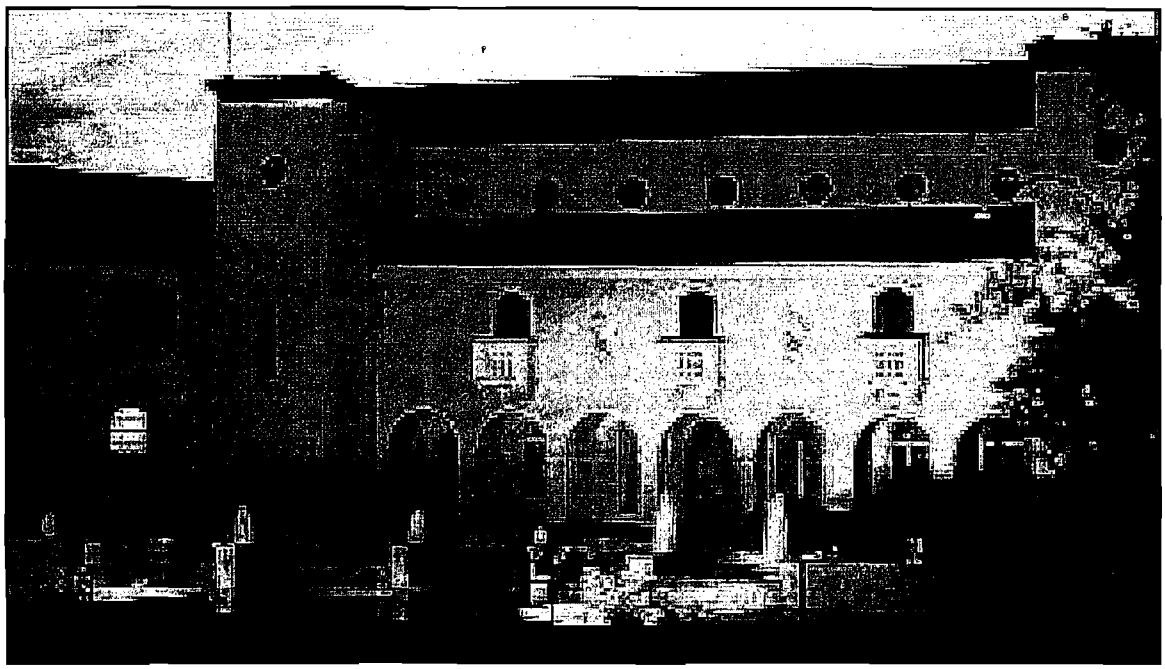
World Karate Federation Championship kumite characteristics determined through video analysis



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Dissertation submitted in fulfillment of the requirements for the magister baccalaureus atrium degree at the Potchefstroom campus of the North-West University

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Co-supervisor: Professor DDJ Malan

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FOREWORD

Completing this study was an amazing experience. Personally and professionally I have learned and grow so much the last four years. I would like to thank the following people for their guidance, and support throughout my study.

Ben, your sport science knowledge is phenomenal, thank you for sharing it with me. I really have learned a lot from you and will always be grateful.

Prof, I consider myself very privileged, for you showing interest in my study. Thank you for your time and input in my study.

Cindy and Yolandi, you're the best colleagues and friends that a person can ask for. Thanks for your friendship and support; I will also treasure our chats and visits. Cinna, thanks for being patient with me, I really appreciate it.

A special thanks to my parents for their financial and emotional support.

Cecilia, thank you for the language editing of my study.

DECLARATION

The co-authors of the two articles which form part of this dissertation, Mr. Ben Coetzee (Supervisor) and Prof. Dawie Malan (Co-supervisor), hereby gives permission to the candidate, Miss. Kobie Ross to include the two articles as part of a Masters dissertation. The contribution (advisory and supportive) of the co-authors was within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as partial fulfilment of the requirements for the Magister Artium degree in Sport Science within the School of Biokinetics, Recreation and Sport Science in the Faculty of Health Sciences at the North-West University (Potchefstroom Campus).

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ABSTRACT

Physically and mentally, kumite karate has become more demanding ever since the focus has shifted towards winning and attaining success. Physical performance and techniques are now being evaluated on a regular basis to determine whether the training and coaching programmes are effective and functional. In this regard, video analysing technology may play a prominent role in attaining and analysing real competition data. It is against this background that the objective of the study was firstly, to determine the kumite characteristics of WKF championship karatekas by making use of video analyses and secondly, to determine the kumite characteristics that discriminate significantly between successful (winners) and less successful (losers) karatekas when making use of video analyses.

The video footage of the kumite finals of the 2004 and 2006 WKF World Senior Championships were analysed by means of the Dartfish Team Pro video analysis software package in order to fulfil the first purpose of this study. The kumite characteristics identified by means of the last-mentioned analyses were then included in the discriminant analysis functions in order to fulfil the second aim of this study. All together eight female and 19 male finals were analysed and the winners of each fight were classified as successful and the losers as less successful karatekas.

The results indicated that among both genders, gyaku tsuki was the most frequently executed technique, followed by grabbing and kizami tsuki. No other karate techniques emerged as frequently executed techniques during the kumite championships. The jodan was the most targeted area, while the lead front leg shift, followed by the forward lunge and then the overstep were the most frequently used foot movements. Poor scoring rates of 9.9% and 12.85% were observed for females and males respectively with, on average, only 29.3% and 28.5% of techniques used to initiate attacks. A work:rest ratio of 4.93:1 and 3.65:1 was calculated for females and males respectively which, together with the time intervals, indicated that the aerobic energy system is the primary energy contributor to kumite performance.

With regard to the discriminators between the successful and less successful kumite karatekas, it was found that gyaku tsuki and kizami tsuki were the primary, significant discriminators for males and only gyaku tsuki for females. Both chudan and jodan were identified as significant discriminators for the males, whereas target area was not identified as a significant discriminator among the female karatekas. The male karatekas also revealed a statistical significant result with regard to the number of initiated attacks.

The conclusion that can therefore be drawn from the above-mentioned results are that video analyzing technology can be used effectively to determine the characteristics of kumite and that the number of initiated attacks, punching techniques and the target area were the significant discriminators between successful and less successful karatekas. Gender differences were, however, observed with regard to the different kumite discriminators.

OPSOMMING

Kumite karate het fisiek en psigies meer veeleisend geraak sedert die fokus verskuif het na wen en die bereiking van sukses. Fisieke vertonings en tegnieke word nou op gereëlde basis geëvalueer om vas te stel of die oefen- en afrigprogramme effektief en funksioneel is. In hierdie verband kan video-analisetegnologie 'n prominente rol speel in die verkryging en analisering van werklike kompetisiedata. Dit is teen hierdie agtergrond dat die doelwit van die studie ten eerste was om die kumite-kenmerke van WKF-kampioenskapkaratekas te bepaal deur van video-analisering gebruik te maak, en tweedens om die kumite-kenmerke wat betekenisvol onderskei tussen suksesvolle (wenners) en minder suksesvolle karatekas (verloorders) deur middel van video-analises te bepaal.

Die videomateriaal van die kumite-eindrondtes van 2004 en 2006 se WKF Senior Wêreldkampioenskappe is geanaliseer deur middel van die Dartfish Team Pro video-analise sagtewarepakket om sodoende die eerste doelwit van die studie te bereik. Die kumite-kenmerke wat deur middel van laasgenoemde analise geïdentifiseer is, is by die diskriminantanalise-funksies ingesluit om die tweede doelwit van die studie te bereik. Altesaam agt eindrondtes waaraan dames en 19 eindrondtes waaraan mans deelgeneem het, is geanaliseer. Die wenners van elke geveg is as suksesvolle en die verloorders as minder suksesvolle karatekas geklassifiseer.

By beide geslagte het die resultate getoon dat gyaku tsuki die tegniek was wat die meeste herhaal is, gevolg deur die vasgryp- en kizami tsuki-tegniek. Geen ander karate-tegnieke het uitgestaan as dié wat dikwels herhaal is tydens die kumite-kampioenskappe nie. Jodan was die mees algemene teikenarea terwyl die "lead front leg shift" gevolg deur die "forward lunge" en die "overstep" as die mees herhaalde voetbewegings geïdentifiseer is. 'n Lae punte-aantekeningstempo van 9.9% en 12.85% is vir dames en mans onderskeidelik waargeneem, met gemiddeld slegs 29.3% en 28.5% onderskeidelik van die tegnieke wat gebruik is om aanvalle te

inisieer. 'n Werks:rus-verhouding van 4.93:1 en 3.65:1 is vir mans en dames onderskeidelik bereken wat, gepaard met die tydsintervalle, daarop gedui het dat die aërobiese energiesisteem die primêre energieverskaffer van kumite is.

Wat die onderskeidingsfaktore tussen die suksesvolle en minder suksesvolle kumite karatekas betref, is gevind dat gyaku tsuki en kizami tsuki die primêre, betekenisvolle onderskeidingsfaktore van mans is en slegs gyaku tsuki vir dames. Beide chudan en jodan is geïdentifiseer as betekenisvolle onderskeidingsfaktore vir mans terwyl teikenareas nie as betekenisvolle onderskeidingsfaktore by dames geïdentifiseer is nie. Die manlike karatekas het ook statisties betekenisvolle resultate getoon met betrekking tot die aantal geïnisieerde aanvalle.

Die gevolgtrekking wat dus uit laasgenoemde resultate gemaak kan word, is dat video-analisetegnologie effektief gebruik kan word om die karate-kenmerke van kumite te bepaal en dat die aantal aanvalle wat geïnisieer is, slaantegnieke en die teikenareas die betekenisvolle onderskeidingsfaktore ten opsigte van suksesvolle en minder suksesvolle karatekas was. Geslagsverskille met betrekking tot die verskillende kumite karate-kenmerke is wel ook waargeneem.

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LIST OF ABBREVIATIONS

m	Meter
Max	Maximum
Min	Minimum
n	Total number
s	Seconds
SD	Standard deviation
WKF	World Karate Federation

CHAPTER 1

PROBLEM STATEMENT AND PURPOSE OF THE STUDY

1. Problem statement
2. Objectives
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1. PROBLEM STATEMENT

Karate started as a weaponless fighting method of ancient Chinese monks, warriors and physicians (Feld *et al.*, 1979:150) and was originally developed for self-defence. Karate has, however, become a popular competitive martial art sport which attracts participants world wide (Gibson & Wallace, 2004:vi). One of the most popular forms of karate in which individuals participate is competition kumite (Searcy, 2001:1). Competition kumite can primarily be described as a semi-contact fighting event which consists of the execution of defensive and offensive techniques, while two karatekas are freely moving in opposition to each other (Imamura *et al.*, 1996:342). Participants' success and their effectiveness during this event depend not only on their technical skills but also on their physical conditioning (Nakayama, 1967:15). Studies have focused on the technical skills of karate (Gibson & Wallace, 2004; Nakayama, 1967) but only a small number of researchers have studied the influence of physical and movement skills on the performance of karatekas (Beneke *et al.*, 2004; Francescato *et al.*, 1995; Imamura *et al.*, 1996). Also despite anecdotal evidence that athletic performance is a reflection of an athlete's physical condition (Beneke *et al.*, 2004:518), most researchers have ignored this aspect of karateka.

According to Nakayama (1967:15), it is necessary to analyse karate continuously to be able to make improvements and describe the physical and technical characteristics of the sport. Sports that have been most commonly analysed by researchers include running, cycling and swimming, probably because people can easily be evaluated by making use of standardised laboratory and field tests (Francescato *et al.*, 1995:355). On the other hand, it is more difficult to simulate a karate fight by making use of pre-standardised tests.

A study by Lehmann and Jedliczka (1998:9) has, for example, shown that athletes perform 30-50% less maximum intensity actions and experience 10-40% lower blood lactate values during a simulated karate fight than during the real competition fight. Beneke *et al.* (2004:519-520) studied the energy contributions of simulated fights and observed that the relative oxygen comsumption per fight was 52.4 ml/kg/min on average and the post-fight blood lactate 7.7 mmol/l. The individual blood lactate concentrations corresponded positively with the number of high intensity actions performed during each fight and negatively with the duration of each interruption during the fight. The work:rest ratio was found to be two to one with 18 seconds of activity for each 9 seconds of inactivity. During the periods of activity, an average of 16.3 high intensity actions per fight each lasting 1-3 seconds, were performed. In view of this data

Beneke *et al.* (2004:522) concluded that the aerobic energy contribution during kumite is more or less 74% of the total energy contribution, while that of the anaerobic energy system through the ATP-CP (adenosine tri-phosphate and creatine phosphate) system is more or less 17.9%. The problem researchers are faced with is that the last-mentioned values were obtained from simulated fights and not from in-time fights. As has been mentioned at the start of this paragraph, the values obtained from simulated fights are less than those obtained from in-time fights.

However, with the Dartfish video analysis software package that appeared on the market a few years ago, it is now possible to analyse a sport such as karate more sport specific and in-time. Despite the availability of the product, only a few studies could be traced that have analyzed karate in such a manner. Nunan (2006:49), for example, utilized video analysing technology to analyse kumite during competitions to determine the most common techniques and then implement the results to develop a sport specific aerobic capacity test for karate. Video analyses have also been used with great success in other martial art sports such as Taekwondo (McDonald, 2006:1). McDonald (2006:1-2) and Kellick (2005:2) state the importance of this type of technology during preparation and conditioning of athletes by attributing the success of the England and USA Taekwondo teams to, amongst other things, video analysing technology.

