ZONES				HR_{max}	VO_{2max}
	OXIDATIVE LIPOLYTIC	OXIDATIVE GLYCOLYTIC	ANAEROBIC	LACTATE		
1	<136	137-168	169+	Not achieved	172	54.1
2	<121	122-162	163-172	173-181+	179	53.7
3	100-138	139-169	170-174+	Not achieved	174	50.3
4	<161	162-190	191+	Not achieved	189	50.2
5	<141	142-151	152-180	181-184+	184	56.3
6	<116	117-173	174-180	181-183+	183	55.6
7	<125	126-145	146-185	186-190+	190	48.3
8	<125	126-178	179-190	191-195+	190	60.7
9	<171	172-190	191+	192+	193	58.4
10	<171	172-190	191+	Not achieved	192	56.4
11	<154	155-181	182-195	196+	195	59.3
12	<160	161-205	206+	Not achieved	209	54
Mean	**100-143**	**144-175**	**176-182**	**183-189+**	**187.5**	**54.775**

4.4. SIMULATED KUMITE TESTING

The following results were obtained during the course of the simulated kumite testing.

4.4.1 Physiological Variables

The subsequent sections pertain to the physiological variables that were measured.

4.4.1.1 Energy System Contribution

During the simulated kumite testing, the Zephyr system recorded the HR responses of each athlete. These recordings were then synchronized with the above-mentioned target heart rates. Table 4.2 represents the percentage of time spent by each athlete in each respective energy system over the course of all the kumite fights. It can be established that the mean percentage of time spent within the oxidative zones was 51.85%, with the anaerobic zone at 25.12% and lactate zone at 23.03%.

Table 4.2:	**Percentage of time spent by each athlete within respective energy systems**				
Athlete	ENERGY SYSTEMS				
	OXIDATIVE LIPOLYTIC	OXIDATIVE GLYCOLYTIC	AEROBIC	ANAEROBIC	LACTATE
1	9.98%	25.09%	35.07%	13.78%	51.15%
2	7.58%	48.96%	56.54%	22.53%	20.93%
3	15.92%	14.24%	30.16%	1.60%	68.24%
4	10.20%	44.60%	54.80%	45.20%	0.00%
5	24.63%	6.18%	30.81%	59.78%	9.41%
6	23.08%	58.79%	81.87%	14.08%	4.05%
7	5.36%	7.23%	12.59%	41.96%	45.45%
8	6.76%	50.05%	56.81%	21.52%	21.67%
9	27.18%	46.20%	73.38%	6.21%	20.41%
10	51.28%	47.38%	98.66%	0.43%	0.91%
11	5.14%	9.60%	14.74%	53.28%	31.98%
12	18.74%	58.10%	76.83%	21.04%	2.12%
Mean	**17.15%**	**34.70%**	**51.85%**	**25.12%**	**23.03%**

Table 4.3 represents the mean percentage of time spent within each energy system as established during the graded maximal effort test (VO_{2max}), for every respective round. The time values are presented as minutes, seconds and tenths of a second (mm:ss:0). It can be noted that the aerobic contribution during the rounds ranged from about 44% in round 3 to approximately 75% in round 5, with a mean of 55.45% per round. Furthermore, it is evident that the mean percentage contributions of the anaerobic and lactate systems are 32.31% and 12.24% respectively, with minimal reliance on the lactate system during the 5th and 6th rounds.

Table 4.3:	**Percentage energy system contribution per round**					
Round	**ENERGY SYSTEMS**					**AVERAGE TIME / FIGHT**
	OXIDATIVE LIPOLYTIC	**OXIDATIVE GLYCOLYTIC**	**AEROBIC**	**ANAEROBIC**	**LACTATE**	
1	13.63%	32.56%	46.19%	38.08%	15.73%	05:14.3
2	7.87%	37.55%	45.41%	38.39%	16.20%	04:07.9
3	9.59%	34.46%	44.05%	42.30%	13.65%	04:35.4
4	21.68%	33.82%	55.49%	27.66%	16.85%	04:34.5
5	27.82%	47.81%	75.63%	19.33%	5.05%	05:50.8
6	25.30%	40.64%	65.94%	28.08%	5.98%	04:29.2
Mean	**17.65%**	**37.81%**	**55.45%**	**32.31%**	**12.24%**	**04:48.7**

4.4.1.2 *Heart Rate (HR) and Breathing Rate (BR)*

During the simulated karate matches, the following mean (± SE) values for HR and BR were recorded per athlete as well as per round. Tables 4.4 and 4.5 show that the mean HR and BR during the fight for the 12 athletes were 169.1 ± 3.92 bpm and 28.66 ± 1.85 breaths per minute (breaths/m), respectively with a mean value of 169.26 ± 4.37 bpm and 28.81 ± 1.19 breaths/m over the six rounds. No statistically significant differences were found between rounds for the following HR measurements: [1]start of fight (F=1.13; P=0.44), [2]end of fight (F=1.19; P=0.44), [3]minimum during fight (F=2.30; P=0.17), [4]maximum during fight (F=0.33; P=0.88), and [5]difference max-min (F=1.81; P=0.28). Similarly, no significant differences were observed between rounds for the associated BR values: [1]start of fight (F=0.98; P=0.50), [2]minimum during fight (F=3.93; P=0.055), and [3]difference max-min (F=0.34; P= 0.87). Significant differences were however found between rounds for values concerning the mean HR during the fight (F=7.05; P=0.03) and BR values regarding: [1]end of fight (F=5.82; P=0.02), [2]maximum during fight (F=10.23; P=0.004), and [3]mean during fight (F=15.43; P=0.001).

Table 4.4: Mean (± SE) HR and BR data of simulated karate sparring for each athlete

	Start of fight		End of fight		Minimum during fight		Maximum during fight		Difference Max-Min		Mean during fight	
	HR*	BR	HR*	BR	HR*	BR	HR*	BR*	HR*	BR*	HR*	BR
1	131.88 ± 5.44	20.48 ± 2.86	177.72 ± 4.46	11.40 ± 2.22	127.96 ± 4.38	11.40 ± 2.22	182.93 ± 3.13	38.02 ± 1.72	55.04 ± 4.35	26.63 ± 2.87	165.47 ± 3.78	25.98 ± 1.64
2	130.57 ± 5.44	24.14 ± 2.86	175.69 ± 4.93	15.56 ± 2.22	126.25 ± 4.45	15.56 ± 2.22	175.90 ± 3.13	43.51 ± 1.79	49.5 ± 4.52	27.99 ± 2.91	155.46 ± 3.78	30.86 ± 1.68
3	137 ± 5.44	26.53 ± 2.86	186.31 ± 4.93	20.43 ± 2.22	134.84 ± 4.45	20.43 ± 2.22	190.14 ± 3.13	34.98 ± 1.79	55.7 ± 4.52	14.44 ± 2.91	169.25 ± 3.78	28.33 ± 1.68
4	156.05 ± 5.44	21.53 ± 2.86	195.26 ± 4.92	15.04 ± 2.22	153.38 ± 4.45	15.04 ± 2.22	200.36 ± 3.13	43.36 ± 1.77	48.48 ± 4.52	28.34 ± 2.91	184.94 ± 3.78	31.45 ± 1.68
5	131.23 ± 6.01	20.91 ± 3.15	182.98 ± 5.44	16.81 ± 2.45	119.83 ± 4.93	16.81 ± 2.45	181.82 ± 3.45	38.4 ± 1.95	62.95 ± 4.96	21.63 ± 3.22	159.52 ± 4.18	29.31 ± 1.83
6	101.92 ± 6.01	20.4 ± 3.15	178.76 ± 6.61	15.33 ± 2.45	86.93 ± 5.14	15.33 ± 2.45	180.31 ± 3.45	37.54 ± 2.14	93.8 ± 5.47	22.15 ± 3.34	150.40 ± 4.18	25.89 ± 1.96
7	126.91 ± 6.73	28.95 ± 3.51	190.85 ± 7.28	17.38 ± 2.74	114.07 ± 5.78	17.38 ± 2.74	195.70 ± 3.85	38.85 ± 2.37	82.50 ± 6.03	21.28 ± 3.72	171.10 ± 4.71	29.19 ± 2.15
8	153.98 ± 5.43	23.18 ± 2.86	184.68 ± 6.45	11.69 ± 2.22	136.94 ± 4.74	11.69 ± 2.22	186.76 ± 3.13	39.97 ± 1.99	51.24 ± 5.14	28.4 ± 3.06	165.93 ± 3.78	25.06 ± 1.82
9	122.36 ± 5.44	20.20 ± 2.86	197.60 ± 5.68	12.82 ± 2.22	108.05 ± 4.63	12.82 ± 2.22	197.30 ± 3.13	40.73 ± 1.83	90.32 ± 4.77	27.85 ± 2.98	174.65 ± 3.78	29.18 ± 1.72
10	102.33 ± 5.44	17.48 ± 2.86	186.45 ± 8.48	12.79 ± 2.22	80.09 ± 5.18	12.79 ± 2.22	189.76 ± 3.13	46.02 ± 2.31	111.17 ± 6.04	33.25 ± 3.3	156.49 ± 3.78	29.13 ± 2.03
11	147.2 ± 5.44	20.59 ± 2.86	206.01 ± 8.47	16.27 ± 2.22	140.69 ± 5.18	16.27 ± 2.22	200.45 ± 3.13	38.56 ± 2.31	60.84 ± 6.04	21.99 ± 3.3	188.62 ± 3.78	27.88 ± 2.03
12	119.11 ± 5.44	17.03 ± 2.86	206.90 ± 8.46	11.01 ± 2.22	106.49 ± 5.18	11.01 ± 2.22	209.67 ± 3.13	44.99 ± 2.32	104.96 ± 6.04	34.25 ± 3.3	187.46 ± 3.78	31.64 ± 2.03
Mean	**130.21 ± 5.64**	**21.785 ± 2.96**	**189.1 ± 6.34**	**14.71 ± 2.3**	**119.63 ± 4.87**	**14.71 ± 2.3**	**190.93 ± 3.24**	**40.41 ± 2.02**	**72.21 ± 5.2**	**25.68 ± 3.15**	**169.11 ± 3.92**	**28.66 ± 1.85**