In view of a lack of research concerning the utilization of video analysing technology in determining the karate kumite characteristics, the following research questions are posed: Firstly, what are the kumite characteristics of World Karate Federation (WKF) championships as determined by means of video analysis? Secondly which of the WKF championship kumite characteristics discriminate significantly ($p \leq 0.05$) between successful (winners) and less successful karatekas (losers) when making use of video analysis? The results of studies in which video analysing technology is used to analyse and describe kumite may provide karate coaches and sport scientists with information that will allow them to condition and prepare athletes more effectively for kumite.

2. OBJECTIVES

The objectives of this study are:

- To determine the kumite characteristics of WKF World Karate Senior Championships by making use of video analysing technology.

- To determine which of the WKF World Karate Senior Championships kumite characteristics discriminate significantly between successful and less successful karatekas when making use of video analysing technology.

3. HYPOTHESIS

The study is based on the following hypothesis:

- Due to the descriptive and explorative nature of the first objective, no hypothesis is set.
- From the available research it is hypothesized that the high scoring techniques such as kicks, leg sweeps and take downs as well the foot movements such as the forward lunge, half step, overstep and lead front leg shift will act as significant discriminators between successful and less successful karatekas.

4. PROPOSED CHAPTERS

The dissertation is submitted in article format as approved by the Senate of the North-West University and is structured as follows:

Chapter 1: Problem statement, objectives and hypotheses, of this study. A bibliography is provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 2: A literature overview titled: The use of video analyses to identify kumite characteristics. A bibliography is provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 3: Article 1 – Kumite characteristics of WKF championships as determined by means of video analysing technology. This article will be presented for publication in the Journal of Strength and Conditioning Research. A bibliography is presented at the end of the chapter in accordance with the guidelines of the journal. Although not according to the guidelines of the journal, tables will be included in the text so as to enable the reader to read and understand the article easier.

Chapter 4: Article 2 – Discriminant analyses of kumite characteristics using video analyses during the WKF championship finals. This article will be presented for publication in the Journal of Strength and Conditioning Research. A bibliography is presented at the end of the chapter in accordance with the guidelines of the

journal. Although not according to the guidelines of the journal, tables and figures will be included in the text so as to enable the reader to read and understand the article easier.

Chapter 5: Summary, conclusions and recommendations.

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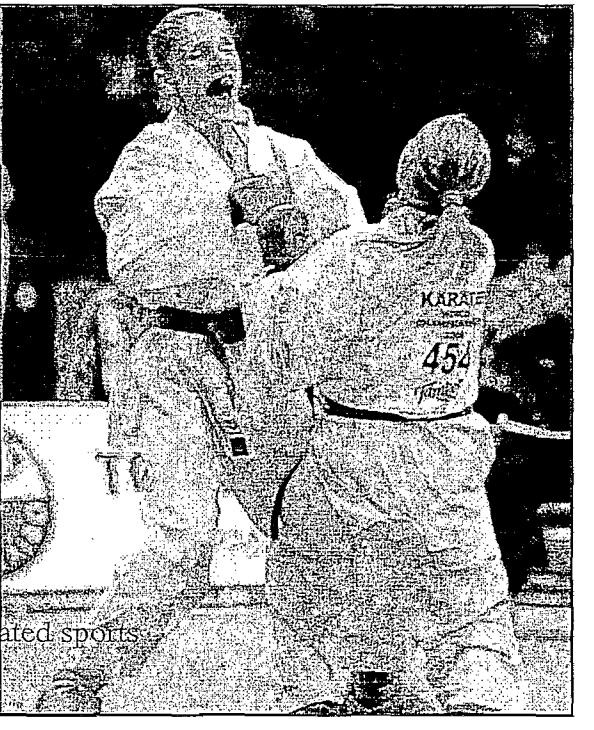
CHAPTER 2

THE USE OF VIDEO ANALYSES TO IDENTIFY KUMITE CHARACTERISTICS



1. INTRODUCTION

Karate is a fast-growing competitive sport that attracts participants and spectators world wide (Gibson & Wallace, 2004:vi). Due to this growth in competitiveness, karate has, similar to many other sports, become physically and mentally more demanding, since the focus has shifted more towards winning and towards attaining success. This shift in focus has also given rise to more scientifically evaluated and constructed programmes as well as training methods which are formulated by qualified sport professionals in accordance with karatekas' individual needs (Jepperson, s.a.:1). The rules of the karate competitions have also been adapted over the years to make the sport more acceptable for inclusion on the list of Olympic sports. The rule change led to an increase from 90 seconds to 120 seconds for females and to 180 seconds for males, in fight duration as well as an increase in the number of points one of the karatekas has to achieve (from a two-point lead to an eight-point lead) to be declared a winner. Due to the rule changes karatekas are now also able to achieve higher points (three in stead of two) for the successful execution of more advanced techniques. All these changes led to an increase in the attractiveness of the sport and a need for more research on the physiological and technical requirements of karate.

Physical performance and techniques are being evaluated on a regular basis to determine whether the training and coaching programmes are effective and functional, as well as for research purposes (McGinnis, 2005:362). Beneke *et al.* (2004:519) did, however, indicate that the data from standardized laboratory tests and simulated fights can be misleading and inaccurate when applied to the real karate competition outcome or situation. In this regard, video analysing technology may play a prominent role in attaining and analysing real competition data. Karate-related sports such as Taekwondo has, for example, attributed the success of the team to the implementation of video analysing technology (Kelleck, 2005:1; McDonald, 2006:1). Several researchers have also used video analysing technology as a tool to accurately determine the different physiological requirements of karate as well as the frequency of techniques that are executed during karate fights (Beneke *et al.*, 2004:519; Nunan, 2006:48). Despite the advantages of video analysing technology, some coaches and sport professionals still feel intimidated by this type of technology and would rather stick to older methods due to ignorance (Liebermann & Franks, 2004:59).

In view of the above-mentioned facts, the purposes of this literature overview are therefore to provide the sport fraternity with a brief background concerning the origin of karate, an explanation of kumite and the most commonly used techniques and movement skills in this category of karate; the physiological characteristics of the sport; and finally, information on the use and benefits of video analysing technology in identifying kumite characteristics.

2. KARATE

2.1 Introduction

The origin of martial arts can be traced to the Chinese monasteries where the students practised martial arts as part of their physical training to build endurance and strength (Nakayama, 1967:13). During the time when the use of all weapons was prohibited, the population in Okinawa developed "empty-hand" fighting (karate) to defend themselves (Nakayama, 1967:13). Master Funakoshi introduced karate to Japan in 1922, established the Shotokan style in 1936 and the Japan Karate Association in 1955 (Nakayama, 1967:13). Over time, different karate styles and techniques were developed which led to the establishment of new forms of karate over the years (Noble, s.a.:2). The Japanese masters from the various styles introduced different forms of karate to countries world wide. However, competition fighting was never the focus of any of the original Japanese fighting masters. It was the French who began a world organization and hosted the first international championships (WKF, s.a.:1). Recent statistics indicate that world-wide some 50 million participants from 173 registered national federations take part in the World Karate Federation (WKF) organization (WKF, s.a.:1). During 2008, WKF karate was also selected for possible inclusion in the Olympic programme (WKF, s.a.:1).

Karate tournaments can be classified in two main divisions, namely: kata (set sequence of movements) and kumite (fighting). Competition kumite can primarily be described as a semi-contact fighting event, which consists of the execution of defensive and offensive techniques while two karatekas are freely moving around on the competition area (Imamura *et al.*, 1999:342). 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. In view of the fact that kumite is the focus of this study, the nature and characteristics of kumite will be explained in the next section. This will be followed by a discussion of the different techniques and tactical skills used by competitors in kumite. Finally, this section will conclude with a review of the physiological characteristics of international kumite.

2.2 World Karate Federation (WKF) kumite

WKF kumite is a semi-contact fighting event during which two opponents are freely moving on a 8x8 m WKF-approved mat while they are wearing WKF-approved protective gear (mitts, shin pads, foot protectors, mouth guards and chest protectors for females). No excessive contact is allowed during the fight and attackers are suppose to control the impact of their contacts (WKF, 2005). Participants receive a three-minute fighting period in the case of men and two minutes in the case of women to score as many points as possible. In order to be declared a winner, the competitor needs to either lead by eight points or have obtained the highest number of points at the full-time signal. The total duration of fights is, however, usually much higher than the allotted two or three minutes (more or less 267 sec on average) due to stopages 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.

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 (sanbon) will be awarded in cases where the head or face (jodan) was "hit" by making use of a kick or the competitor executed a take-down technique and then made use of another scoring technique while the competitor is down. Two points (nidan) are granted in situations where the competitor has "hit" the opponent's back, abdominal or chest area (chudan) by making use of a kick or punches the opponent's back or the back of the head or when a combination of at least two hand techniques "hit" the target area or a scoring technique was executed successfully while the opponent was off balance. One point (ipon) is awarded in cases where hand techniques were successfully performed to the head, face (jodan), back, abdominal or chest area (chudan).

Each of the different karate techniques and movement skills used during fighting (kumite) will subsequently be explained and discussed to make clear why different points are being awarded to different techniques as well as why certain techniques are more frequently used during competition kumite. This will also provide background information to bring about a better understanding and interpretation of the physical and physiological impact and requirements of the sport.

2.3 Kumite techniques

"Fundamentally karate is the practice and development of blocking and striking techniques" (Evans, 1997:7). To build a kumite foundation, all beginners start with Kihon training which consists of the execution and repetition of basic defensive and attacking techniques in a prearranged setup (Kato, 2002:1). A review of the different karate curriculums show that beginners are first taught the different punch variations followed at a later stage by the different kicking techniques. Karatekas must repeat the different techniques in such a manner that the different body parts travel to the target across the correct route (Nakayama, 1967:15). Seven to ten grades are completed before karatekas reach black belt (Evans, 1997:7). It is expected that karatekas who have reached this level have developed the different techniques almost to perfection (Sforza *et al.*, 2000:957).

2.3.1 Punching techniques

The hands are more agile than the feet and more commonly used for attacks and as a defensive tool or shield to protect the body against attacks (Lee & Uyehara, 1977:29). With the execution of punching techniques, the hand can reach a peak velocity of between 10 and 14 m/sec if techniques are executed correctly (Feld *et al.*, 1979:150). According to Lee and Uyehara (1977:45), a well-executed punching technique should be performed effortlessly and muscle tightening should only occur a split second before impact.

The three different punching techniques most commonly used in kumite are:

- Gyaku tsuki (Figure 1): A punch that is executed with the hand that is on the opposite side of the front leg is called a gyaku tsuki. The key to a well-executed gyaku tsuki is to utilize the power from the hips. The punching action is coordinated in such a manner that execution takes place when hip rotation occurs. The fist is located to the side at hip height with the palm facing upwards, and travels in a straight line to the target. The elbow is brushed against the side during the execution of the punch and the forearm is turned 180 degrees inwards as the muscles contract at the moment of impact. The range of the attack can be extended by a forward step with the front foot in the direction of the attack while lowering and rotating the hips in an inward and forward position.

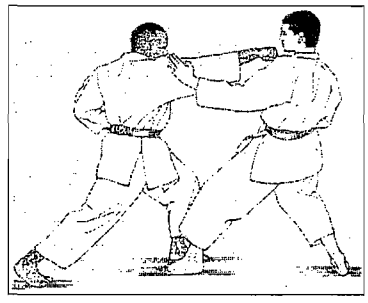


Figure 1: The karateka on the left is demonstrating the final position of a jodan (head, face) gyaku tsuki (Evans, 1997:71).

- Oi tsuki (Figure 2): The technique is a stepping punch that is executed with the hand that is on the same side as the foot that steps forward. However, it is very easy for opponents to anticipate this technique due to the initial movements that are performed at the start of the technique. In view of this, karatekas need to execute the technique by making use of fast foot work and by turning the hips forward and pushing the rear leg hard off the ground.

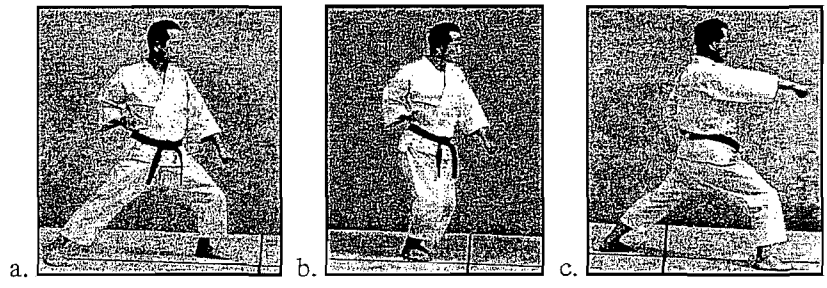


Figure 2: a. The karateka demonstrate the starting position of a oi tsuki; b. is the transition phase and c; is the final position of a chudan (mid-section) oi tsuki (Nakayama, 1967:114).

- Kizami tsuki (Figure 3): A punch that is executed by "snapping" the wrist of the hand that is on the same side as the front foot is called a kizami tsuki. Well-known fighter Bruce Lee, a Jeet Kune Do (a martial art style) master, believed that the leading straight punch (kizami tsuki) is the most important punch because the lead hand travels a shorter distance to the target which makes it a very fast movement (Lee & Uyehara, 1977:30). However, he believed that the fist should be positioned vertically instead of horizontally like in other karate styles.

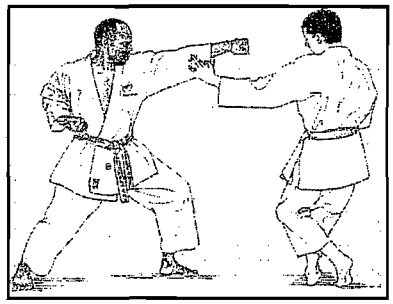


Figure 3: The karateka on the left is demonstrating the final position of a jodan (head, face) kizami tsuki (Evans, 1997:70).