*** Statistically significant difference between means per athlete (P < 0.05)**

Table 4.5: Mean (± SE) HR and BR data of simulated karate sparring for each round

	Start of fight		End of fight		Minimum during fight		Maximum during fight		Difference Max-Min		Mean during fight	
	HR	BR	HR	BR*	HR	BR	HR	BR*	HR	BR	HR*	BR*
1	127 ± 6.43	19.09 ± 2.04	184.33 ± 2.8	37.79 ± 1.61	122.33 ± 7.15	15.89 ± 2.19	190.83 ± 2.05	44.08 ± 1.33	68.5 ± 6.2	28.18 ± 3.05	175.46 ± 3.8	32.13 ± 0.98
2	131.67 ± 6.31	23.08 ± 2.18	187.17 ± 3.12	35.81 ± 3.41	125.17 ± 7.19	19.08 ± 1.89	192.5 ± 2.86	42.75 ± 1.79	67.33 ± 7.22	23.68 ± 2.78	174.85 ± 3.54	31.57 ± 1.27
3	137.92 ± 6.12	23.33 ± 1.59	186.33 ± 3.63	35.04 ± 2.72	128.08 ± 7.26	13.97 ± 1.23	191.33 ± 3.05	41.82 ± 1.48	63.25 ± 7.96	27.85 ± 2.3	175.35 ± 3.49	28.97 ± 1.19
4	127.92 ± 4.6	19.91 ± 1.75	184.83 ± 4.29	34.53 ± 2.56	117 ± 7.45	14.96 ± 1.49	189.83 ± 4.26	40.46 ± 1.49	72.83 ± 8.54	25.5 ± 2.52	167.46 ± 4.83	29.48 ± 1.13
5	132.15 ± 7.86	24.77 ± 2.23	168.61 ± 7.96	25.85 ± 2.88	116.11 ± 5.6	12.47 ± 1.21	190.72 ± 3.39	37.82 ± 1.05	75.02 ± 6	25.04 ± 1.33	162.08 ± 5.07	26.48 ± 1.28
6	127.17 ± 4.69	21.29 ± 2.6	182.48 ± 4.55	30.69 ± 2.23	112.18 ± 5.99	11.38 ± 1.38	189.51 ± 5.29	35.59 ± 1.56	77.15 ± 5.7	25.08 ± 1.9	160.36 ± 5.48	24.21 ± 1.3
Mean	**130.64 ± 6.00**	**21.91 ± 2.07**	**182.29 ± 4.39**	**33.26 ± 2.57**	**120.15 ± 6.77**	**14.62 ± 1.57**	**190.79 ± 3.48**	**40.42 ± 1.45**	**70.68 ± 6.94**	**25.89 ± 2.31**	**169.26 ± 4.37**	**28.81 ± 1.19**

*** Statistically significant difference between means per round ($P < 0.05$)**

Mean HR and BR values were also recorded for the 1-minute recovery and set rest periods between the respective rounds for each athlete. Tables 4.6 and 4.7 show that the mean HR and BR over the rest periods were 127.33 ± 6.10 bpm and 26.85 ± 1.73 breaths/m per athlete, with 128.93 ± 5.53 bpm and 26.39 ± 1.23 breaths/m per round, respectively. No significant differences were found between rounds for HR values concerning; [1]start of 1 minute recovery ($F= 2.57$; $P=0.14$), [2]mean during 1-minute recovery ($F= 4.21$; $P=0.06$), [3]end of set rest ($F=1.71$; $P=0.26$), and [4]mean during set rest ($F= 14.54$; $P=0.06$). For BR values recorded, no differences were found regarding; [1]end of 1-minute recovery ($F=0.45$; $P=0.80$), [2]mean during 1-minute recovery ($F=0.58$; $P=0.72$), [3]end of set rest ($F=2.91$; $P=0.11$), and [4]mean during set rest ($F=4.47$; $P=0.06$). Differences were however, observed regarding the HR values at the end of the 1-minute recovery period ($F=6.17$; $P=0.03$) and BR values at the start of the 1-minute recovery period ($F=4.78$; $P=0.04$). The HR reserve was also calculated as the difference between the HR at the start of the 1 minute recovery period and the HR at the end of the 1-minute rest period. The mean HR reserve for all the athletes were 30.28 ± 5.57 bpm and 20.66 ± 4.34 bpm for each round respectively.

Table 4.6: Mean (± SE) HR and BR values for the recovery and rest periods for athletes

Athlete	Start of 1-minute recovery		End of 1-minute recovery		Mean during 1-minute recovery		Heart rate reserve (End-Start)	End of set rest period		Mean during set rest period	
	HR*	BR*	HR*	BR*	HR	BR*	HR	HR*	BR	HR*	BR
1	179.87 ± 3.91	25.53 ± 2.72	161.67 ± 5.48	24.76 ± 3.46	174.62 ± 4.99	25.97 ± 2.96	18.2 ± 4.69	122.70 ± 6.85	21.78 ± 3.14	117.57 ± 5.89	26.71 ± 1.66
2	176.81 ± 4.24	41.71 ± 2.85	169.83 ± 5.48	44.23 ± 3.46	174.49 ± 5.29	42.70 ± 2.96	6.98 ± 4.86	125.71 ± 6.96	25.84 ± 3.14	130.13 ± 5.89	26.46 ± 1.66
3	187.67 ± 4.24	31.87 ± 2.85	175.33 ± 5.48	27.24 ± 3.46	182.55 ± 5.29	29.20 ± 2.96	12.34 ± 4.86	126.28 ± 6.96	26.05 ± 3.14	135.53 ± 5.89	23.80 ± 1.66
4	197.35 ± 4.23	39.11 ± 2.85	164.33 ± 5.48	24.87 ± 3.46	181.28 ± 5.29	30.77 ± 2.96	33.02 ± 4.86	153.80 ± 6.96	22.12 ± 3.14	141.80 ± 5.89	25.14 ± 1.66
5	185.56 ± 4.79	38.58 ± 3.11	151.27 ± 6.06	23.80 ± 3.81	172.66 ± 5.95	31.21 ± 3.26	34.29 ± 5.43	128.37 ± 7.66	25.28 ± 3.46	125.75 ± 6.49	27.95 ± 1.84
6	185.48 ± 5.64	28.03 ± 3.49	149.57 ± 6.06	20.49 ± 3.81	169.55 ± 6.76	25.32 ± 3.26	35.91 ± 5.85	110.20 ± 8.01	20.53 ± 3.46	120.14 ± 6.49	26.22 ± 1.84
7	196.53 ± 6.29	23.20 ± 3.82	162.55 ± 6.83	21.11 ± 4.24	185.30 ± 7.55	21.29 ± 3.63	33.98 ± 6.56	116.32 ± 8.88	27.62 ± 3.87	120.52 ± 7.21	28.95 ± 2.07
8	187.87 ± 5.48	22.52 ± 3.30	171.83 ± 5.48	28.25 ± 3.46	178.66 ± 6.48	23.40 ± 2.96	16.04 ± 5.48	164.57 ± 7.38	20.24 ± 3.13	159.66 ± 5.90	28.31 ± 1.66
9	202.10 ± 5.16	31.60 ± 3.02	160.67 ± 5.48	26.84 ± 3.46	186.82 ± 6.16	28.77 ± 2.96	41.43 ± 5.32	118.76 ± 7.10	24.71 ± 3.14	118.76 ± 5.89	31.28 ± 1.66
10	188.09 ± 7.11	42.27 ± 3.93	168.50 ± 5.48	37.60 ± 3.46	179.26 ± 8.10	38.93 ± 2.96	19.59 ± 6.29	124.81 ± 8.02	21.04 ± 3.14	111.08 ± 5.89	25.22 ± 1.66
11	206.17 ± 7.10	32.83 ± 3.93	148.50 ± 5.48	24.73 ± 3.46	182.63 ± 8.10	26.37 ± 2.96	57.67 ± 6.29	121.89 ± 8.02	19.35 ± 3.14	129.15 ± 5.89	25.80 ± 1.66
12	208.22 ± 7.09	40.69 ± 3.93	154.33 ± 5.48	28.46 ± 3.46	186.08 ± 8.09	33.78 ± 2.96	53.89 ± 6.29	116.00 ± 8.02	16.76 ± 3.14	117.86 ± 5.89	26.29 ± 1.66
Mean	**191.81 ± 5.44**	**33.16 ± 3.32**	**161.53 ± 5.69**	**27.7 ± 3.58**	**179.49 ± 6.51**	**29.81 ± 3.07**	**30.28 ± 5.57**	**127.45 ± 7.57**	**22.61 ± 3.25**	**127.33 ± 6.10**	**26.85 ± 1.73**

*** Statistically significant difference between means per athlete (P < 0.05)**

Table 4.7: Mean (± SE) HR and BR values for the recovery and rest periods between the respective rounds

Round	Start of 1-minute recovery		End of 1-minute recovery		Mean during 1-minute recovery		Heart rate reserve (End-Start)	End of total rest period		Mean during rest period	
	HR	BR*	HR*	BR	HR	BR	HR	HR	BR	HR	BR
1	180.42 ± 2.51	32.57 ± 2.27	142.25 ± 5.81	29.48 ± 2.06	161.73 ± 4.43	29.09 ± 1.99	38.17 ± 4.16	131.5 ±6.54	23.08 ± 2.38	113.5 ± 3.45	23.87 ± 0.72
2	187.75 ± 2.88	37.05 ± 2.88	150.83 ± 4.77	27.08 ± 2.52	172.7 ± 2.32	30.63 ± 2.37	36.92 ± 3.83	129.92 ± 5.54	22.79 ± 2.3	118.57 ± 3.57	24.84 ± 0.81
3	188.58 ± 3.1	35.89 ± 2.7	159.83 ± 3.96	28.31 ± 3.29	179.75 ± 2.01	31.51 ± 2.71	28.75 ± 3.53	124.25 ± 4.26	20.77 ± 2.08	118.46 ± 3.49	26.51 ± 0.82
4	186.75 ± 3.63	33.58 ± 2.54	170 ± 4.12	29.08 ± 3.24	181.12 ± 2.87	31.74 ± 3.12	16.75 ± 3.88	122 ± 6.44	26.51 ± 1.88	132.56 ± 6.28	28.79 ± 0.92
5	169.47 ± 8.08	24.88 ± 3.01	170.47 ± 4.35	24.86 ± 2.89	177.27 ± 7.72	26.34 ± 2.42	-1 ± 6.22	120.69 ± 5.75	18.74 ± 1.43	136.08 ± 7.33	25.15 ± 1.49
6	186.63 ± 3.86	30.84 ± 2.43	182.26 ± 4.93	33.36 ± 4.04	186.01 ± 3.47	31.55 ± 2.68	4.38 ± 4.39	137.33 ± 8.4	21.99 ± 2.87	154.43 ± 9.04	29.23 ± 2.63
Mean	**183.26`± 4.01**	**32.47 ± 2.64**	**162.61 ± 4.66**	**28.69 ± 3.01**	**176.43 ± 3.80**	**30.14 ± 2.55**	**20.66 ± 4.34**	**127.62 ± 6.16**	**22.31 ± 2.16**	**128.93 ± 5.53**	**26.39 ± 1.23**

*** Statistically significant difference between means per round (P < 0.05)**

4.4.1.3 Estimated Core Temperature (T_c)

Estimated T_c was recorded during the simulated karate matches and rest periods. The means of the rounds are represented in Table 4.8. The estimated T_c during the fight over all six rounds was 38.0 ± 0.05 °C, with the mean T_c during the one minute recovery period and set rest periods being 38.2 ± 0.08 °C and 38.1 ± 0.06 °C respectively. Significant differences between rounds were reported for all the estimated T_c values calculated, with $P < 0.05$.

Table 4.8: Mean (± SE) estimated core temperature (T_c) during the simulated karate matches and rest periods

Round	Start of Fight*	End of Fight*	Minimum During Fight*	Maximum During Fight*	Peak Through Max – Min*	Mean During Fight*
1	37.783 ± 0.066	38.375 ± 0.105	37.783 ± 0.066	38.375 ± 0.105	0.592 ± 0.057	37.991 ± 0.075
2	37.867 ± 0.036	38.033 ± 0.063	37.867 ± 0.036	38.033 ± 0.063	0.167 ± 0.045	37.928 ± 0.040
3	37.925 ± 0.035	38.100 ± 0.063	37.925 ± 0.035	38.100 ± 0.063	0.175 ± 0.043	37.991 ± 0.050
4	37.975 ± 0.028	38.142 ± 0.066	37.967 ± 0.028	38.142 ± 0.066	0.175 ± 0.048	38.028 ± 0.041
5	38.107 ± 0.065	38.261 ± 0.076	38.061 ± 0.049	38.282 ± 0.074	0.217 ± 0.044	38.141 ± 0.060
6	38.018 ± 0.067	38.082 ± 0.071	38.004 ± 0.048	38.108 ± 0.075	0.101 ± 0.035	38.044 ± 0.056
Mean	**37.946 ± 0.050**	**38.165 ± 0.074**	**37.934 ± 0.044**	**38.173 ± 0.074**	**0.238 ± 0.045**	**38.021 ± 0.054**

Round	Start Of 1-Minute Recovery*	End Of 1-Minute Recovery*	Mean During 1-Minute Recovery*	End Of Rest Period*	Mean During Rest Period*
1	38.425 ± 0.105	38.542 ± 0.112	38.482 ± 0.114	37.883 ± 0.037	38.055 ± 0.048
2	38.050 ± 0.071	38.108 ± 0.075	38.082 ± 0.071	37.925 ± 0.035	38.031 ± 0.047
3	38.108 ± 0.068	38.175 ± 0.079	38.142 ± 0.072	37.975 ± 0.028	38.107 ± 0.051
4	38.183 ± 0.065	38.283 ± 0.073	38.243 ± 0.070	38.183 ± 0.064	38.313 ± 0.070
5	38.272 ± 0.073	38.329 ± 0.083	38.306 ± 0.077	38.084 ± 0.057	38.241 ± 0.080
6	38.108 ± 0.084	38.167 ± 0.116	38.125 ± 0.089	38.280 ± 0.094	38.278 ± 0.088
Mean	**38.191 ± 0.078**	**38.267 ± 0.090**	**38.230 ± 0.082**	**38.055 ± 0.052**	**38.171 ± 0.064**

*** Statistically significant difference between means per round ($P < 0.05$)**

4.4.2 Time- Motion Analysis (TMA)

The following section pertains to the data collected through time motion analysis.

4.4.2.1 Activity Contribution

The following means per athlete and rounds were recorded during the TMA of the respective kumite matches. Tables 4.9 and 4.10 revealed that per athlete, 82.3% of fighting activities can be attributed to setting up the opponent with only 18.06% actual contact (high-intensity, active and passive contact) with the opponents. In addition, 61.06% of the total fighting time can be attributed to the various fighting activities and 38.94% to the stoppages, whether the fight suspensions were due to the referee, medical interventions or stoppages concerning the adjustment of the athletes' attire. As far as the mean values per round are concerned, it can be concluded that 82.48 ± 2.15% of the fight is attributed to the setup of the opponent and 17.72 ± 0.93% to contact with the opponent. Once again, 60.15% is attributed to the various fighting activities and 39.86% to the stoppages. In addition, no significant differences between rounds were found for bouncing/low intensity actions (F=1.05; P=0.54), active contact (F=0.47; P=0.79), and passive contact (F=0.49; P=0.78). There was however, a significant difference found between the means per round for techniques/high intensity actions (F=4.48; P=0.04).

Table 4.9: Activity Contribution per athlete

Athlete	Fighting activity (%- Percentage)								Contact (High-intensity, active & passive contact)	Fighting Activity	Total fight	Activity vs total fight
	Bouncing/Low-intensity actions		Techniques/High-intensity action		Active contact		Passive contact					
1	02:04.2	75.82%	00:12.4	7.57%	00:14.8	9.04%	00:12.4	7.57%	24.18%	03:00.0	04:42.3	63.75%
2	02:25.8	85.22%	00:10.3	6.01%	00:08.3	4.87%	00:06.7	3.89%	14.78%	03:00.0	05:07.8	58.47%
3	02:16.1	82.09%	00:11.9	7.15%	00:11.7	7.03%	00:06.2	3.72%	17.91%	03:00.0	04:02.0	74.38%
4	02:22.9	80.60%	00:11.6	6.54%	00:12.9	7.28%	00:09.9	5.58%	19.40%	03:00.0	05:05.2	58.89%
5	02:13.2	81.07%	00:10.1	6.17%	00:06.2	3.77%	00:14.8	8.99%	18.93%	03:00.0	04:37.4	64.89%
6	02:08.2	73.47%	00:09.3	5.35%	00:23.6	13.52%	00:13.4	7.67%	26.53%	03:00.0	05:39.0	53.10%
7	01:41.5	74.16%	00:08.9	6.53%	00:12.7	9.29%	00:13.7	10.02%	25.84%	03:00.0	05:29.2	54.67%
8	01:54.7	72.54%	00:20.4	12.9%	00:12.5	7.88%	00:10.6	6.68%	27.46%	03:00.0	05:27.8	54.91%
9	02:38.4	89.44%	00:10.5	5.93%	00:04.9	2.77%	00:03.3	1.86%	10.56%	03:00.0	05:05.7	58.89%
10	02:39.9	92.55%	00:07.6	4.40%	00:02.8	1.63%	00:02.4	1.42%	7.45%	03:00.0	05:16.0	56.96%
11	02:40.9	91.88%	00:09.3	5.30%	00:04.9	2.80%	00:00.0	0.02%	8.12%	03:00.0	04:16.0	70.31%
12	02:27.2	88.95%	00:11.5	6.94%	00:01.1	0.66%	00:05.7	3.45%	11.05%	03:00.0	04:43.7	63.45%
Mean	**02:17.7**	**82.32%**	**00:11.2**	**6.73%**	**00:09.7**	**5.88%**	**00:08.3**	**5.07%**	**17.68%**	**03:00.0**	**04:57.7**	**61.06%**