Research by Nunan (2006:50) found that gyaku tsuki is the most frequently used technique during competitions. Lee and Uyehara (1977:30) are, however, of opinion that the kizami tsuki is a better punch technique in situations where seven or more centimetres in reach are to be obtained. Researchers also concluded that the speed of punch techniques is more important in achieving a point than the amount of strength applied (Harvard University, 2006:1). Furthermore, Cesari and Bertacco (2008:355) state that the efficiency of the techniques is rather determined by the body position and stability of the karateka than by anything else.

2.3.2 Kicking techniques

Kicking techniques are technically more difficult than most punching techniques; therefore they require much more time and effort during training (Nakayama, 1967:136). The legs and feet are, however, very important body parts for attacking and scoring points during kumite. The legs are, for example, longer than the arms which make it possible to score points over a longer reach distance. Kicking techniques are especially important in situations where the karateka wants to keep his/her distance from the opponent (Lee & Uyehara, 1977:58).

The four kicking techniques most commonly used in kumite are:

- Mawashi geri (Figure 4): This technique is a roundhouse kick that is performed with either the front (front mawashi geri) or back leg (back mawashi geri). The foot is moving in a large circle around the body, by rotation of the hips. The foot moves from the outside, inward. The mawashi geri may not be as powerful as the other kicks, but can be very deceptive and effective due to the quick recovery that is associated with the execution of this kick (Lee & Uyehara, 1977:65).

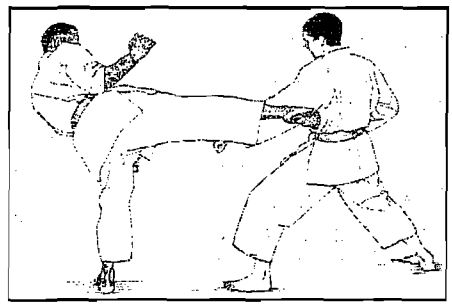


Figure 4: The karateka on the left is demonstrating the final position of a chudan (mid-section) mawashi geri (Evans, 1997:62).

- Ushiro mawashi geri (Figure 5): This kick is known as a reverse roundhouse kick that is either performed by the front or back foot. The foot starts the kick in front of the body and moves in a half circle outwards towards the opponent.

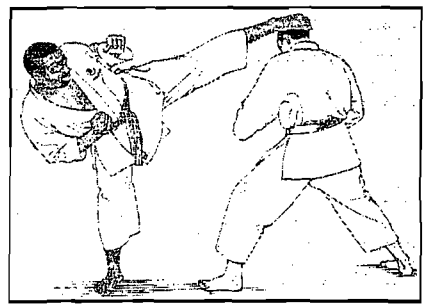


Figure 5: The karateka on the left is demonstrating the final position of a jodan (head, face) ushiro mawashi geri (Evans, 1997:64).

- Mae geri (Figure 6): A front kick that is performed with the ball of the foot.

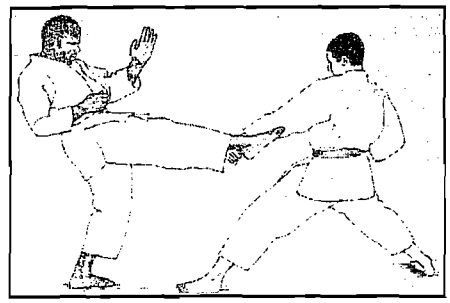


Figure 6: The karateka on the left is demonstrating the final position of a chudan (mid-section) mae geri (Evans, 1997:68).

- Yoko geri (Figure 7): The technique is a side kick that can be directed to the side or to the front. The hips are utilized to push the kicking leg into full extension when the foot "hits" the target. The side kick is the most powerful kick in karate and is used to knock the opponent off balance or to stop the opponent in his/her tracks (Beasley, 2003:75).

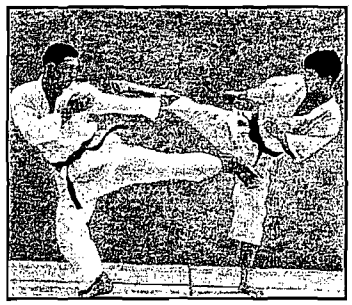


Figure 7: The karateka on the right is demonstrating the final position of a jodan (head, face) yoko geri (Nakayama, 1967:152)

The power of a kick is determined by the amount of "whiplash" generated by the foot due to the contracting leg muscles (Nakayama, 1967:137). A kinetic analysis of the kicking action shows that the thigh decelerates while the lower leg simultaneously accelerates, which makes it possible to perform the "whiplash" kicking action (Sorensen *et al.*, 1996:483). The most important part of all kicks is the initial movement during which the knee is lifted up and bended to its maximum (Evans, 1997:29). During training, karatekas will be taught to lift the knee to the side for a mawashi geri and to the front for a mae geri, but for kumite competitions karatekas must use the same position for all kicks in order to make it difficult for opponents to anticipate which kick is going to be performed (Evans, 1997:29). Furthermore, elite karatekas must be able to alternate quickly from one kick to another by judging the distance from the opponent correctly and by timing their action (Hickey, 1997:139). In addition, karatekas also need a high degree of flexibility to perform jodan kicks effectively (Evans, 1997:29).

The reason for the knee lift at the start of the kicking action is to force the hip muscles to initiate the kicking action after which the thigh muscles will be activated to perform the rest of the movement. It is also extremely important that the hips and ankles of the non-kicking leg should be stabilized while performing a kick. Stabilizing will make it difficult for the opponent to perform a leg sweep, a throw or a take-down on a karateka (Nakayama, 1967:136). Most

opponents will try to use the sweep technique the moment the karateka shifts his/her weight to a particular leg (Hickey, 1997:137).

2.3.3 Additional techniques

Additional techniques such as the leg sweep and take-downs are used in order to position the opponent in a vulnerable position to create an opportunity to score higher points (three points). However, the execution of the last-mentioned techniques can only be awarded with points if it is combined with another technique. Grabbing on the other hand is used as a defensive strategy, due to the fact that a karateka is more vulnerable to be scored on when moving backwards.

- Leg sweep (Figure 8): A leg sweep is executed with the inside part of the foot that makes contact with the lower leg of the opponent. The opponent's leg is taken from underneath him/her which leads to an unstable position and the fall.

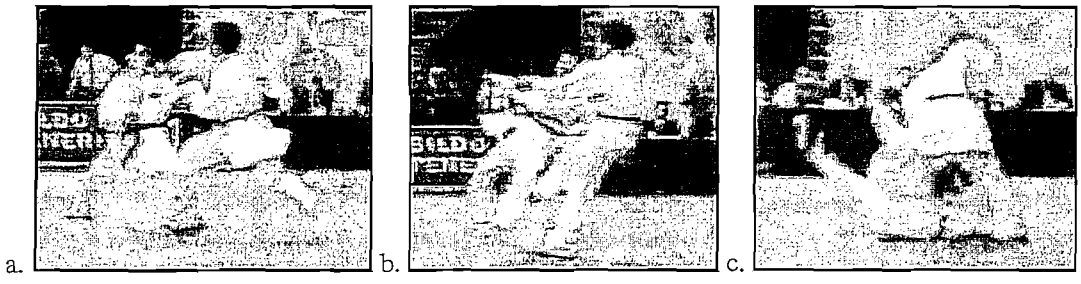


Figure 8: a. The karateka on the right hand side demonstrates the start of a leg sweep; b. the front leg of the karateka on the right is used to throw the opponent off balance; c. the karateka on the left falls to the ground as the end result of a correctly executed leg sweep (Kombatklub, 2005).

- Take-down (Figure 9): The take-down technique can be done in more than one way. The take-down is executed by rotating the hips, while the knees are bent and the hips lowered. In most cases the take-down is combined with the leg sweep in order to increase the effectiveness of the technique.

Figure 9: a. The karateka on the left hand side demonstrates the start of a take-down; b. the opponent is thrown over his shoulder; and c. the throw to the floor after which a punch is executed to the head (Kombatklub, 2005).

- Grab (Figure 10): Grabbing an opponent is illegal, but is used by karatekas to prevent the opponent from scoring a point.

Figure 10: a-c. The karatekas on the right hand are demonstrating the grab technique (Kombatklub, 2005).

The movement skills karatekas perform in order to execute the above-mentioned techniques are subsequently discussed. This has been pointed out by coaches as an important part of kumite as movement skills determine the time and manner in which karatekas attempt to score points.

2.3.4 Movement skills

Movement skills are used to control the exact fighting distance and reach during kumite competitions (Jung & Lawler, 2000:1). Karatekas will usually try to maintain a non-strikeable fighting distance when they first want to evaluate the opponent's abilities and fighting techniques and want to plan counter attacks to score points. During times when karatekas want to attack they will use half or double steps, shifts or a forward lunge to close the fighting distance as fast as possible and surprise the opponent (Evans, 1997:45). Side-stepping is mainly used as a defensive tactic but in certain situations can also serve as a movement to initiate an attack or

counterattack (Lee & Uyehara, 1977:21). Side-stepping must, however, be executed explosively in these situations (Evans, 1997:44).

Karatekas have different body types and limb lengths which determine the fighting and reaching distance that will be most effective in scoring points or avoiding attacks (Jung & Lawler, 2000:1). Karatekas who have flaws in their attacking techniques will also be able to compensate for it by moving effectively (Evans, 1997:43). Movement skills are also used to manipulate the opponent's position and in forcing him/her to make positional errors. In this regard forward, backward and side-way hopping movements are mainly used to obtain a positional advantage over the opponent (Beneke *et al.*, 2004:518). To perform these hopping movements effectively, the body weight needs to be transferred in a wide range of directions and be followed by some or other hip action and limb expansion (Kato, 2002:3). The body must also, at all times, be aligned correctly so as to facilitate the correct muscle actions and provide stability by lowering the centre of gravity (Nakayama, 1967:15).

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

2.4 Competition tactics

Tactics refer to the details of a plan by which a strategy can be used to outsmart an opponent (Verstappen, s.a.:1). A common tactic is to attack in threes (Hickey, 1997:134). The first two attacks will usually be targeted to jodan, which will likely force the opponent to move his/her hands over the face. This can create an opening for the attacker to score points in the chudan (abdominal, back or chest) area by making use of a third movement (Beasley, 2003:117). Karatekas also fake certain techniques as a tactic to draw the opponent forward and analyse his/her intentions and main scoring technique. The fake technique must, however, be performed in such a manner that it looks real and forces the opponent to react to it (Hickey, 1997:139). Successful kumite karatekas have the ability to quickly analyse and evaluate their opponents' tactics and to apply tactics to counter the opponent's attacks (Nishimura, 1995:3).

Furthermore, it is crucial during kumite that karatekas move smoothly and directly into attacks without providing the opponent with hints concerning the type of technique/s or attack/s that are going to be used (Nishimura, 1995:3). One of the primary aims of the karateka is to surprise his/her opponent and make it difficult for the opponent to anticipate the next move. Karatekas

who want to maintain the surprise element will have to be able to move the feet rapidly in different directions (Evans, 1997:53). Surprise attacks can also only be executed if the hands and feet are continually being positioned in such a manner that attacks can be performed from any place or at any time (Nakayama, 1967:18). The timing of the attack will also affect the surprise element (Hickey, 1990:1). In this regard it is better to attack either when the opponent is readying him/herself for an attack, or at the beginning of the opponent's attack or when the opponent has completed his/her attack (Hickey, 1997:130). A further requirement is to always counter immediately after the opponent has struck. It is important not to block, retreat and then counter but rather to block and counter immediately (Nishimura, 1995:2). In cases where this action is not followed and a delay occurs, the opponent will be in a position to move out of range or to score a point.

Bobbing and weaving that consist of side to side and in and out movements are often used as defensive tactics (Lee & Uyehara, 1977:119). The drawback of these tactics is that it can occasionally be time consuming to perform, and because of this, allow the opponent to adapt and change his/her attacking sequence. For example, to weave to the inside of a right kizami tsuki, the karateka needs to move to the outside by dropping the head and body with more or less 22-30 centimetres, which may take approximately 0,25 sec (Kato, 2002:3).

It is important that karatekas select tactics that fit their participation levels and abilities, that are easily mastered in training sessions and that are built on previously learned skills (Hickey, 1997:135). Tactics alone will not guarantee success. The karateka must still be able to evaluate his/her opponent successfully, anticipate the opponent's tactics and be able to make accurate and fast decisions (Beasley, 2003:117).

Several physiological characteristics are also important for success in kumite. The next section will discuss some of the physiological characteristics of karatekas relevant to the performance of the sport.

2.5 Physiological characteristics of kumite

Kumite used to be categorized as an explosive activity which primarily makes use of the anaerobic energy system (Kato, 2002:5). The physiological characteristics of kumite with regard to the contribution of the different energy systems have, however, changed due to the allocated fighting time that was increased from 90 to 180 sec and from 90 to 120 sec for the male and

female competitors respectively. One way in which researchers and sport scientists can determine the ergogenesis of a specific sport is by calculating the work: rest ratio that applies to that specific sport (Bompa, 1999:81). The work: rest ratio is dependant on the total duration and intensity of the specific activity. In this regard Bompa (1999:347-350) states that activities that depend on the anaerobic energy system usually last between 5 and 120 seconds and are executed at a sub-maximum or maximum intensity level. Rest periods between these types of activities are usually between 6 to 10 min (Bompa, 1999:347-350). Aerobic energy system-dependant activities take place over much longer periods of between 2 min and 2 to 3 hours at a lower intensity level (70% of maximum intensity level) and are followed by shorter rest periods of between 45 and 90 sec (Bompa, 1999:347-350). Both the aerobic and anaerobic energy systems do, however, contribute to the energy requirements of activities in kumite. It is the percentage contribution of the different energy systems that differ from one activity to the next.