Table 4.10: Mean (± SE) Activity Contribution over 6 Rounds (%- Percentage)							
Fighting Activity	**Rounds**						**Mean %**
	1	**2**	**3**	**4**	**5**	**6**	
Low-intensity/ Bouncing	80.10 ± 2.24	83.78 ± 2.44	81.97 ± 2.81	82.04 ± 2.72	82.95 ± 2.85	84.02 ± 2.12	**82.48% ± 2.15%**
High-Intensity/ Techniques*	6.80 ± 0.51	6.88 ± 0.88	7.52 ± 0.73	6.44 ± 1.43	6.88 ± 0.86	6.66 ± 0.79	**6.86% ± 0.65%**
Active Contact	7.27 ± 1.48	5.15 ± 1.44	6.05 ± 1.69	6.99 ± 2.31	5.27 ± 0.97	5.10 ± 1.32	**5.97% ± 1.28%**
Passive Contact	5.83 ± 1.11	4.18 ± 1.13	4.46 ± 1.73	4.52 ± 1.32	4.68 ± 1.56	5.70 ± 1.78	**4.89% ± 0.87%**
Contact (High-intensity, active and passive contact)	19.90 ± 1.03	16.21 ± 1.15	18.03 ± 1.38	17.95 ± 1.69	16.83 ± 1.32	17.46 ± 1.29	**17.72 ± 0.93**
Total Fighting Activity	~54.5	~63.6	~59.49	~53.49	~62.8	~65.99	**~60.15%**
Stoppages (Referee, Medical, Attire)	~44.5	~36.4	~40.51	~46.51	~37.2	~34.01	**~39.86%**
*** Statistically significant difference between means per round (P < 0.05)**							

Tables 4.11 and 4.12 refer to the mean time spent per activity period as calculated per athlete and per respective round. Table 4.11 illustrates that the quickest mean duration for a high intensity activity period is recorded at 0.65 seconds with a mean value of 0.80 seconds. By contrast, it is clear that the mean duration for a low intensity period ranges from 5.86 seconds to 12.73 seconds with a mean value of 9.48 seconds. The values are represented as seconds and hundredths of a second (ss:00). In addition, the mean duration of the stoppages for the athletes ranged from 9.15 to 38.95 seconds, with a mean per athlete at 17.52 seconds.

Table 4.11: Mean duration of activity period per athlete					
Athlete	**Low-Intensity/ Bouncing**	**High-Intensity/ Techniques**	**Active Contact**	**Passive Contact**	**Stoppages (Referee, Medical, Attire)**
1	7.07	0.81	1.99	1.67	11.61
2	11.76	0.89	1.82	1.22	16.69
3	8.75	0.93	1.95	1.50	9.15
4	11.26	0.97	2.10	1.87	10.22
5	11.26	0.74	1.95	2.38	10.93
6	9.16	0.76	4.70	2.67	15.39
7	6.95	0.78	2.37	1.84	38.95
8	5.86	0.94	2.01	2.31	14.19
9	10.66	0.79	1.46	1.29	12.72
10	12.73	0.65	1.59	1.31	33.81
11	9.92	0.65	1.41	0.04	18.46
12	8.34	0.74	0.45	1.58	18.14
Mean	**9.48**	**0.80**	**1.98**	**1.64**	**17.52**

Table 4.12 shows that the mean duration of a low-intensity period ranged between 8.03 to 11.02 seconds, with a mean duration of 9.55 seconds per round. It can be seen that the high-intensity periods ranged from 0.76 to 0.84 seconds, with a mean of 0.81 seconds, with a mean value of 16.67 seconds attributed to stoppages per round.

Table 4.12: Mean duration of activity period per round

Round	Low-Intensity/ Bouncing	High-Intensity/ Techniques	Active Contact	Passive Contact	Stoppages (Referee, Medical, Attire)
1	8.17	0.83	2.01	1.86	28.02
2	10.29	0.84	1.66	1.78	15.06
3	8.03	0.78	1.87	1.42	15.94
4	11.02	0.82	2.29	1.64	19.40
5	9.77	0.76	1.79	1.49	11.64
6	10.01	0.82	1.95	1.42	9.98
Mean	**9.55**	**0.81**	**1.93**	**1.60**	**16.67**

In addition to the mean durations of the respective activity periods, the mean durations of the effort periods and the stoppage (rest) periods were also calculated per round as well as for all the matches that took place, as represented in Table 4.13. It may be noted that the effort-to-rest ratios ranged from ~1:0.9 to ~2:1 during the respective rounds and revealed a mean ratio of ~1.5:1 per round. Accordingly, the mean ratio as measured across all the matches revealed a value of ~1.4:1.

Table 4.13: Mean effort-to-rest periods per round (ss:00) for all athletes

Round	Effort	Rest	Ratio
1	17.36	12.77	~1.4 :1
2	19.35	10.19	~1.9 :1
3	17.38	11.29	~1.5 :1
4	16.88	19.40	~1 :0.9
5	18.48	11.64	~1.6 :1
6	19.62	9.98	~2 :1
Mean	**18.18**	**12.55**	**~1.5 :1**
All Matches	**18.03**	**12.65**	**~1.4 :1**

4.4.2.2 Scoring techniques

During the simulated karate matches, the means for the number of offensive, defensive and the total techniques per athlete and round were recorded. From tables 4.14 and 4.15 it is evident in the values recorded that most of the athletes had an offensive strategy with a mean offensive value of 1.60 versus a mean defensive value of 1.21. It can also be noted that on average all the athletes scored 2.83 techniques during a fight and 2.65 techniques per round. No significant differences between the means per round were found for offensive techniques (P=0.86), defensive techniques (P=0.96) and total techniques scored (P=0.96) as well as the means recorded between athletes for defensive techniques (P=0.57). Differences were however, observed between the means of athletes for offensive techniques (P=0.01) and total techniques scored (P=0.01).

Table 4.14: Mean values for offensive, defensive and the total techniques per Athlete

Athlete	Offensive Techniques*	Defensive Techniques	Total Techniques*
1	2.48	0.99	3.49
2	1.82	1.82	3.66
3	1.16	0.83	1.99
4	1.98	0.83	2.83
5	1.57	1.64	3.21
6	0.59	0.77	1.37
7	0.72	0.74	1.47
8	3.14	1.99	5.15
9	1.32	0.99	2.33
10	1.16	1.66	2.83
11	0.83	1.16	1.99
12	2.48	1.16	3.66
Mean	**1.60**	**1.21**	**2.83**

*** Statistically significant difference between means per athlete (P < 0.05)**

Table 4.15: Mean values for offensive, defensive and the total techniques per Athlete			
Round	**Offensive Techniques**	**Defensive Techniques**	**Total Techniques**
1	1.55	1.26	2.88
2	1.40	1.10	2.56
3	1.18	1.26	2.49
4	1.77	1.02	2.88
5	1.34	1.31	2.70
6	1.35	0.96	2.37
Mean	**1.43**	**1.15**	**2.65**
* Statistically significant difference between means per round (P < 0.05)			

The data concerning the quantity of left- and right-handed techniques were also collected as well as the techniques executed by the upper and lower extremities. The results are displayed in Table 4.16 in terms of the technique counts for winners and losers. It indicated that approximately 35.57% of all the techniques scored can be attributed to left-handed techniques and 64.42% to right-handed, where 52.33% of the points were scored with the upper limbs and 47.67% with the lower limbs.

Table 4.16: Technique counts for winners and losers						
	LEFT	**%**	**RIGHT**	**%**	**TOTAL**	**%**
Winners	50	38.76%	79	61.24%	129	65.46%
Losers	20	29.41%	48	70.59%	68	34.54%
Total	**70**	**35.57%**	**127**	**64.42%**	**197**	
	UPPER-LIMB	**%**	**LOWER-LIMB**	**%**	**TOTAL**	**%**
Winners	62	48.06%	67	51.94%	129	65.46%
Losers	41	60.29%	27	39.71%	68	34.54%
Total	**103**	**52.33%**	**94**	**47.67%**	**197**	

A fully detailed, descriptive discussion of all the results reflected in Chapter 4 will follow in Chapter 5.

CHAPTER 5: DISCUSSION

The aim of this study was to conduct a time-motion analysis (TMA) to determine the characteristics of karate kumite matches and to determine the physiological demands imposed on the athlete during competition with regards to the body's energy systems, heart rate response to the fight situation, breathing rates and core temperature regulation. To the researcher's knowledge, studies such as this particular one are limited in both frequency and scope.

The results as depicted in chapter 4 will be discussed under two main headings: (1) physiological variables and (2) TMA, where, firstly, group characteristics will be discussed, followed by the profiles of individual athletes.

5.1 PHYSIOLOGICAL VARIABLES

The following discussions pertain to the physiological variables that were measured.