One way of determining this contribution is by making use of video analyses to calculate the work: rest ratio of a specific event and evaluating the intensity levels of the different activities. In this regard a previous study by Francescato (1995:356) on eight inexperienced karatekas (1-3 years of karate participation and 2 hours of training per week), indicated that the anaerobic energy system was predominantly used during karate. In contrast, Beneke *et al.* (2004:519) discovered that the aerobic energy system was the primary energy supplier during the karate activities of ten nationally and internationally ranked karatekas.

Beneke *et al.* (2004:519) classified the different movement intervals of kumite according to the intensity that was maintained during simulated competition fights. The first type of intervals consisted of forward, backward and sideways hopping movements that were used in preparation for attacks and categorized as low intensity activities. The second type of intervals comprised offensive and defensive techniques that were executed at fast speeds and were categorized as high intensity activities. During a normal simulated fight, Beneke *et al.* (2004:519) observed 16.3 high intensity actions with a duration of 1-3 seconds each. The third type of intervals consisted of activities during which karatekas rested. This was, for example, periods during which karatekas stood still while referee/s decisions took place or points were awarded. On average, the duration of these intervals was 9 sec, which resulted in a work: rest ratio of two to one. The accuracy and relevancy of these observations can, however, be questioned in view of the research of Lehmann and Jedliczka (1998:60) who proved that the frequency of attacking and

defending actions during simulated competitions were 30-50% lower than during real competitions.

The intensity of a fight is, however, also influenced by the fight duration. In this regard Iide *et al.* (2008:841) reported significantly higher heart rate, maximum oxygen consumption, lactate and energy expenditure values during three minutes compared to two minutes of fighting among boys. They also showed that the total duration of attacks increased from 13.3 sec during two minutes of fighting to 19.4 sec during three minutes of fighting, which also has an impact on the work: rest ratio and the ergogenesis of the specific kumite event (Iide *et al.*, 2008:841). The last-mentioned research results coupled with the fact that the WKF has changed the duration of kumite competition events from 90 sec to two minutes for females and three minutes for males, emphasize the importance of re-evaluating the physiological characteristics of kumite by means of real-time video analyses.

The next sections will focus on the literature that relates to the practical use and possible benefits of video analyses for karate and other karate related sports.

3. VIDEO ANALYSES

3.1 Introduction

Video technology gives athletes "instant visual feedback" of their performances (Dartfish, 2008:1) and is an excellent way of getting practical concepts across from the coach/analyser to the athlete (Bray, 2008:6). This type of feedback seems to improve and accelerate the learning process of the participants, but only if appropriately applied (Schmidt & Lee, as quoted by Liebermann & Franks, 2004:40). In this regard the intervention of coaches is required to administer the process by highlighting the relevant information of the video capturing (Liebermann & Franks, 2004:40). Athletes will not always be able to regulate the feedback from the video material and in some cases the available information may exceed the athlete's processing ability (Liebermann & Franks, 2004:41). Hence the communication between the coach and athlete is crucial in determining the feedback process and analysis. Coaches are also the people who decide whether feedback-base technologies will be used in training and also how it will be integrated into the training (Liebermann & Franks, 2004:41). Although coaches value the scientific information gained from making use of technology such as video analysis, they are

often sceptical about the advantages of such sophisticated technology and still prefer using simple methods to analyse and evaluate the training process (Liebermann & Franks, 2004:57).

Despite the preferences of coaches, immediate and detailed kinematic analyses are dependant on complex technologies due to the capability that it has to track and record motion events in real time (Liebermann & Franks, 2004:57). Thus it is inevitable that researchers and other sport professionals will make use of this type of technology to analyse the detail of very fast and complex movements which are often executed by elite athletes and cannot be tracked or processed by the human eye and brain (Andrzejewski & Elbaum, s.a.:1). Processing of detail is especially important in view of the fact that the slightest mistake or flaw in the execution of movements may be detrimental to optimal performances. With video analyses the coach and support staff will be able to highlight certain flaws in techniques and movements as well as to compare these activities with reference clips.

Video analyses can also be used to analyse the exact nature of a specific sport in order to develop a sport specific profile. Real-time analyses is also much more accurate in developing profiles and describing the nature of a certain sport compared to the use of simulated actions and movements. In this regard a study on karatekas has for example shown that karatekas perform 30-50% less maximum intensity actions and experience 10-40% lower blood lactate levels during simulated fights compared to when the real competition fights take place (Lehmann & Jedliczka, 1998:60).

It is against this background that the review of literature that has focused on the use of video analyses among martial art sports is revealed.

3.2 Video analyses of kumite and other related sports

Information on opponents' strong and weak points will allow karatekas to outsmart their opponents during kumite competitions. Video analyses will allow the coach and other support staff to obtain this information so that karatekas can be prepared and trained for international competitions. Other related sports, such as full contact karate, have used video analyses to determine which techniques are most commonly used to score points in order to develop effective attacking and counter-attacking combinations (Sevostyanov & Kholodov, 2005:15). Poland's national judo coach recorded and analysed the frequency as well as the efficiency index of the techniques during several judo fights and discovered that 78% of all points were scored by

making use of basic and auxiliary techniques. Other techniques were only used in situations where opponents made mistakes (Adam, 2007:217).

The practical significance and importance of video analyses have also been emphasized by authors such as McDonald (2006:1) and Kellick (2005:1) who attributed the success of the England and USA Taekwondo teams to, among other things, video analysing technology. Both teams used video analyses to identify their opponents tactics and movements as well as their weaknesses and strengths to develop the best strategies to achieve success (McDonald, 2006:2).

Nakayama (as quoted by Sforza, 2000:948) has made use of video analyses during the early nineteen sixties to maximize the effectiveness of different karate techniques. Nakayama (as quoted by Sforza, 2000:948) investigated two different punches, namely the choku tsuki (straight punch) and oi tsuki (step and punch), by making use of a special stroboscopic camera and electromyography. The acceleration and velocity of the hands as well as the electric activity of the muscles that were involved in these movements were determined for different levels of karatekas. It was concluded that the speed of both techniques was faster for experienced karatekas than for beginners (Nakayama, as quoted by Sforza *et al.*, 2000:948). In a more recent study of Sforza *et al.* (2000:948) the same two punches were studied by making use of an Italian computerized system (ELITE) and eight infra-red cameras. The patterns of different body movements were analysed during the repetitive executions of the punches. It was discovered that the execution of the oi tsuki was faster than the choku tsuki and that the effectiveness of any technique was dependant on the karateka's ability to keep his/her centre of gravity parallel to the ground while moving (Sforza *et al.*, 2000:948).

Beneke *et al.* (2004:518) made use of video analyses of simulated karate fights to determine the physiological requirements and the energy contribution of different energy systems during kumite competitions. All the fights where video recorded and the different activities that took place were analysed. The different activities were characterized according to the intensity level of each and used together with the maximum oxygen consumption and blood lactate results to determine the energy contribution during kumite.

These findings and statements accentuate the importance of identifying the characteristics of kumite by means of video analyses. This is especially true in view of the different techniques and movements that are performed during kumite.

4. CONCLUSION

To conclude, the analysing and evaluation of all kumite-related components should form part of the preparation of all top[s] level kumite competitors. Coaches and other related professionals therefore need to compile a profile for kumite and make use of real-time video analysis instead of simulated methods to do so. Real-time video analyses will also allow researchers and other people in the karate fraternity to identify the best scoring techniques and the flaws in technique execution.

The frequency, intensity and duration of each activity during kumite can also be analysed and noted. The last-mentioned information will enable coaches and other related persons to develop tactics for each competition and to prepare karatekas specifically for the kumite event. It is, however, important not to exclude laboratory testing but to use this in collaboration with video analyses. This will allow researchers to accurately identify the different components of kumite.

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CHAPTER 3

KUMITE CHARACTERISTICS OF WKF CHAMPIONSHIPS AS DETERMINED BY MEANS OF VIDEO ANALYZING TECHNOLOGY

TITLE: KUMITE CHARACTERISTICS OF WKF CHAMPIONSHIPS AS DETERMINED BY MEANS OF VIDEO ANALYZING TECHNOLOGY

RUNNING HEAD: KUMITE CHARACTERISTICS DETERMINED BY MEANS OF VIDEO ANALYSES

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ABSTRACT

The purpose of this study was to determine the kumite characteristics of the 2004 and 2006 WKF World Karate Senior Championships by making use of video analyses. Eight female and 19 male fight finals were analyzed by means of the Dartfish Team Pro video analysis software package. Each fight was analysed according to the different phases identified and the activities that took place during each phase. The clock function of the Dartfish software was used to determine the duration of each fight, phase, "pre" and "post-attack", "attacking" moves as well as breaks or periods of inactivity. One of the most significant findings from this study was that among both genders, gyaku tsuki was the most frequently executed technique followed by grabbing and kizami tsuki. The body area mostly targeted during kumite was jodan, while the lead front leg shift, followed by the forward lunge and the overstep were the most frequently used foot movements. Poor scoring rates of 9.9% and 12.85% were observed among the female and male competitors respectively with only 29.3% and 28.5% of the average number of techniques used to initiate attacks. From the analyses a work:rest ratio of 4.93:1 for females and 3.65:1 for males were calculated. In conclusion it can be pointed out that the results demonstrated that video analyzing technology can be used effectively to determine the characteristics of kumite.

KEY WORDS karate, karate techniques, video analyses, WKF profile, karate physiological requirements

INTRODUCTION

Karate started as a weaponless fighting method of ancient Chinese monks, warriors and physicians and was originally developed for self-defence (7). However, karate has become a popular competitive martial art sport which attracts participants world wide (9). One of the most popular forms of karate in which individuals participate is competition kumite (18). Competition kumite can primarily be described as a semi-contact fighting event which consists of the execution of defensive and offensive techniques, while two karatekas are freely moving in opposition to each other (11).

Kumite used to be described as a high intensity activity (1) but more recent research has shown that the aerobic energy system contributes more or less 74% and the anaerobic, phosphagen system more or less 17.9% of the energy for the execution of the different movements (3). In this regard Beneke et al. (3) also demonstrated that 16.3 high intensity actions, each lasting between one and three seconds, which relate to 3.4 high intensity actions per minute, take place during simulated fights that last 267 s on average.

A comparison between the characteristics of a simulated karate fight and a real competition fight has revealed that karatekas perform 30-50% less maximum intensity actions and experience 10-40% lower blood lactate levels during simulated karate fights than during real competition fights (14). These research results have led researchers to rather make use of real-time video recordings and analyses of the actual fights instead of simulated fights and standardized laboratory and field tests to analyse the exact nature and characteristics of a specific sport. The introduction of the Dartfish video analysis package a few years ago made it possible for researchers and sport-related professionals to analyse sport in this manner. Despite the availability of this technology for analyses and other similar products (Siliconcoach and Sports Motion), only a few studies have analysed karate by means of video analysing technology.

With the use of video analysis Nunan (17), determined that the straight punch and the roundhouse kick were the most used techniques during kumite competitions. These results enabled him to consequently develop a karate-specific aerobic test which included the observed techniques to determine the aerobic capacity of karatekas (17).

The practical significance and importance of video analyzing technology has also been emphasized by McDonald (15) and Kellick (12) who attributed the success of the England and USA Taekwondo teams, amongst other things, to video analyzing technology. Both the teams used video analysis to identify their opponent's tactics, movements as well as weaknesses and strengths with a view to develop strategies to achieve success (12,15). With regard to movements, karatekas make use of different forward, backward, sideward and hopping movements to attain the best possible attacking position (2). The timing and nature of the attack will depend on the fighter's response to his/her opponent's movements. Some of the tactics that are, for example, used during fights are to fake various techniques and movements to initiate an attack from the opponent and then use this to set a counterattack in place (2). Some karatekas also believe that a strong lead-off technique will distract opponents from concentrating on their own balance, distance and aim which will provide the attacker with an opportunity to score (2).

The above-mentioned findings and statements accentuate the importance of video analysis so that researchers and sport-related professionals (such as sport scientists and coaches) can identify and note the different kumite characteristics and are enabled to develop better and more effective training techniques and strategies. Despite the mentioned benefits, no research could be traced that has focused on the different kumite characteristics by using video analyzing technology. Therefore, the purpose of the present study was to determine the kumite characteristics of WKF (World Karate Federation) World Karate Senior Championships by making use of video analyzing technology.

METHODS

Experimental Approach to the Problem

The study was designed to analyse and describe the different kumite characteristics by analysing the video footage of the WKF World Karate Senior Championship finals of 2004 and 2006. The video footage of the different fights is commercially available and can therefore be purchased by the general public. In view of this, the research committee of the authors' institution did not deem it necessary to obtain ethical permission to conduct the research. The research methods and procedures of this study were however evaluated and approved by the research committee of the authors' institution before commencement of the study. Due to the limited number of finals for each competition year, it was decided to combine the finals of 2004 and 2006 to have a more desirable number of fights. The same rules applied, and competition conditions were experienced during 2004 and 2006. The video analysis method was preferred because of the real-time data that could be captured and the capability to use slow motion to detect different movements and techniques during the fighting periods. The Dartfish Team Pro video analysis software package (6) was used to do different analyses due to the wide range of features that can be used. These include, amongst other things: the capacity to break down movements for analysing different aspects; record the duration of different stadia of the fight and track the different limbs and body movements during the executions of various techniques. The design of the study was, therefore, an observational, descriptive and "ex post facto" design.