5.1.1 Somatotyping

Referring to chapter 2, a review article by Chaabène *et al*. (2012:829-843) considered various anthropometrical characteristics recorded during several different studies, and the similarities among them. The main findings of Chaabène *et al*. were that the mean weight and percentage body fat for male participants ranged from 66.8 ± 8.9 kg and 7.5% for top-level Japanese karatekas (Imamura *et al*., 1997:9-13) to 86.1 ± 8.25 kg and 16.8% for elite- level Polish karatekas (Sterkowicz-Przybycien, 2010:195-201). However, the French international-level team had a mean 13.7% body fat and mean weight of 71.9 ± 11.4 kg (Ravier *et a*l., 2005:810-817). In the current study the participants had a mean weight of 68.6 ± 3.2 kg, mean body fat percentage of 8.52 ± 0.5 % and mean height of 176.9 ± 2.71 cm. It is evident that South African and Japanese karatekas have similar anthropometrical characteristics.

5.1.2 High intensity activity and VO_{2max}

The main findings of this study suggest that a karate kumite match can be characterized as a high-intensity activity with regards to physiological variables, where athletes are subjected to maximal cardiovascular responses. According to previous research, an athlete's aerobic fitness is an important factor in coping with high-intensity intermittent exercise, as this relates to the athlete's ability to recover within a match as well as between matches (Glaister, 2005:757-77).

As stated in chapter 2, the VO_{2max} measurements of national and international male karate athletes range from 47.8 ± 4.4 to 61.4 ± 2.6 ml/kg/min (Ravier *et al*., 2009:687-694). It may be noted that during the graded maximal effort test (VO_{2max}) the research group's mean HR_{max} and VO_{2max} were 187.5 ± 2.9 bpm and 54.76 ± 1.1 ml/kg/min respectively, with the HR_{max} ranging from 172 to 209 bpm and VO_{2max} from 48.3 to 60.7 ml/kg/min. These recordings were similar to the above-mentioned ranges and values reported in a recent review of the physical and physiological profile of elite karate athletes (Chaabène *et al*., 2012:829-843). Athletes also, in some cases, reached a higher HR_{max} than what was achieved in the graded maximal effort testing, during the simulated kumite matches.

5.1.3 Energy system contribution

The findings regarding the energy system contribution will be discussed first in group and round format, followed by individual variances.

5.1.3.1 Group and round findings with regards to energy system contributions

Iide *et al*. (2008:839-844) emphasized that it is important, especially for sport nutritionists, to be aware of the energy expenditure during competition in order to advise athletes about the consumption of adequate energy from a variety of foods to avoid injuries and problems that may arise due to nutritional deficiencies. Referring to tables 4.1, 4.2 and 4.3, which represent the percentage of time spent within each energy system during the simulated fights as established by the graded maximal effort test (VO_{2max}), the following remarks can be made.

According to the mean values calculated in table 4.3, the athletes made very little use of the oxidative lipolytic system during the first three rounds and mainly performed within the oxidative glycolytic and anaerobic systems, with noticeable time spent in the lactate zone. As the rounds progressed, the contribution from the oxidative lipolytic and oxidative glycolytic systems became more dominant and the anaerobic and lactate systems became less prominent, which is pertinently observed in the 5th and 6th rounds where the lactate contribution dropped from 16.85% to approximately 5%. This could be due to the adaptation of a more conservative fighting style, with an increasing percentage of low-intensity fighting activity which contributed to setting up the opponent and to a reduction in the actual contact with the opponent. (Refer to table 4.10, page 58.) This finding is in accordance with a statement by Glaister (2005:757-777) that an increase in the aerobic contribution can occur because of the systems' responsibility for restoring homeostasis during periods of low-intensity efforts.

Campos *et al.* (2012:1221-1228) reported that karate has a very high aerobic contribution in relation to the anaerobic and lactate systems, with values of 66 ± 6% for aerobic and 34 ± 4% for anaerobic and lactate. In contrast with this finding, the mean values per round observed in this research study showed that 55.45% can be attributed to the aerobic (oxidative) systems and 44.55% to the combined anaerobic and lactate systems.

5.1.3.2 Individual variances with regards to energy system contributions

If individual rounds and athletes are considered, some remarkable characteristics come to light.

It may be noted in table 5.1, that athlete 2 displayed no oxidative lipolytic activity during the first four rounds, but did show a very high lactate activity during both round 1 and 4. What makes this finding noteworthy is that in both rounds 1 and 4 the same opponent was fought and the increase in lactate activity could be due to the high calibre of the opponent and the increased intensity of the fight. The athlete also spent minimal time in the anaerobic zones during rounds 1 & 4, with values totalling 9.86% and 10.11% respectively. In round 5, this athlete used mostly the oxidative lipolytic (23.64%) and oxidative glycolytic (67.61%) systems. However, in the last round, the athlete switched his reliance on the type of energy system again to mostly oxidative glycolytic (60%) and anaerobic (23.83%).

Table 5.1: Athlete 2 energy system analysis

Round	ENERGY SYSTEMS									TIME
	OXIDATIVE LIPOLYTIC	%	OXIDATIVE GLYCOLYTIC	%	TOTAL AEROBIC	Anaerobic	%	Lactate	%	
1	**00:00.0**	**0.00%**	01:56.0	32.68%	32.68%	00:35.0	**9.86%**	03:24.0	**57.46%**	05:55.0
2	**00:00.0**	**0.00%**	01:36.0	35.42%	35.42%	02:02.0	45.02%	00:53.0	19.56%	04:31.0
3	**00:00.0**	**0.00%**	02:07.0	49.03%	49.03%	02:12.0	50.97%	00:00.0	0.00%	04:19.0
4	**00:00.0**	**0.00%**	02:05.0	45.13%	45.13%	00:28.0	**10.11%**	02:04.0	**44.77%**	04:37.0
5	**01:40.0**	**23.64%**	**04:46.0**	**67.61%**	91.25%	00:37.0	8.75%	00:00.0	0.00%	07:03.0
6	00:38.0	16.17%	**02:21.0**	**60.00%**	76.17%	**00:56.0**	**23.83%**	00:00.0	0.00%	03:55.0
Mean	**00:23.0**	**6.64%**	**02:28.5**	**48.31%**	**54.95%**	**01:08.3**	**24.75%**	**01:03.5**	**20.30%**	**05:03.3**

Considering athlete 7, table 5.2 shows similar responses, with zero to limited oxidative lypolytic activity during rounds 1 to 3, but very high lactate responses especially in rounds 1 and 4. However, the athlete withdrew from the study after round 4 because of injury. It is the opinion of the researcher that the injury could have been caused by the premature elevated use of the lactate energy system. Elevated lactate levels are indicative of very high-intensity activity, which could have led to premature fatigue or acidosis (Jansen van Rensburg, 2010:135).

Table 5.2: Athlete 7 energy system analysis										
Round	ENERGY SYSTEMS									TIME
	OXIDATIVE LIPOLYTIC	%	OXIDATIVE GLYCOLYTIC	%	TOTAL AEROBIC	ANAEROBIC	%	LACTATE	%	
1	**00:00.0**	**0.00%**	00:11.0	3.62%	3.62%	00:35.0	11.51%	04:18.0	**84.87%**	05:04.0
2	**00:16.0**	**6.13%**	00:39.0	14.94%	21.07%	02:27.0	56.32%	00:59.0	22.61%	04:21.0
3	**00:05.0**	**1.24%**	00:31.0	7.67%	8.91%	04:46.0	70.79%	01:22.0	20.30%	06:44.0
4	00:48.0	15.09%	00:12.0	3.77%	18.86%	01:12.0	22.64%	03:06.0	**58.49%**	05:18.0
5	Withdrew									
6	Withdrew									
Mean	**00:17.3**	**5.62%**	**00:23.2**	**7.50%**	**13.12%**	**02:15.0**	**40.32%**	**02:26.3**	**46.57%**	**05:21.7**

It is evident that in some cases athletes show minimal reliance on particular energy systems. This particular trend is visible in athlete 5, as represented in table 5.3. The athlete predominantly uses the anaerobic system for energy contribution, with minimal reliance on the oxidative glycolytic energy system, totalling values of 1.66%, 1.08% and 1.77% in rounds 1, 3 and 4 respectively. The athlete, however, withdrew from round 5 as a result of athlete 7's withdrawal after round 4. As a result of the extended rest period for athlete 5, the oxidative lipolytic system became dominant in round 6. In concordance with group statistics, as depicted in table 4.3, athlete 5 showed a significant decrease in the percentage contribution of the lactate system during the last round.