Subjects

Karatekas that participated in the kumite finals of the WKF World Karate Senior Championships during 2004 and 2006 were used in this study. All participants were 18 years or older. Eight fight finals in which 16 female karatekas and 19 fight finals in which 38 male karatekas participated were analysed. Kumite is divided into male and female divisions as well as into individual and

team events for each gender. Individuals competed according to different weight categories, which consisted of the following: males - u/60 kg, u/65 kg, u/70 kg, u/75 kg, u/80 kg, over 80 kg and open (any karateka could enter regardless of his weight); females - u/53 kg, u/60 kg, over 60 kg and open. Individuals could also compete as part of a team that comprised of three or five female or male participants. For purposes of this study two female fights of 2004 and four and three male fights of 2004 and 2006 respectively were analysed. Some of the fight finals were not analysed due to the unavailability of video footage. These include the following: 2004 - females over 60 kg and team kumite as well as males over 80 kg; 2006 – females u/53 kg.

Procedures

The same person analysed all the fights in order to prevent interpersonal variability in the different observations and interpretations of activities. Ten percent of all fights were randomly selected to be re-analysed so as to verify the accuracy of the original analysis. A re-analysis coefficient of $r = 0.9866$ was found when the re-analyses was performed. The person who analysed the different fights was a qualified sport scientist who has been participating in kumite at international level and who also had experience in evaluating and conditioning karatekas.

Each fight was analysed according to the different phases identified and the activities that took place in each phase. A phase commenced when the referee called out "shobu hajime" (start the fight) and one of the karatekas moved his/her foot over the line and ended when the referee called out "yame" (stop fighting) and both karatekas' feet were back behind the line. Each phase consisted of "attempts to score", which was subdivided into "pre" and "post-attack" as well as "attacking" moves. "Pre-attack" moves were classified as moves that took place from the time the referee called out "shobu hajime" up until the point when one of the karatekas moved his/her hand or foot in an attempt to score a point. "Attacking" (interactivity) moves were categorized as moves that started when the karateka attempted to score a point up to the point when the arm/leg

was fully extended, contact was made, a recoil action took place in preparation for another attack or the karateka started to move back to his/her original position. "Post attack" moves were defined as the moves that took place once the attacking moves were completed until the next attack began or until the referee called "yame" and both karatekas were behind their lines.

Every attack was also categorized according to the type of karate techniques and movement skills used in an attempt to score a point as well as the body area at which the attack was aimed. Three different punches, four different kicking techniques, three additional techniques, five types of foot movements and two attacking areas were identified. The name of each of these last-mentioned techniques and movements together with an explanation of each follow:

Punching techniques

- Gyaku tsuki: A punch executed with the hand on the opposite side of the front leg.
- Oi tsuki: A punch executed with the hand on the same side as the front foot and performed while stepping forward.
- Kizami tsuki: A punch executed by snapping the wrist of the hand that is on the same side as the front foot.

Kicking techniques

- Mawashi geri: A roundhouse kick performed with either the front leg (front mawashi geri) or back leg (back mawashi geri).
- Ushiro mawashi geri: A reverse roundhouse kick performed by the front or back foot. The foot starts the kick in front of the body and moves in a half circle outward towards the opponent.
- Mae geri: A front kick performed with the ball of the foot.
- Yoko geri: A side kick usually directed to the side and performed without turning the body.

Additional techniques

- Take down: Throwing techniques applied to take the opponent down.

- Leg sweep (ashi barai): A technique applied to throw the opponent off balance.
- Grab: A holding technique used to prevent the opponent form attacking. However, it is illegal to apply this technique.

Attacking areas

- Jodan: Attacks targeting the head and face area.
- Chudan: Attacks targeting the mid-stion (abdominal, lower back and chest area) of the body.

Foot movements

- Forward lunge: A forward movement with the front leg while the back leg stays static.
- Lead front leg shift: The front leg shifting forwards with the back leg following.
- Half step: The back foot moved next to the front foot and then the front foot moved forward to form the original fighting stance.
- Overstep: The back foot steps past the front foot into a fighting stance.
- Moving back: Backward movements used to obtain a better distance from the opponent.
- No foot movement: A term used for periods when no specific foot movements occur during the fight.

The term "not clear" was used to define periods when no techniques or movements could be identified due to the angle of the camera or other reasons. Movements that could be defined as fake moves (moves that were aimed at evoking reaction from the opponent) or as hopping movements were not used as markers to stop the time for the pre-attacking period.

The clock function of the Dartfish Team Pro video analysis software package was used to determine the duration of each fight, phase, "pre" and "post-attack" as well as the "interactivity period". The duration of each break between phases was also recorded.

In order to calculate the percentage contribution of each phase, the following formula was used: Percentage contribution = [(Average time duration of the pre-attack or interactivity or post-attack or break * n) / (Total n)] / [(Average time of the total phase * n) / (Total n)] * 100

n = the number of times the phase occurred, whereas the total n refers to the total number of fights analysed. To calculate the work:rest ratio, the mean value of the pre-attack, post-attack, interactivity and break phases were used in the following formula:

Work = [(Average time duration of the pre-attack * n) + (Average time duration of the interactivity * n) + (Average time duration of the post-attack * n)] / (Total n)

Rest = (Average time duration of the break * n) / (Total n)

n = the number of times the phase occurred, whereas the total n refers to the total number of fights analysed.

Statistical Analysis

The Statistical Consultation Services of the North-West University determined the statistical methods and procedures for analysing the research data. The Statistical Data Processing package (StatSoft Inc., 2007) was used to process the data. The descriptive statistics that were calculated included the means, standard deviations, minimum and maximum values for each of the variables.

RESULTS

The frequency of techniques, attacking areas and foot movements

The descriptive statistics of the different karate techniques, attacking areas and foot movements performed by each of the karatekas during the finals of the WKF World Karate Senior Championships are presented in Tables 1 and 2 respectively.

TABLE 1. Results of descriptive statistics of the female kumite characteristics (n = 16).

Variables	Total group (n =16) Mean ± SD	Total group (n =16) Min – max range
Score	1.69 ± 1.78	0.00 – 6.00
The number of initiated attacks	5.00 ± 3.16	1.00 – 12.00
Total number of techniques used	17.06 ± 7.84	6.00 – 30.00
Punching techniques		
Kizami tsuki	2.60 ± 1.64	1.00 – 7.00
Gyaku tsuki	8.25 ± 3.70	2.00 – 15.00
Oi tsuki	1.19 ± 1.22	0.00 – 4.00
Kicking techniques		
Front mawashi-geri	1.06 ± 1.98	0.00 – 8.00
Back mawashi-geri	0.75 ± 1.18	0.00 – 4.00
Ushiro mawashi geri	0.25 ± 0.58	0.00 – 3.00
Mae geri	0.19 ± 0.54	0.00 – 2.00
Yoko geri	0.25 ± 0.58	0.00 – 2.00
Additional techniques		
Grab	3.38 ± 2.63	0.00 – 9.00
Leg sweep	0.88 ± 1.82	0.00 – 7.00
Take down	0.50 ± 1.32	0.00 – 5.00
Attacking area		
Jodan	9.19 ± 5.36	2.00 – 20.00
Chudan	5.44 ± 2.78	2.00 – 12.00
Foot movements		
Lead front leg shift	2.56 ± 1.90	0.00 – 6.00
Forward lunge	2.00 ± 1.79	0.00 – 6.00
Half step	1.56 ± 1.86	0.00 – 6.00
Overstep	1.81 ± 1.47	0.00 – 5.00
Moving back	0.56 ± 1.09	0.00 – 5.00
No foot movement	2.88 ± 2.28	0.00 – 8.00
Not clear	0.19 ± 0.75	0.00 – 3.00

SD = Standard deviation, Min = Minimum, Max = Maximum

The techniques most frequently executed were the gyaku tsuki, followed by grabbing. The kicks were far less frequently used, with the front mawashi geri being the most popular kick. Kicks such as the mae geri and ushiro mawashi geri were so seldomly used that they were excluded from the study results. On average, female karatekas performed 17.06 techniques in total during a fight and only scored 1.69 points for the total amount of techniques performed. Female kumite karatekas therefore scored 9.9% of the time when executing different techniques. Only 29.3% (5 out of 17.06) of the average number of techniques performed were used to initiate attacks during each of the fights. No foot movements occurred for 2.88 times on average during fights. During periods when movements took place, the lead front leg shift and forward lunge movements were performed most frequently. Jodan was the most targeted area (9.19), while chudan was targeted less (5.44) compared to jodan.

TABLE 2. Results of the descriptive statistics of the male kumite characteristics (n = 38).

Variables	Total group (n=38) Mean ± SD	Total group (n =16) Min – max range
Score	3.11 ± 2.76	0.00 – 9.00
The number of initiated attack	6.89 ± 3.02	2.00 – 17.00
Total number of techniques used	24.21 ± 8.08	11.00 – 48.00
Punching techniques		
Kizami tsuki	4.32 ± 2.90	0.00 – 16.00
Gyaku tsuki	9.95 ± 5.13	2.00 – 26.00
Oi tsuki	0.37 ± 0.59	0.00 – 2.00
Kicking techniques		
Front mawashi geri	1.18 ± 1.83	0.00 – 9.00
Back mawashi geri	1.71 ± 2.31	0.00 – 10.00
Ushiro mawashi geri	0.58 ± 1.11	0.00 – 5.00
Mae geri	0.26 ± 0.72	0.00 – 4.00
Yoko geri	0.00 ± 0.00	0.00 – 0.00
Additional techniques		
Grab	4.26 ± 2.56	0.00 – 10.00
Leg sweep	0.58 ± 0.98	0.00 – 3.00
Take down	1.00 ± 1.76	0.00 – 9.00
Attacking area		
Jodan	12.89 ± 5.37	4.00 – 24.00
Chudan	5.74 ± 3.67	1.00 – 18.00
Foot movements		
Lead front leg shift	3.21 ± 2.09	0.00 – 9.00
Forward lunge	2.34 ± 2.03	0.00 – 8.00
Half step	2.00 ± 1.71	0.00 – 6.00
Overstep	2.24 ± 2.21	0.00 – 9.00
Moving back	0.32 ± 0.57	0.00 – 2.00
No foot movement	8.42 ± 4.23	2.00 – 20.00
Not clear	0.29 ± 0.57	0.00 – 2.00

SD = Standard deviation, Min = Minimum, Max = Maximum

Table 2 indicates that the techniques most frequently performed by the males were the gyaku tsuki followed by the kizami tsuki. Male karatekas made use of a smaller number of kicking techniques compared to females. The back mawashi geri was performed the most, while the mae geri was performed the least number of times. On average, male karatekas performed 24.21 techniques in total for each fight and scored 3.11 points. A scoring accuracy of 12.85% was therefore achieved for each of the techniques performed. Only 28.5% (6.89 out of 24.21) of the total number of executed techniques were, however, used to initiate attacks during fights. No foot movements occurred for 8.42 times on average during fights. During periods when movements took place, the lead front leg shift and forward lunge were performed most frequently. Jodan was the most targeted area (12.89), while chudan was targeted less than half the number of times (5.74) compared to jodan.

Time intervals

The descriptive statistics of the time intervals measured during the WKF World Karate Senior Championship kumite finals are presented in Tables 3 and 4 respectively.

TABLE 3. Results of the descriptive statistics of the time intervals measured for females during the WKF Senior Championship kumite finals (n=8).

	n	Mean ± SD	Min – max range	Percentage contribution
Phase time (s)	55	28.94 ± 16.14	5.92 – 92.44	
Pre-attack time (s)	83	9.38 ± 9.31	0.40 – 63.56	48.00%
Interactivity (s)	83	3.44 ± 2.59	0.52 – 13.60	17.20%
Post-attack (s)	56	4.64 ± 1.86	0.16 – 9.64	16.30%
Break (s)	50	5.37 ± 3.21	0.80 – 18.84	18.50%

n = total number, Min = Minimum, Max = Maximum

A phase lasted for 28.94 s on average with more or less half of the time spent on the pre-attack (9.38 s; 48% ((9.38*83/8)/(28.94*55/8)*100)); 18.50% (5.37 s) spent on breaks; 16.30% (4.64 s) spent on the post-attack and only 17.20% (3.44 s) spent on interactivities. The total duration of fights was 199 s (3.32 minutes) on average. Hence a work:rest ratio of 165.49 s:33.56 s, which relates to a ratio of 4.93:1 was observed.

TABLE 4. Results of the descriptive statistics of the time intervals that were measured for males during the WKF World Karate Senior Championship kumite finals (*n*=19).

	n	Mean ± SD	Min – max range	Percentage contribution
Phase time (s)	195	27.00 ± 18.27	7.92 – 133.30	
Pre-attack time (s)	267	9.45 ± 11.00	0.04 – 83.90	47.80%
Interactivity (s)	267	2.87 ± 2.62	0.00 – 27.80	14.50%
Post-attack (s)	194	4.34 ± 1.62	0.00 – 10.88	16.00%
Break (s)	195	5.81 ± 4.00	0.00 – 32.72	21.5%

n = Total number, Min = Minimum, Max = Maximum

A phase lasted for 27 s on average with more or less half of the time spent on the pre-attack (9.45 s; 47.8%); 21.5% (5.81 s) spent on breaks; 16% (4.34 s) spent on the post-attack and only 14.5% (2.87 s) spent on interactivities. The total duration of fights was 277.1 s (4.62 minutes) on average. Therefore a work:rest ratio of 217.44 s:59.62 s, which relates to a ratio of 3.65:1 was observed.