Table 5.3: Athlete 5 energy system analysis										
Round	ENERGY SYSTEMS									TIME
	OXIDATIVE LIPOLYTIC	%	OXIDATIVE GLYCOLYTIC	%	TOTAL AEROBIC	Anaerobic	%	Lactate	%	
1	00:12.0	3.99%	00:05.0	**1.66%**	5.65%	04:37.0	**92.03%**	00:07.0	2.33%	05:01.0
2	00:11.0	4.18%	00:49.0	18.63%	22.81%	02:41.0	**61.22%**	00:42.0	15.97%	04:23.0
3	00:33.0	11.83%	00:03.0	**1.08%**	12.91%	02:56.0	**63.08%**	01:07.0	**24.01%**	04:39.0
4	01:04.0	28.32%	00:04.0	**1.77%**	30.09%	02:26.0	**64.60%**	00:12.0	**5.31%**	03:46.0
5	Withdrew									
6	03:35.0	73.88%	00:23.0	7.90%	81.78%	00:53.0	18.21%	00:00.0	0.00%	04:51.0
Mean	**01:07.0**	**24.44%**	**00:16.8**	**6.21%**	**30.65%**	**02:42.6**	**59.83%**	**00:25.6**	**9.52%**	**04:32.0**

Table 5.4 presents the data for athlete 9 who showed tendencies similar to those of previously mentioned athletes, with limited reliance on the anaerobic system, as is evident in rounds 2, 4, 5 and 6. In contrast with group data as depicted in table 4.3, this particular athlete showed a marked increase in the reliance on the lactate system during the last three rounds. This could be due to the calibre of matches

fought in rounds 4, 5 and 6, but definitely shows contrasting values to those of the rest of the group and tactics explained previously. This reliance could also be due to the decrease in the rest periods between rounds, 3-4 (12 minutes), 4-5 (7 minutes), 5-6 (12 minutes), as his mean $HR_{reserve}$ decreased from 51bpm in the first three rounds to 16bpm in the last three rounds. With regards to his fighting style, his opponents provided more rigorous opposition the second time round, resulting in the athlete becoming frustrated with himself for not scoring the techniques becoming more aggressive as a result.

Table 5.4: Athlete 9 energy system analysis

Round	ENERGY SYSTEMS									TIME
	OXIDATIVE LIPOLYTIC	%	OXIDATIVE GLYCOLYTIC	%	TOTAL AEROBIC	Anaerobic	%	Lactate	%	
1	02:34.0	36.58%	03:23.0	48.22%	84.8%	00:47.0	11.16%	00:17.0	4.04%	07:01.0
2	00:53.0	23.35%	02:15.0	59.47%	82.82%	00:13.0	**5.73%**	00:26.0	11.45%	03:47.0
3	00:59.0	20.77%	02:36.0	54.93%	75.7%	00:24.0	8.45%	00:45.0	15.85%	04:44.0
4	01:05.0	20.00%	01:54.0	35.08%	55.08%	00:00.0	**0.00%**	02:26.0	**44.92%**	05:25.0
5	01:18.0	28.47%	01:58.0	43.07%	71.54%	00:15.0	**5.47%**	01:03.0	**22.99%**	04:34.0
6	01:17.0	29.96%	01:40.0	38.91%	68.87%	00:12.0	**4.67%**	01:08.0	**26.46%**	04:17.0
Mean	**01:21.0**	**26.52%**	**02:17.7**	**46.61%**	**73.14%**	**00:18.5**	**5.91%**	**01:00.8**	**20.95%**	**04:58.0**

Again referring to table 4.2, which represents a summary of each athletes' mean percentage of time spent within each energy zone, it can be noted that 50% of the athletes spent less than 10% of all their fights in the oxidative lipolytic zone. 25% of the athletes also spent less than 10% in the oxidative glycolytic zone, where 41.6% of them had very low anaerobic system contributions during their fights. It can also be noted that athlete 4 never fully utilized the lactate zone during any of the rounds, however athletes 1, 3 and 7 predominantly operated within the lactate zone. It is thus important to note that athletes uniquely respond to fairly similar situations, consequently, the use of profiling might obscure individual variability.

5.1.4 Heart rate (HR)

HR responses will be discussed in a particular order dictated by the HR recording during the graded maximal effort test (VO_{2max}) and the simulated kumite matches, followed by the HR responses during the 1-minute recovery and set rest periods.

5.1.4.1 Heart rate during the graded maximal effort testing and kumite fights

The mean HR during the simulated kumite matches was 169.26 ± 4.37 bpm with a HR_{max} of 190.79 ± 3.48 bpm per round, which represents approximately 90.57% of the HR_{max} recorded during the VO_{2max} test and 88.81% of the HR_{max} recorded during the simulated fights. This particular finding agrees with results from a recent study by Tabben *et al*. (2013:263-271), where the competitors performed at 91 ± 3% of their HR_{max}.

However, the HR_{max} recorded during the graded maximal effort test (VO_{2max}) was lower than the values recorded during the various kumite rounds (187.5 < 190.8 bpm). It is evident that the athletes exerted a seemingly above maximal effort during the kumite matches and the HR_{max} remained fairly stable across the various rounds. These findings correspond with a study by Toyoshima *et al*. (2003:31-38), where higher HR responses were elicited during five types of karate exercises when compared with HR measured using a cycle ergometer or treadmill. The mean HR however, decreased from 175.46 ± 3.8 bpm in round 1 to 160.36 ± 5.48 bpm in round 6 ($F=7.05$; $P=0.03$), where the difference between the HR_{max} and HR_{min} increased as the rounds progressed with a mean difference of 70.68 ± 6.94 bpm per round ($F=1.81$; $P=0.28$). As observed, a significant difference was found between means per round regarding the mean HR during the fight ($P < 0.05$) but not between the means calculated for the HR difference max-min ($P > 0.05$).

Regarding the mean HR values of rounds 4 to 6, it may be noted that there was a considerable decrease from round 3 to 4 and from round 4 onwards, as depicted in table 4.5. This decrease is possibly the result of the athletes fighting the same opponent for a second time. The athletes tend to be more reserved in the second fight with the same opponent, as the athletes are now more familiar with the fighting style of the opponent. Athletes also tend to fight more conservatively as the rounds progressed perhaps because the importance of winning became more apparent. The athletes enter a state where they want to be assured of a score. Making a mistake can result in a counter attack and the added pressure to retaliate. The urge to retaliate as quickly as possible could give the opponent another opportunity to counter attack, which would exert even more pressure, and the expenditure of unnecessary extra energy on hunting points. It is with this mind-set that the athletes seem to become more conservative in their fighting as the rounds progress.

A similar decrease from round 3 onwards was observed in the minimum HR (HR_{min}) values during the fight, with values decreasing from 128.08 ± 7.26 bpm in round 3 to 117 ± 7.45 bpm in round 4 and then to 112.18 ± 5.99 bpm in round 6, as indicated in table 4.5. The same explanation that was previously mentioned with regards to the mean HR values per round may be given for this finding. The athletes become more reserved in their fighting styles by utilizing more low-intensity bouncing activities and minimizing contact with their opponent, thus lowering the rate of fatigue and resulting in a lower HR_{min} value.

When referring to the HR values at the end of the fight, it was evident that there was a substantial drop from round 4 to 5, with values dropping from 184.83 ± 4.29 bpm to 168.61 ± 7.96 bpm, respectively. It is the researcher’s opinion that this variance is due to the athletes revealing a more defensive attitude when regarding the techniques that were utilized and an increase of low-intensity activity and decrease of contact with the opponent. A decrease of the mean durations of the various fighting activity periods were also observed, which in turn, lowers the intensity level of the round.

5.1.4.2 Heart rate during 1-minute recovery and set rest periods

The mean HR values during the 1-minute recovery and rest periods increased as the rounds progressed. During the 1-minute recovery period taken directly after each round, the mean HR increased from 161.73 ± 4.43 bpm in round 1 to 186.01 ± 3.47 bpm in round 6 with a mean HR of 176.43 ± 3.8 bpm per round. However, no significant differences were observed among the means with $P > 0.05$. The findings are represented in tables 4.6 and 4.7 (pages 54 and 55).

Regarding the heart rate reserve calculated as the HR at the end of the fight minus the HR at the end of the 1-minute recovery period, it may be noted that the mean $HR_{reserve}$ per round was approximately 20.66 ± 4.34 bpm and 30.28 ± 5.57 bpm per athlete. A decrease in these values could be observed as the rounds progressed. These findings correlate with the difference in resting periods between rounds allowing for progressively less time to recover between fights. The various resting periods were calculated based on the average times between rounds as in an official competition (Tabben *et al*., 2013:265). The resting periods for this study are presented in table 5.5.

Table 5.5: Duration of recovery and rest periods in between rounds

Rounds	Recovery period (seated position)	Set rest periods	Total rest duration
1-2	1 minute	21 minutes	22 minutes
2-3	1 minute	16 minutes	17 minutes
3-4	1 minute	11 minutes	12 minutes
4-5	1 minute	6 minutes	7 minutes
5-6	1 minute	11 minutes	12 minutes
6+	1minute	3 minutes	4 minutes

However, the $HR_{reserve}$ values calculated are surprisingly low relative to the ideal value of 50-60 bpm (Edwards & Robinson, 2004:36). As observed in table 4.6 (page 54), only one athlete managed to reach the desired value with a mean $HR_{reserve}$ of 58 bpm. Thus, it seems that 91.7% of the athletes have a limited ability to recover fully after a high-intensity bout. This might be due to the type of conditioning executed with this group of athletes in the months leading to the research study. On the other hand, the mean HR during the set rest periods increased from 113.5 ± 3.45 bpm to 154.43 ± 9.04 bpm (F=14.54; P=0.06) as represented in table 4.7 (page 55). This increase in values per round is also due to the difference in duration of the set rest periods as the rounds progressed, as mentioned previously. Therefore, it is imperative to remember that the time period between rounds in official competitions is not fixed but depends on the number of contestants and the total fighting time, including stoppages. In accordance with this notion, the researcher strived to conduct this study as realistically as possible, with conditions closely resembling an official competition situation.

Individual variability was also observed among the athletes, where 2 of the 12 athletes demonstrated abnormally high HR responses at the end of the set rest period in relation to the other athletes, as depicted in table 4.6 (page 54). Athletes 4 and 8 showed values of 153.80 ± 6.96 where athlete 8 showed values of 164.57 ± 7.38 at the end of the set rest period. This is in contrast with the mean HR which is calculated at 127.45 ± 7.57. Possible reasons for these observations include poor aerobic fitness levels causing an inability to recover quickly after a high-intensity bout, or the presence of stress hormones released during the fight which may remain elevated during the rest period. This may also keep heart rate values elevated. Another possibility is that the athlete utilized the set rest periods for active participation for the next round, although this is highly unlikely as conditions were standardized for all athletes.

5.1.5 Breathing rate (BR)

The findings regarding the breathing rate will be discussed in a format similar to the heart rate responses. The simulated kumite matches will be discussed first, followed by the responses during the 1-minute recovery and set rest periods.

5.1.5.1 Breathing rate during the graded maximal effort testing and kumite fights

During the fight the mean BR per round was 28.81 ± 1.19 breaths/m and showed a steady reduction from 32.13 ± 0.98 breaths/m in round 1 to 24.21 ± 1.3 breaths/m in round 6 (F=15.43; P=0.001). A decrease was also observed for the BR_{max} from round 4 to 6. This finding may be the result of the athletes utilizing more low-intensity actions in rounds 5 and 6 than in round 4, with calculations at 82.04 ± 2.72% in round 4 and 82.95 ± 2.85% and 84.02 ± 2.12% in rounds 5 and 6, respectively. Athletes also scored fewer techniques during the last two rounds which is in accordance with the high energy contribution by the aerobic systems during these respective rounds, with round 5 at 75.63 % and round 6 at 65.94%. As previously discussed with regard to the HR values during the fight, the decrease in BR may be due to an increasingly conservative fighting style as the rounds progressed.

Table 4.4 (page 52) shows that per athlete the BR on average decreased from the start of the fight to the end of the fight, with values of 21.79 ± 2.96 and 14.71 ± 2.3 breaths/m, respectively. This decrease is due to the athletes' attempt to regain control over the body's physiological functions in order to relax, slow down the HR and recover faster. However, the mean of the athletes' maximum BR recorded during the fight was much higher at 40.41 ± 2.02 breaths/m. It can be established that the maximum BR occurs during the high-intensity actions of the fight and not throughout the entire fight, as the mean BR during the fight was calculated at 28.66 ± 1.85 breaths/m per athlete.

5.1.5.2 Breathing rate during 1-minute recovery and set rest periods

The mean BR values recorded during the 1-minute recovery period remained fairly stable across the rounds with a mean BR of 30.14 ± 2.55 bpm (F=0.58; P=0.72), refer to table 4.7 (page 55). However, there was a dramatic decrease from round 4 to 5 and again an increase from round 5 to 6. As previously stated, round 5 was characterised as a lower-intensity round with less actual contact with the opponent. This round also had the largest aerobic contribution, which in turn resulted in a lower HR and BR. The increase from round 5 to 6 is thus, due to the slight increase in contact with the opponent, and a corresponding decrease of the aerobic contribution. These findings are also in accordance with the fact that round 6 was the final round and that the athletes no longer needed to prepare for a subsequent match.

During the additional set rest periods, the mean BR appeared to follow the same trend as the mean HR values, increasing from round to round with a mean BR at 26.39 ± 1.23 bpm per round (F=4.47; P=0.06). This finding is in accordance with the duration of the rest periods between rounds as previously mentioned in the discussion of the mean HR values. It can then be established that these physiological variables (HR and BR) are closely correlated during a kumite competition.

5.1.6 Estimated Core temperature

According to Moran and Mendal (2002:879-885) the proper functioning of the human body is dependent on the maintenance of a body T_c between 36.5 to 38.5°C and the body's systems start to malfunction when the T_c is outside this range. For the duration of this study, the estimated T_c was calculated per round with a mean T_c at 38.021 ± 0.054°C during the fight (F=8.50; P=0.02), 38.23 ± 0.082°C during the 1-minute recovery period (F=9.00; P=0.02) and 38.171 ± 0.064°C during the set resting periods (F=7.35; P=0.02), refer to table 4.8, page 56. These recordings are substantiated by Sessler's statement that the normal body core temperature remains approximately 37 ± 1°C regardless of the environmental conditions

(2014:25-31). It can thus be established that the estimated T_c remained constant throughout the study with little variance, and that the values remained within the guidelines provided by Moran and Mendal (2002: 879-885).

5.2 TIME-MOTION ANALYSIS (TMA)

The results referring to the TMA conducted during this study will be discussed according to the athletes' activity contributions during the respective matches as well as the characteristics regarding the techniques scored.

5.2.1 Activity Contribution

Regarding the TMA, it was evident that the percentage of time spent on low-intensity activities or bouncing, increased slightly as the rounds progressed, from 80.1 ± 2.24% in round 1 to 84.02 ± 2.12% in round 6 (F=1.05; P=0.54), as shown in table 4.10 (page 58). This increase can be correlated with the importance of winning as the competition approached its conclusion. As previously stated, the athletes will enter a state of absolute assurance of a score and will not attempt an attack prematurely to avoid the possibility of a counter attack. Thus, it is undeniably vital to have the appropriate set-up of the opponent before attempting a technique. In accordance with this finding, the high-intensity activities or techniques attempted, and the percentages contributing to active contact decreased slightly from round 1 to 6, from 6.8 ± 0.51% to 6.66 ± 0.79% for high-intensity activities (F=4.48; P=0.04) and 7.27 ± 1.48% to 5.1 ± 1.32% for active contact (F=0.47; P=0.79), respectively. The remainder of the fighting activities can be attributed to passive contact actions where the athletes are standing chest to chest and not attempting any technique, or are being thrown. There seemed to be a general increasing tendency of these passive activities across the rounds as the athletes approached the final match. This finding can be attributed to the athlete's respect for the opponent's capabilities, and preferring to avoid working the clinch scenario, but rather electing to break and start the setup again. However, this increase can also be the result of attempts at time wasting, with every attempt resulting in either a stoppage or a break and re-setup of the opponent.

The current study also revealed that the mean effort periods during the kumite match were ~18 seconds while the mean stoppage intervals were ~12 seconds, resulting in an effort-to-rest ratio of ~1.5:1. In accordance with these findings, Beneke *et al.*(2004:518-523) also reported the average effort periods during the karate matches to be ~18 seconds, however they revealed an average stoppage time of ~9 seconds, concluding an effort-to-rest ratio of 2:1.

The present study catalogued the high-intensity action durations, ranging from 0.49 to 1.29 seconds with a mean of 0.76 seconds, resulting in a high-intensity-to-rest ratio of ~1:16. The above mentioned conclusions contrast a recent study by Chaabène *et al.* (2014:302-308), where an action-to-rest ratio of ~1:1.5 and a high-intensity-action-to-rest ratio of ~1:11 was reported. In addition to the high-intensity-to-rest and activity-to-rest ratios, a high-intensity-to-low-intensity ratio of ~1:12 was calculated as well as a contact-to-low-intensity ratio of 1:~4.6.

5.2.2 Scoring techniques

As far as scoring techniques are concerned, it was evident that more offensive techniques were scored throughout the fights (~52%), as shown in table 4.11 (page 58). However, the defensive techniques that were scored were of high scoring value, specifically two or three points, resulting in the fact that approximately 48% of all points scored were attributed to defensive techniques.

Referring to table 4.13 (page 59) regarding the ratio of scored techniques between the left and right side, as well as the techniques scored by the upper and lower extremities, it was clear that approximately 64% of all the scoring techniques were scored by the right side. Regardless of the winners and losers, this finding would be the result of the clear-right handed dominance of the subject group. However, athletes 2, 8, 11 and 12 had a more equal spread of their techniques with regards to left- and right-sided techniques scored. Regarding the techniques scored by the upper and lower limbs, previous research by Chaabène *et al.* (2014:24) showed that ~73% of all the techniques scored were by the upper limbs and only ~27% by the lower extremities. In the present study, it may be noted that there was a fairly equal distribution, with approximately 52% of techniques scored by the upper limbs and 48% by the lower limbs, indicating that with regard to their techniques, the athletes are well rounded. Nonetheless, the winners surprisingly scored more points from lower limb techniques (~52%), demonstrating their superior technical abilities during the fights, as these techniques mainly consist of various kicks and take downs, resulting in a higher point score.

The following and final chapter, chapter 6 will conclude the study with a summary of the findings as well as offering various recommendations regarding future training and testing protocols.

CHAPTER 6: CONCLUSION

6.1 INTRODUCTION

The concluding chapter to this research study refers to the deductions derived from the study and aims to provide guidelines for developing specific training programs for athletes, coaches and fitness specialists, as well as providing recommendations regarding future research in this field.

The objective of this study was to identify the various physiological demands placed on the athlete during a simulated competition situation. This was done by conducting a TMA to determine the characteristics of the karate-kumite matches and, in turn, outlining the physiological demands imposed on the athlete during competition with regards to the body's energy systems, heart rate response to the fight situation, breathing rates and core temperature regulation.