DISCUSSION

According to the authors, this is the first study to comprehensively analyse the techniques and movements performed, the attacking areas mainly targeted as well as the time intervals that occur during kumite at the WKF World Karate Senior Championships. A few studies have,

however, made use of simulated fights or standardized field and laboratory tests in an attempt to analyse and describe the kumite characteristics. The accuracy and relevance of data obtained by means of simulated fights and laboratory tests can be queried in view of the statement by Lehmann and Jedliczka (14) that inaccurate information arises from studies in which these methods are used.

One of the most significant findings from this investigation was that gyaku tsuki was the most frequently executed technique by both genders during kumite. Another punching technique, namely kizami tsuki, was the third most frequently applied technique among the karatekas. Karatekas are generally more inclined to score points by making use of fundamental punching techniques such as the gyaku tsuki and kizami tsuki due to the fact that the hands are much more agile than the feet (13). Furthermore, the gyaku tsuki and kizami tsuki are very fast and powerful punching techniques that do not require a high degree of skill and are usually taught to karatekas from a very young age (16). In view of these last-mentioned facts it is reasonable to assume that karatekas will therefore prefer to use punching techniques during kumite. Some of these results are in agreement with data of Lee and Ugyhara (13) who revealed that kizami tsuki was the most used and powerful technique in other martial art sports such as Jeet Kune Do.

A rather unexpected finding of the study was that grabbing was identified as the second most frequently applied technique during kumite among male and female karatekas. Despite the existence of a rule that prohibits grabbing between opponents, karatekas in this study frequently made use of grabbing. This may probably be related to the lack of foot movements observed in the study. The lack of foot movements suggests that the majority of attacks took place while the opponents were standing still and near to each other. A karateka would usually move towards the opponent to execute an attack. In situations where an attacker fails to score during the initial attack, it would be more beneficial to keep the distance between him-/herself and the defender

close, than for him/her to move backwards after the attack. A retreat would leave the attacker vulnerable for counter attacks. Grabbing would usually occur in situations where the gap between the two karatekas is very small; thus preventing the karatekas from attacking effectively. In these situations karatekas would rather grab each other and receive a warning than risk the chance of being scored against.

The results also demonstrated that the back mawashi geri was the only kicking technique executed more than once during male fights. On average, female karatekas executed the different kicking techniques for no more than once during the course of a fight. Due to the nature of the sport, it is reasonable to assume that kicking techniques will be executed more frequently during fights due to the large number of points that are awarded for successful execution of a kick compared to a punch. The same applies to the importance of take down techniques in scoring points. Take down techniques were, however, also used seldomly during fights. In view of this finding it is clear that male and female karatekas do not apply kicking and take down techniques during kumite. Kicking and take down techniques are far more difficult to perform due to the technical requirements and the difficulty in generating a large amount of speed and power continuously during execution (16), which may explain this observation. No other karate techniques displayed frequencies high enough to warrant further discussion.

The body area mostly targeted during the kumite was the face and head (jodan). The targeted body area will affect the number of points that karatekas score. Kicks to the mid section (chudan) will, for example, score two points, whereas kicks to the face or head (jodan) will score three points. Karatekas will therefore rather target the jodan than the chudan area to score points at a faster rate.

The lead front leg shift was the foot movement used most frequently in this study, followed by the forward lunge and then the overstep (see Table 1 and 2). The overstep (forward step) is a more advance foot movement and is more easily anticipated by opponents than other foot

movements (16). Karatekas will therefore seldom make use of this foot movement and would usually perform this movement after another foot movement. The forward lunge is a short, fast foot movement that is usually performed during quick attacks over a short distance. The forward lunge does not allow the karatekas to move over a great distance and does not put a karateka in an ideal position from which to execute karate techniques. On the other hand, the front leg shift is the most desirable foot movement due to the fact that a karateka can cover a huge distance in a short period of time and can easily perform any karate technique from this position. It is therefore not surprising that it was the most frequently used foot movement.

From the results it is also clear that both genders maintained poor scoring rates during the kumite finals. Female and male karatekas could only succeed in scoring 9.9% and 12.85% of the time respectively when executing different techniques. Furthermore, only 29.3% and 28.5% of the average number of techniques executed by the females and males respectively were used to initiate attacks during each of the fights. Several facts may have contributed to the low scoring rate, including ineffective execution of karate techniques, good evasive techniques by the opponents or the use of different fighting strategies. It was, for example, observed that a large number of karatekas used attacking techniques to defend themselves during fights. In the present study, only karatekas who reached the finals of the different World Championships were analysed, which may have influenced the scoring efficiency. Karatekas who have more experience in kumite will probably be able to better anticipate the attacking moves of their opponents and evade possible attacks, compared to less experienced competitors. This may also serve as a possible explanation for the low scoring rate.

With regard to the time intervals, the data showed that female fights lasted for 199 s compared to male fights that lasted 277.1 s. During the different phases which lasted between 27 and 28.94 s on average, more or less half (47.8% and 48%) of the time was spent on the pre-attack compared to 14.5% and 17.2% respectively spent on interactivities. Breaks lasted between 5.37

(18.5%) and 5.81 s (21.5%) per phase which led to a work:rest ratio of 4.93:1 and 3.65:1 for the females and males respectively. Previously, Iide et al. (10) revealed that a longer series of techniques are performed by karatekas during a 2-minute fight compared to a 3-minute fight, which may possibly serve as a explanation for the higher work:rest ratio calculated for the female participants. Another point to consider is the fact that the male karatekas' break durations were longer than those of the females. Breaks usually occur due to referee decisions and the awarding of points or penalties. The scoring rate of the males was 2.95% higher than that of the females which may explain the longer break periods. The work:rest ratio of the males was therefore decreased because of the longer durations of breaks.

What the different work:rest ratios and time intervals indicate, is that karatekas only spent a small amount of time (2.87–3.44 s) on the execution of high intensity, explosive types of movements during the different phases. Therefore the anaerobic alactic energy system will possibly be the major contributor during these types of movements (4). The anaerobic alactic energy system is usually depleted after 5 to 10 s of high intensity activities and needs at least 3 to 5 minutes to allow the resynthesis of high energy phosphates (4). During a fight the breaks in between two high intensity periods are usually too short for resynthesis of the relevant energy sources. Because of this the anaerobic lactic system will probably be the primary contributor of energy after the first high intensity period. The pre and post-attack phases usually consist of low intensity movements such as forward, backward and sideway hopping movements. The aerobic energy system will most probably play a primary role during the last-mentioned movements.

From the above-mentioned it is apparent that aerobic energy delivery is important for kumite performances. However, despite the fact that the anaerobic energy system does not play a primary role during participation in the kumite event, it is still an important energy source due to the fact that karatekas need to execute their techniques with high speed and explosive power if they wish to penetrate their opponents' defences. In this regard a previous study by Francescato

(7) on eight inexperienced karatekas (1-3 years of karate participation and 2 hours of training per week), indicated that the anaerobic energy system was predominantly used during karate. In contrast, Beneke et al. (3) showed that the aerobic energy system was the primary energy supplier during karate activities of nationally and internationally ranked karatekas. The work:rest ratio results in this study are not in agreement with those of Beneke et al. (3) who found a work:rest ratio of 2:1 for male karatekas. It is difficult to directly compare the work:rest ratio results of the present study with those of Beneke et al. (3), since their study analysed simulated karate fights and not real competition fights. In this regard Lehmann and Jedliczka (14) showed that karatekas performed 30-50% fewer techniques during simulated fights compared to real competition fights. The execution of fewer techniques may reduce the duration of the interaction phase and consequently affect the work:rest ratio.

Unfortunately the researchers in this study were unable to directly measure the intensities of different activities performed during kumite. It has previously been suggested that heart rate data can be used to determine the intensities of different activities (5). This would probably be advisable in cases where a more accurate determination of exercise intensities is warranted. Furthermore, it may be necessary to do an even more detailed analyses of the different foot movements executed during kumite. This would mean that the researchers must try to expand the list of possible foot movements so that more detailed analyses can be done. It would also be advisable to include all the fights of a kumite competition for analysis in a study of this kind instead of only the finals. A more accurate and representative profile of kumite characteristics will thus be obtained.

PRACTICAL APPLICATIONS

This study is the first to document the kumite characteristics of karatekas during WKF World Karate Senior Championships. The results of the present study suggest that gyaku tsuki and

kizami tsuki are the most frequently used techniques during kumite karate. Despite the fact that it is illegal to use grabbing during kumite, this technique was also identified as one of the most frequently used techniques by both genders during kumite. The application of kicking techniques such as the back mawashi geri was more relevant among male than female karatekas. Jodan was by far the most targeted area whereas no movements were observed the highest number of times when foot movements were analysed.

Seen from a practical point of view, it could therefore be suggested that coaches and sport scientists spend more training time on the execution of the punching techniques by simulating kumite competition conditions. Also, it would be beneficial for talented karatekas to develop evasion and blocking techniques for the jodan area, as this is the main targeted area. Moreover, grabbing seems to be a very important technique that needs to be developed for karatekas to obtain success in kumite. In spite of what is commonly believed, karatekas perform many of their attacking techniques while standing still. What this would imply is that coaches and sport scientists must teach karatekas how to perform different punching and kicking techniques from a static position. Despite the observation that kicking and foot movements were not frequently executed, the importance of these characteristics must not be underestimated. Karatekas who are able to apply kicking techniques successfully will be at an advantage in terms of scoring rate when compared with their opponents. Efficient and correct foot movements will also allow karatekas to obtain the best attacking position and evade the opponents successfully during attacks.

The importance of the aerobic energy system in contributing to the energy requirements of kumite was highlighted by the work:rest ratio of 4.93:1 and 3.65:1 that was calculated for the females and males respectively. Kumite karatekas conditioning programs must therefore primarily focus on aerobic activities performed continuously for fixed periods of time. In view of the fact that short periods (2.57-3.44 s) of high intensity, explosive type of movements are also

performed during kumite, the anaerobic alactic energy system cannot be neglected. Additionally, due to the limited rest periods in between high intensity activities, the anaerobic lactic system will also serve as an important energy contributor during kumite. This fact also needs to be considered during the set-up and execution of kumite conditioning programmes. What these results indicate, is that karatekas can no longer depend on the old traditional training methods, where karatekas only focus on the repetition of karate techniques to prepare them for the requirements of kumite, but need to consider and apply more modern techniques which make use of video analysis technology and the application of the results from these analyses in the periodization and se-up of conditioning programs

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CHAPTER 4

DISCRIMINANT ANALYSES OF KUMITE CHARACTERISTICS USING VIDEO ANALYSES DURING THE WKF CHAMPIONSHIP FINALS

TITLE: DISCRIMINANT ANALYSES OF KUMITE CHARACTERISTICS USING VIDEO ANALYSES DURING THE WKF CHAMPIONSHIP FINALS

RUNNING HEAD: DISCRIMINANT ANALYSES OF KUMITE CHARACTERISTICS

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ABSTRACT

The purpose of this study was to determine the kumite characteristics that significantly discriminate between successful (winners) and less successful (losers) karatekas of the 2004 and 2006 WKF World Karate Senior Championships, when making use of video analyses. Eight female and 19 male final fights were analyzed by means of the Dartfish Team Pro video analysis software package. The kumite characteristics identified as the primary, significant discriminators by the standard and forward discriminant analyses were gyaku tsuki and kizami tsuki for the males and gyaku tsuki for the females, respectively. Both chudan and jodan target areas were identified as significant discriminators for the males whereas target area was not identified as a significant discriminator among the female karatekas. The number of initiated attacks was also a statistically significant discriminator in the case of the male karatekas. In conclusion it was found that the number of initiated attacks, punching techniques and the target area were the significant discriminators between successful and less successful kumite karate groups. Gender differences were also observed with regard to the different discriminators.

KEY WORDS karate, karate competitions, video analyses, karate techniques

INTRODUCTION

Fundamentally, karate can be described as a weaponless fighting method during which blocking and striking techniques are used (6). Karate tournaments are divided into two main divisions, namely kata (set sequence of movements) and kumite (fighting). Competition kumite can primarily be described as a semi-contact fighting event during which two opponents are freely moving on an 8 x 8 m World Karate Federation (WKF) approved mat while wearing WKF approved protective gear. Participants receive a three-minute period in the case of men and two minutes in the case of women to score as many points as possible by applying different kicking and punching techniques.

Karate and especially kumite has, like other sports codes, become more physically demanding, since the focus during competition has shifted more towards winning and attaining success. This shift in focus has resulted in new training methods and the use of modern technology in an attempt to gain a leading edge in the competitive world. The physical performance of individuals is evaluated on a regular basis to determine the strengths and weaknesses of the participants and the effectiveness and functionality of the training programmes (16). Several researchers have made use of laboratory oriented tests such as the vertical jump test, medicine ball throw test and standing on a bench eyes closed test as well as specific motor ability tests to evaluate karatekas' physical performance abilities (2,3,19). However, Lehmann and Jedlicka (14) have stated that the accuracy and relevance of these types of tests can be questioned, since they found that karatekas' level of exertion is much lower in simulated tests (such as laboratory tests) than in real competition fights. It has also been proven that athletes must be evaluated as sport specifically as possible due to the detrimental effect that inaccurate data and feedback may have on the athlete's preparation and success.

The need for real time and detailed kinematic analyses in identifying and discriminating the kumite characteristics of WKF Championships can therefore not be underestimated. The detail of

very fast and complex movements, which are often executed by elite karatekas during the karate championships, cannot be tracked and processed by the human eye and brain (15). However, with the Dartfish video analysis software package it is now possible to analyse a sport such as kumite karate accurately. Despite the availability of this and other similar products, only a handful of researchers have used this technology to identify the characteristics that are distinctive of more successful kumite karatekas.

In this regard Nakayama (20) already made use of video analyses during the early nineteen sixties and concluded that the speed of the choku tsuki (straight punch) and oi tsuki (step and punch) was faster for experienced karatekas than for beginners. Furthermore, Sforza et al. (20) found that the karatekas who were able to keep their centre of gravity parallel to the ground when moving were more effective in terms of technique execution compared to others. Cesari and Bertucco (3) also concluded that karatekas who wish to be successful in kumite need to maintain the correct position and distance from the opponent to attack at a precise moment with the correct timing of movements. The fighting distance does, however, depend on the karatekas' body type, limb lengths, technique preferences and fighting strategy (1).

Despite the above-mentioned research findings, no research has thus far attempted to identify the kumite characteristics of WKF Championships that discriminate between different levels of karatekas by making use of video analysing technology. Therefore, the purpose of the present study was to determine the kumite characteristics of the WKF Senior World Karate Championships that discriminate significantly between the successful and less successful karatekas by using video analyses. The results of this study may possibly provide coaches, sport scientists and other related professionals (eg. coaches) with important knowledge concerning the exact characteristics needed to achieve success in kumite karate. It can also help professionals to develop and refine their training programmes and testing protocols.

METHODS

Experimental Approach to the Problem

The study was designed to determine the kumite characteristics that discriminated between successful (winner) and less successful (looser) kumite karatekas that participated in the finals of the WKF World Karate Senior Championships of 2004 and 2006 by making use of video analysing technology. The video footage of the different fights is commercially available and can therefore be purchased by the general public. In view of this, the research committee of the authors' institution did not deem it necessary to obtain ethical permission to conduct the research. The research methods and procedures of this study were however evaluated and approved by the research committee of the authors' institution before commencement of the study. Due to the limited number of finals for each competition year, it was decided to combine the finals of 2004 and 2006 to have a more desirable number of fights. The same rules applied, and competition conditions were experienced during 2004 and 2006. The video analysis method was preferred because of the real-time data that could be captured and the capability to use slow motion to detect different movements and techniques during the fighting periods. The Dartfish Team Pro video analysis software package (5) was used to do different analyses due to the wide range of features that can be used. This includes, amongst other things, the capacity to break down movements for analysing different aspects; record the duration of different sections of the fight and track the different limbs and body movements during the executions of various techniques. The design of the study was, therefore, an observational, descriptive and "ex post facto" design.

Subjects

Competitive karatekas that participated in the kumite finals of the WKF World Karate Senior Championships during 2004 and 2006 were used in this study. All participants were 18 years or

older. Eight fight finals in which 16 female karatekas and 19 fight finals in which 38 male karatekas participated were analysed. The kumite is divided into male and female divisions as well as into individual and team events for each gender. Individuals competed according to different weight categories which comprise the following: males - u/60 kg, u/65 kg, u/70 kg, u/75 kg, u/80 kg, over 80 kg and open (any karateka could enter regardless of his weight); females - u/53 kg, u/60 kg, over 60 kg and open. Individuals could also compete as part of a team that consisted of three or five female or male participants. Some of the fight finals were not analysed due to the unavailability of video footage. These included the following: 2004 - females over 60 kg and team kumite as well as males over 80 kg; 2006 – females u/53 kg.

Procedures

The same person analysed all the fights in order to prevent interpersonal variability in the different observations and interpretations of activities. Ten percent of all fights were randomly selected to be re-analysed so as to verify the accuracy of the original analysis. A re-analyses coefficient of $r = 0.9866$ was found when the re-analyses were performed. The person who analysed the different fights was a qualified sport scientist who has been participating in kumite at international level and who also had experience in conditioning and evaluating karatekas.

The Dartfish Team Pro video analysis software package was used to analyse the video footage of the 27 kumite finals. Every attack was categorised according to the type of karate techniques and movement skill that were used in an attempt to score a point as well as the body area at which the attack was aimed. Three different punches, four different kicking techniques, three different additional techniques, five types of foot movements and two target areas were identified. The name of each of these last-mentioned techniques and movements together with an explanation of each are as follow:

Punching techniques

- Gyaku tsuki: A punch executed with the hand on the opposite side of the front leg.
- Oi tsuki: A punch executed with the hand on the same side as the front foot and performed while stepping forward.
- Kizami tsuki: A punch executed by snapping the wrist of the hand that is on the same side as the front foot.

Kicking techniques

- Mawashi geri: A roundhouse kick performed with either the front leg (front mawashi geri) or back leg (back mawashi geri).
- Ushiro mawashi geri: A reverse roundhouse kick performed by the front or back foot. The foot starts the kick in front of the body and moves in a half circle outward towards the opponent.
- Mae geri: A front kick performed with the ball of the foot.
- Yoko geri: A side kick usually directed to the side and performed without turning the body.

Additional techniques

- Take down: Throwing techniques used to take the opponent down.
- Leg sweep (ashi barai): A technique used to throw the opponent off balance.
- Grab: An illegal holding technique used to prevent the opponent from attacking.

Target areas

- Jodan: Attacks targeting the head and face area.
- Chudan: Attacks targeting the mid-section (abdominal, lower back and chest area) of the body.

Foot movements

- Forward lunge: A forward movement with the front leg while the back leg stays static.
- Lead front leg shift: The front leg shifting forwards with the back leg following.

- Half step: The back foot moves next to the front foot and then the front foot moves forward to form the original fighting stance.
- Overstep: The back foot steps past the front foot into a fighting stance.
- Moving back: Backward movements used to obtain a better distance from the opponent.
- No movement: A term used for periods when no specific foot movements occur during the fight.

The term "not clear" was used to define periods when no techniques or movements could be identified due to the angle of the camera or other reasons. Furthermore, the frequency of initiating attacks as well as the competitor who initiated each of the attacks were also noted as "the number initiated attacks"

Statistical Analysis

The Statistical Consultation Services of the North-West University determined the statistical methods and procedures for analysing the research data. The Statistical Data Processing package (20) was used to process the data. Firstly, descriptive statistics of each variable for each of the fights analysed were calculated. Secondly, standard discriminant analyses were performed to determine the variables that discriminated most between the successful (winners of the finals) and less successful (losers of the finals) group of karatekas. Forward stepwise discriminant analyses were then performed on the variables which emerged from the standard discriminant analyses as strong discriminators. Finally, a classification matrix was compiled for the groups of karatekas to indicate which percentage of the karatekas could be classified back into their respective groups by means of the prediction functions. The level of significance was set at $p \leq 0.05$.

RESULTS

The descriptive statistics of the different karate techniques and movements performed by the different groups and genders of karatekas are presented in Tables 1 and 2, respectively.

TABLE 1. Results of the descriptive statistics of the kumite characteristics of the total group (n = 16), successful (n = 8) and less successful (n = 8) groups of female karatekas.

	Total group	Successful group	Less successful group
	Mean ± SD	Mean ± SD	Mean ± SD
Score	1.69 ± 1.78	2.60 ± 1.92	0.80 ± 1.04
The number of initiated attacks	5.00 ± 3.16	5.40 ± 3.16	4.60 ± 3.34
Total number of techniques used	17.06 ± 7.84	18.50 ± 8.37	15.60 ± 7.54
Punching techniques			
Kizami tsuki	2.60 ± 1.64	2.70 ± 2.21	2.50 ± 1.07
Gyaku tsuki	8.25 ± 3.70	10.40 ± 3.24	6.10 ± 2.70
Oi tsuki	1.19 ± 1.22	1.50 ± 1.51	0.90 ± 0.83
Kicking techniques			
Front mawashi geri	1.06 ± 1.98	0.50 ± 0.76	1.60 ± 2.67
Back mawashi geri	0.75 ± 1.18	0.25 ± 0.46	1.25 ± 1.49
Additional techniques			
Grab	3.38 ± 2.63	3.50 ± 2.88	3.30 ± 2.55
Target area			
Jodan	9.19 ± 5.36	10.00 ± 5.76	8.40 ± 5.18
Chudan	5.44 ± 2.78	5.60 ± 3.11	5.30 ± 2.60
Foot movements			
Lead front leg shift	2.56 ± 1.90	3.10 ± 1.73	2.00 ± 2.00
Forward lunge	2.00 ± 1.79	2.60 ± 2.00	1.40 ± 1.41
Half step	1.56 ± 1.86	1.50 ± 1.93	1.60 ± 1.92
Overstep	1.81 ± 1.47	2.60 ± 1.41	1.00 ± 1.07
No foot movement	2.88 ± 2.28	3.00 ± 2.07	2.80 ± 2.60

SD = Standard deviation

The results of the females indicate that the successful group achieved higher values for thirteen of the kumite characteristics when compared with the less successful group. The less successful group achieved higher average values for only three of the kumite characteristics, namely the front and back mawashi geri as well as the half step.

TABLE 2. Results of the descriptive statistics of kumite characteristics of the total (n = 38), successful (n = 19) and less successful (n = 19) groups of male karatekas.

Variables	Total group Mean ± SD	Successful group Mean ± SD	Less successful group Mean ± SD
Score	3.11 ± 2.76	4.68 ± 2.58	1.53 ± 1.93
The number of initiated attacks	6.89 ± 3.02	7.68 ± 3.35	6.11 ± 2.49
Total number of techniques used	24.21 ± 8.08	23.79 ± 7.85	24.63 ± 8.49
Punching techniques			
Kizami tsuki	4.32 ± 2.90	4.42 ± 3.55	4.21 ± 2.15
Gyaku tsuki	9.95 ± 5.13	10.58 ± 5.49	9.32 ± 4.80
Oi tsuki	0.37 ± 0.59	0.42 ± 0.69	0.32 ± 0.48
Kicking techniques			
Front mawashi geri	1.18 ± 1.83	0.89 ± 0.94	1.47 ± 2.41
Back mawashi geri	1.71 ± 2.31	1.42 ± 2.34	2.00 ± 2.31
Ushiro mawashi geri	0.58 ± 1.11	0.42 ± 1.02	0.74 ± 1.19
Mae geri	0.26 ± 0.72	0.11 ± 0.32	0.42 ± 0.96
Additional technique			
Grab	4.26 ± 2.56	3.95 ± 2.46	4.58 ± 2.69
Leg sweep	0.58 ± 0.98	0.63 ± 1.01	0.53 ± 0.96
Take down	1.00 ± 1.76	0.95 ± 1.47	1.05 ± 2.04
Target area			
Jodan	12.89 ± 5.37	12.89 ± 4.54	12.89 ± 6.22
Chudan	5.74 ± 3.67	5.53 ± 4.01	5.95 ± 3.39
Foot movement			
Lead front leg shift	3.21 ± 2.09	3.32 ± 2.06	3.11 ± 2.18
Forward lunge	2.34 ± 2.03	2.63 ± 2.29	2.05 ± 1.75
Half step	2.00 ± 1.71	1.89 ± 1.73	2.11 ± 1.73
Overstep	2.24 ± 2.21	2.37 ± 2.39	2.11 ± 2.08
Moving back	0.32 ± 0.57	0.16 ± 0.37	0.47 ± 0.70
No movement	8.42 ± 4.23	8.00 ± 3.90	8.84 ± 4.61
Not clear	0.29 ± 0.57	0.26 ± 0.45	0.32 ± 0.67

SD = Standard deviation

For the males, only nine kumite characteristics obtained higher values for the successful group compared to the less successful group. Both groups used the same number of attacks to the jodan area, whereas the less successful group obtained higher values in twelve of the kumite characteristics, which are total techniques, front and back mawashi geri, grab, chudan, half step, moving back, no movement, not clear, take down, ushiro mawahsi geri and mae geri.

The standard discriminant analysis results of the females are presented in Table 3.

TABLE 3. Standard discriminant analysis of the female kumite characteristics.

Variables	F value	P value
The number of initiated attacks	0.86	0.40
Gyaku tsuki	2.23	0.20
Kizami tsuki	0.05	0.83
Grab	0.45	0.53
Jodan	0.54	0.49
Chudan	0.26	0.63
Lead front leg shift	0.01	0.93
Forward lunge	0.73	0.43
No foot movement	0.41	0.55

From the statistical analysis, nine variables were identified as the primary kumite characteristics that are responsible for the difference between the two groups of female karatekas which include the following: the number of initiated attacks, gyaku tsuki, kizami tsuki, grab, jodan, chudan, lead front leg shift, forward lunge and no movement. No significant results were, however, obtained.

In a further analysis of the data, a forward stepwise discriminant analysis was performed to determine which variables contribute most to group separation. The results of this analysis are presented in Table 4.

TABLE 4. Forward stepwise discriminant analysis of the female kumite characteristics.

Variables	F value	P value
Gyaku tsuki	13.64	0.0035*
Kizami tsuki	3.30	0.0965
Lead front leg shift	1.86	0.2002

* Significant discriminator ($p \leq 0.05$)

The results of the forward stepwise discriminant analysis indicate that only three variables served as the primary discriminators between the successful and less-successful female kumite karatekas. They are gyaku tsuki, kizami tsuki and lead front leg shift. Only gyaku tsuki did, however, serve as a statistically significant discriminator.