In addition, it was hypothesized that the majority of actions in the kumite matches would ensue from the oxidative glycolytic and anaerobic energy systems, with the maximum heart rate achieved during a fight being similar to the maximum heart rate achieved during the graded exercise tests. It was also hypothesized that there would be a dominance in upper-limb attack techniques.

6.2 CONCLUSIONS

The following conclusions may be drawn from findings of this study in relation to the stated objectives and hypothesis.

ANTHROPOMETRY: The research participants revealed similar anthropometrical characteristics to a study conducted on Japanese karate athletes (Imamura *et al*. 1997: 9-13). However, this research study has shown contrasting values to the findings found by the Polish karate athletes (Sterkowicz-Przybycien, 2010: 195-

201). It was found that the average karate athlete of this particular study has a height of 176.9 ± 2.71 cm, a weight of 68.6 ± 3.2 kg and a fat % of 8.52 ± 0.5%.

ACTIVITY: With respect to the activity contributions during the kumite matches, it is evident that a high percentage of time (~82.5%) was spent on low-intensity or bouncing actions and only ~17.5% on contact with the opponent. In addition to the activity contributions, there seemed to be a close distribution of upper- and lower-limb techniques scored at ~52% attributed to upper-limb techniques, and ~48% to techniques applied by the lower-limbs. Thus, according to these values, the hypothesis that upper-limb techniques would dominate can be regarded as true, although the distribution between upper and lower limbs was very similar.

With regard to the energy systems utilized during the kumite matches, as was hypothesized, the majority (57.82%) of actions in the kumite fights stemmed from the oxidative glycolytic and anaerobic energy systems. The data shows that the athletes made very little use of the oxidative lipolytic system during the first three rounds. However, as the rounds progressed, the contribution from the oxidative lipolytic and oxidative glycolytic systems become more dominant. A relationship of 55.45% aerobic and 44.55% combined anaerobic and lactate system activity was established over the course of the simulated kumite competition.

The athletes exerted a seemingly above maximal effort during the kumite matches as the HR_{max} during the kumite matches were higher than what was recorded during the graded maximal effort testing (187.5 < 190.8 bpm), thus disproving the hypothesis set. The HR_{max}, however, remained fairly stable across the various rounds at ~191 bpm with a mean HR frequently distributed at 88 to 91% of the HR_{max}. It was also established that the HR and BR are closely correlated during physical activity. However, T_c remains a fairly stable variable irrespective of the environmental conditions.

The main findings of this study suggest that a karate-kumite match can be characterized as a high-intensity activity with regard to physiological variables, where athletes are subjected to maximal cardiovascular responses. It is thus advisable that coaches remain focussed on the technical and tactical aspects of training and that conditioning specialists focus more specifically on improving the athletes' ability to sustain the high-intensity activities through several interval training protocols of various durations during the conditioning sessions. However, it remains important to remember that each athlete is unique and that each athlete will respond differently to fairly similar situations. Thus, by implementing various interval durations, the conditioning specialists will be able to modify each athletes' energy system contribution individually.

6.3 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

Throughout the course of this research study, the researcher established certain limitations and recommendations for the purpose of enhancing further studies:

1. Include more test subjects from various regions across the country.
2. Conduct a similar study on more specific subject groups, for example female subjects, only junior or cadet age groups, weight divisions etc.
3. Conduct related studies to create a larger database to assist in the accurate profiling of elite karatekas.
4. Make use of more specialised equipment such as a mobile VO_{2max} analyser to measure VO_{2max} during fighting activities.
5. Acquire data from official karate competitions.
6. Do blood lactate testing during VO_{2max} and kumite fights and relate back to aerobic and anaerobic heart rate zones to make training guidelines even more specific.

Given the fact that only a relatively small amount of published literature on the physiological responses during karate-kumite matches exists, it is likely that there is still much to learn and significant benefit to be gained from performance analysis research. It is important that basic notational analysis of WKF karate continues so as to thoroughly document the physical demands of the sport at all levels and categories, including men, women and youth. Increased knowledge of the different fitness components needed, skilled coaches and conditioning specialists will finally be able to assist in the development of optimal training programs according to the athlete's strengths and weaknesses. Subsequently, specific conditioning interventions to assist in the performance enhancement of karate athletes could also flow from an expanding body of knowledge.

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APPENDICES

APPENDIX A – ETHICAL CLEARANCE

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HUMANITIES
GEESTESWETENSKAPPE

1 August 2014

Miss E. Le Roux
Department of Exercise and Sport Science
UFS

Ethical Clearance Application: Physiological demands and time-motion analysis of simulated elite karate kumite matches

Dear Miss Le Roux

With reference to your application for ethical clearance with the Faculty of the Humanities, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence, is:

UFS-HUM-2014-43

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension in writing.

We request that any changes that may take place during the course of your research project be submitted in writing to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours sincerely,

Katinka de Wet

Ethics Committee (Faculty of the Humanities)

Copy: Mrs Charné Vercueil (Research Co-ordinator: Faculty of the Humanities)

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APPENDIX B – PERMISSION TO CONDUCT RESEARCH (FSSSI)

sport, arts & culture
Department of
Sport, Arts and Culture
FREE STATE PROVINCE

Free State Sport Science Institute [FSSSI]

Bloemfontein

South Africa

Tel +2751 407 3571

To whom it may concern

Miss E. le Roux
Student at the University of the Free State

RE: APPROVAL OF RESEARCH PROJECT: Magister Artium

PHYSIOLOGICAL DEMANDS AND TIME-MOTION ANALYSIS OF SIMULATED ELITE KARATE KUMITE MATCHES.

As part of the collaboration agreement between the University of the Free State and the Free State Sport Science Institute[FSSSI] , permission is granted to Elsabe le Roux (Student at the University of the Free State), to conduct an empirical research study at the FSSSI in fulfillment of the degree Magister Artium (Human Movement Science).

Mr. Jan du Toit
(Free State Sport Science Institute)

2 July 2014

Physical address: 4 CNR President Brandt & Victoria Street, Oranjesig, Bloemfontein, 9301
Postal address: P.O. Box 20015, Willows, Bloemfontein, 9300
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APPENDIX C - PERMISSION TO CONDUCT RESEARCH (COACH)

Telephone: 0824556629 Email: spookleroux@gmail.com Enquiries: Ian le Roux	FREE STATE KARATE FEDERATION	Free State Karate Federation Bloemfontein 9301 01 July 2014

To whom it may concern

RE: APPROVAL OF ATHLETE PARTICIPATION

PHYSIOLOGICAL DEMANDS AND TIME-MOTION ANALYSIS OF SIMULATED ELITE KARATE KUMITE MATCHES

I, Ian le Roux hereby give permission to Elsabe le Roux (student of the University of the Free State) to utilize the athletes of the Free State Karate High Performance Program for her study in fulfilment of the degree Magister Atrium (Human Movement Science).

Ian le Roux
Head Coach Free State Karate High Performance Program

APPENDIX D – CONSCENT TO PARTICIPATE IN RESEARCH

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS
UV

Skool vir Aanvullende Gesondheidsberoepe (SAGB)/School for Allied Health Professions (SAHP), UV/UFS, Bloemfontein 9300

INFORMED CONSENT

Physiological demands and time-motion analysis of simulated karate kumite matches in elite athletes

Herewith I, __________________, give consent that the information gathered from the testing sessions may be used for this research project. It is my understanding that the information gathered through the physical testing sessions will be evaluated to determine the physiological demands of simulated competition kumite matches.

The researcher will take precautions to preserve the confidentiality of the research data and that all reports of the research will be devoid of identifiers.

______________________ ______________
Participants signature Date

______________________ ______________
Parent/Guardian signature Date

______________________ ______________
Researcher's signature Date

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YUNIVESITHI YA FREISTATA

APPENDIX E – QUESTIONAIRE

Participant Information From

Name & Surname			**TESTING DATE:**				
Date of Birth		**Ethnicity**	Black		White	Other	
Your Contact Nr?		**Gender**	M	F	**Right/Left dominant**	Left	Right
Email address?		**Age**			**Years of Practice**		
Coach Name?		**Sport Events:**					
Represent FS?		**Club / Team?**					

1. MEDICAL HISTORY	Mark with a **X** in the blocks over of the risk factors, if applicable to you.					
1.1 RISK FACTORS	**YES**	**NO**		**1.2 OTHER CONDITIONS**	**YES**	**NO**
Chest pains and/or palpitations				Flu or bronchitis currently?		
Heart disease				Regular dizziness or fainting		
History of tic or gland fever				Frequent headache		
Asthma				Allergies		
High blood pressure				Epilepsy		
High cholesterol				Arthritis		
Diabetes Type 1				Pregnant		
Diabetes Type 2				Any other condition/illness		
Strokes				Muscle injuries		
Cancer				Bone injuries/Lower back		
1.3 ELABORATE ON CONDITIONS YOU HAVE MARKED **YES** IN THE ABOVE						
1.4 Do you use any medication? Specify the name and quantity of the medication.						

 # I hereby confirm that all the information above are correct and have completed the questionair with honesty and accuracy.

Athlete Signature	…………………………	Date	…………………………
Researcher Signature	…………………………	Date	…………………………