The following functions emerged from the above-mentioned discriminant analysis:

Group 1 (Successful group) = 2.03265 (Gyaku tsuki) – 0.98024 (Kizami tsuki) – 0.99154 (Lead front leg shift) – 9.05324

Group 2 (Less successful group) = 0.74590 (Gyaku tsuki) + 0.14190 (Kizami tsuki) – 0.18256 (Lead front leg shift) – 2.90774

The results of the classification matrix, which was compiled by making use of the above-mentioned functions, are presented in Table 5.

TABLE 5. Classification matrix of the female kumite characteristics.

Group classification	Percentage correct	Group 1	Group 2
Group 1 (Successful)	100.00	7	0
Group 2 (Less successful)	87.50	1	7
Total	93.33	8	7

The results of the classification matrix show that the prediction functions are 93.33% accurate in classifying the female karatekas back into their respective groups.

The standard discriminant analysis results of the male karatekas are presented in Table 6.

TABLE 6. Standard discriminant analysis of the male kumite characteristics.

Variables	F value	P value
The number of initiated attacks	18.40	0.0003*
Kizami tsuki	5.32	0.0304*
Gyaku tsuki	9.99	0.0044*
Front mawashi geri	3.82	0.0630
Back mawashi geri	0.95	0.3398
Grab	1.56	0.2236
Jodan	6.49	0.0180*
Chudan	7.40	0.0122*
Lead front leg shift	0.59	0.4506
Forward lunge	0.91	0.3495
Half step	1.76	0.1972
No foot movement	1.37	0.2532
Overstep	2.20	0.1516
Take down	0.37	0.5470

* Significant discriminators ($p \leq 0.05$)

From the statistical analysis, fourteen variables were identified as the primary kumite characteristics responsible for the difference between the two groups of male karatekas, which include the following: the number of initiated attacks, gyaku tsuki, kizami tsuki, front and back mawashi geri, grab, jodan, chudan, lead front leg shift, forward lunge, half step, no movement, overstep and take down. Five of the above-mentioned variables did produce significant *P*-values. They are the number of initiated attacks, gyaku tsuki, kizami tsuki, jodan and chudan.

The results of the forward stepwise discriminant analysis are presented in Table 7.

TABLE 7. *Forward stepwise discriminant analysis for male kumite techniques.*

Variables	F value	P value
The number of initiated attacks	13.12	0.0010*
Chudan	10.85	0.0024*
Gyaku tsuki	10.21	0.0031*
Jodan	9.56	0.0041*
Kizami tsuki	2.02	0.1652

* Significant discriminators ($p \leq 0.05$)

The results of the forward stepwise discriminant analysis indicate that five variables were identified as the primary discriminators between the two groups of karatekas. They are the number of initiated attacks, gyaku tsuki, jodan, chudan and kizami tsuki. The first four named variables produced significant F-values.

The following functions emerged from the above-mentioned discriminant analysis:

Group 1 (Successful group) = 0.84933 (The number initiated attacks) – 0.14112 (Chudan) + 0.39873 (Gyaku tsuki) – 0.05607 (Jodan) + 0.37840 (Kizami tsuki) – 6.15045

Group 2 (Less successful group) = 0.16680 (The number initiated attacks) + 0.43200 (Chudan) – 0.08063 (Gyaku tsuki) + 0.43388 (Jodan) + 0.11762 (Kizami tsuki) – 5.15637

The results of the classification matrix are presented in Table 8.

TABLE 8. *Classification matrix of the male kumite characteristics.*

Group classification	Percentage correct	Group 1	Group 2
Group 1 (Successful)	84.21	16	3
Group 2 (Less successful)	73.68	5	14
Total	78.95	21	17

The classification matrix showed a 78.95% accuracy in classifying the male karatekas back into their respective groups.

DISCUSSION

According to the authors, no studies have thus far made an attempt to identify the main kumite characteristics that act as discriminators between successful and less successful karatekas. It is therefore difficult to compare the results of the present study with that of others. The results do, however, suggest that punching techniques such as the gyaku tsuki and kizami tsuki are some of the primary discriminators between successful and less successful kumite karatekas of both genders. Gyaku tsuki was the only statistically significant punching technique discriminator for females and for males, the gyaku tsuki and kizami tsuki. Some of these results are in accordance with those previously reported by Katic et al. (12) who found that kizami tsuki was the only technique that had a very favourable impact on the overall success of karatekas. Lee and Uyehara (13) also stated that kizami tsuki was the most used and powerful technique in other martial art sports such as Jeet Kune Do. Both the gyaku tsuki and kizami tsuki are very fast and powerful punching techniques that do not require a high degree of skill and form the basis of most karatekas' technique repertoire. Furthermore, Lee and Uyehara (13) previously found that the hands are much more agile than the feet in karate and would therefore be more frequently used during kumite attacks. This would suggest that karatekas are generally more inclined to score points by making use of fundamental punching techniques such as the kizami tsuki and gyaku tsuki, than of other techniques.

Despite this observation, punching techniques are low scoring techniques due to the fact that only one point can be scored at a time during a successful execution of a punch. It is therefore reasonable to think that kicking or take down techniques, which are normally high scoring techniques (up to three points for a successful execution), would also act as primary discriminators between successful and less successful karatekas. The front and back mawashi geri were, however, identified as non-significant discriminators between the two groups of male karatekas in the standard discriminant analysis and were not identified as discriminators in the

forward stepwise discriminant analysis. No kicking technique emerged as a primary discriminator between women kumite karatekas in any of the analyses. Kicks are much more difficult to perform due to the technical requirements and the difficulty in generating a high amount of speed and power continuously during execution (18), which may explain this result together with the observation that a low frequency of kicks were performed during the different fight finals. A rather unexpected result of the study was that the less successful group performed a higher frequency of kicks during the kumite finals than the successful group. The conclusion of Lee and Uyehara (13), who observed that karatekas used kicks, especially kicks from the front leg, as defensive techniques to maintain distance between themselves and the opponent, may explain this result.

Karate techniques used during fighting are, however, not the only variables determining the final score. The body area targeted during the fight will also affect the number of points accumulated by a participant (22). Kicks to the mid section (chudan) will, for example, score two points, whereas kicks to the face or head (jodan) will score three points (22). Both chudan and jodan were identified as significant discriminators for the males in the standard and forward stepwise discriminant analyses, which emphasises the importance of the target area in determining success in the male gender group. A common strategy that karatekas use, is to initially attack the face or head (jodan), which will likely force the opponent to move his/her hands over the face (1). The opening that is then created can be exploited by targeting the mid-section of the body (chudan). This strategy can also be reversed by first targeting the mid-section and then focusing the attacks to the head or face (jodan) (1). The target area was, however, not identified as a significant discriminator among the female karatekas.

Karatekas, who wish to be effective and successful in executing the different punching and kicking techniques need to be able to perform different foot movements successfully (13,18,8,6,11). Despite the importance of foot movements, no research has thus far focused on

the differences between the footwork of successful and less successful karatekas. The results of the standard discriminant analysis did, however, reveal that the lead front leg shift and forward lunge are non-significant discriminators between successful and less successful female karatekas. The lead front leg shift was also identified as a non-significant discriminator for the female group in the forward stepwise discriminant analysis. The foot movements that were identified as non-significant discriminators among males by the standard discriminant analysis are the lead front leg shift, the forward lunge and overstep. None of the variables were, however, identified as discriminators in the forward stepwise discriminant analysis. These research results indicate that foot movements were absent during the majority of attacks and that several of the attacks took place while the two opponents were standing still. The distance between the opponents needs to be closed in order to execute an attack. However, once the distance is closed by either making use of the lead front leg shift or forward lunge, the karatekas are forced to maintain their position in view of the fact that a backward move would place them in a vulnerable position for counterattacks. The only option they then have is to perform a couple of techniques or to grab the opponent. This may also explain why karatekas performed such a large number of techniques for a small number of points that were scored.

Another variable which emerged as an important discriminator between the different gender groups was the number of initiated attacks. Only the males did, however, show a statistically significant result. According to Frank (7), the competitors who normally initiate attacks by making use of different techniques will usually be the competitors who have more self-confidence, are more determine to win and show better anticipation, which may explain the emergence of this variable as a primary discriminator.

A number of differences were observed between the discriminant analysis results of the male and female karatekas. These results may be explained by the difference in the total duration of fights between the two genders. Similar findings regarding the frequency of techniques executed

for the two-minute compared to the three-minute fights were observed by Iide et al. (8). The number of fights analysed for each of the genders may also have influenced the discriminant analysis results. Only eight fights of the females were analysed, compared to nineteen fights for the males.

For future research it may be necessary to expand the scope of this study so that the elimination rounds of the WKF World Karate Senior Championships, are also included for possible analyses. The profile of the kumite discriminators will probably differ between the finals and the elimination rounds. The analyses of the elimination rounds will provide researchers with a better and more accurate picture of the discriminant profiles of kumite karatekas. Also, these results are related to kumite techniques, attacking areas and movements and not to the physiological requirements or profile of elite kumite karatekas. It would therefore be advisable to also include physiological parameters as variables in a study of this nature. Nevertheless, the study highlights the critical role of different karate techniques, attacking areas and certain movements in kumite performances.

PRACTICAL APPLICATIONS

This study is the first to document the kumite characteristics that discriminate between successful and less successful karatekas during competition fighting. The main findings of this study were that the number of initiated attacks, the punching techniques (kizami tsuki and gyaku tsuki) and the target area (jodan and chudan) were the most important discriminators between successful and less successful kumite karateka groups. Seen from a practical point of view, the results of the present study firstly suggest that coaches, sport scientists and conditioners must focus their attention more on karatekas' ability to make use of different techniques to initiate attacks. As mentioned before, the karatekas who are usually more inclined to initiate attacks are those who have the highest self-confidence levels and who can anticipate the opponent's next

move more accurately. In view of this it would probably be advisable to include sport psychologists and biomechanical analysts in the team that are responsible for the karatekas' preparations. The last-mentioned personnel may assist the karatekas in improving their self-confidence and in identifying certain "clues" opponents provide before the execution of certain movements so that they can anticipate potential attacks better.

Secondly, the results emphasised the importance of punching techniques in attaining success when participating in kumite at international level. Repetitive training will allow karatekas to perfect these techniques, but will probably not be enough to prepare the karatekas for kumite competitions. Coaches also need to subject karatekas to simulated and real fights to perfect these techniques in competition situations. Despite the observation that kicking techniques and foot movements did not emerge as significant discriminators between the kumite groups, the importance of these characteristics must not be underestimated. Kicking techniques are high-scoring techniques, but due to difficulty in performing these techniques successfully, karatekas will often revert to the simple punching techniques. Karatekas who have perfected these techniques will, however, be at an advantage in terms of scoring rate. Foot movements form the foundation for most of the kicking and punching techniques executed during kumite championships. Correct and efficient foot movements will allow karatekas to obtain the best attacking positions and evade the opponent when attacks are being launched.

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CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. Summary
2. Conclusions
3. Recommendations

1. SUMMARY

The purpose of the study was firstly to determine the kumite characteristics of WKF (World Karate Federation) World Karate Senior Championships by making use of video analyses. Secondly, to determine which of the WKF World Karate Senior Championship kumite characteristics discriminate significantly between successful (winners) and less successful karatekas (losers) when making use of video analyses. Chapter 1 provided a brief summary of the problem that underlies the research question of the study, the research question itself, the objectives and hypotheses of the study as well as the structure of the dissertation.

A literature overview titled "The use of video analyses to identify kumite characteristics", was presented in Chapter 2. The purposes of this literature overview was to provide the sport fraternity with a brief scientific background concerning the origin of karate, an explanation of kumite and the most commonly used techniques and movement skills in this category of karate; the physiological characteristics of the sport; and finally, information on the use and benefits of video analysing technology in identifying kumite characteristics. The overview revealed that the French began a world organization and hosted the first international kumite championship. It further pointed out that kumite was described as a semi-contact fighting event during which two opponents move freely on a 8x8m WKF-approved mat wearing WKF-approved protective gear. Men receive three minutes and women two minutes to score as many points as possible. According to the literature the different punching and kicking techniques as well as movement skills most commonly used during kumite are gyaku tsuki, oi tsuki and kizami tsuki (punching techniques); the front and back mawashi geri, ushiro mawashi geri, mae geri and yoko geri (kicking techniques); the leg sweep, take down and grab (additional techniques) as well as half or double steps, shifts, forward lunge, side stepping, forward, backward and side-way hopping movements (movement skills).

What the literature seems to suggest in terms of the physiological characteristics of kumite is that the aerobic energy system is the primary energy supplier with the anaerobic energy system playing a smaller role in terms of energy contribution to kumite. A work:rest ratio of two to one was also observed by researchers when kumite was analysed. It was, however, concluded that the physiological requirements of kumite need to be evaluated in view of the fact that the duration of kumite has been increased.

Only a small number of research papers have focused on the use and benefits of video analysing technology in identifying characteristics among karatekas. The available research indicated that video analysing technology is especially used to analyse the detail of very fast and complex movements which are often executed by elite athletes and cannot be traced or processed effectively enough by the human eye or brain. This type of technology therefore allows karatekas to identify opponents' strong and weak points as well as the techniques mostly used in order to prepare and train better for competitions. Several researchers have also attributed the success of Taekwondo to, among other things, video analyzing technology.

Chapter three comprises the first article, titled "Kumite characteristics of WKF Championships as determine by means of video analyses". The purpose of this article was to determine the kumite characteristics of WKF World Karate Senior Championships by making use of video analyses. One of the most significant findings from this article was that among both genders, gyaku tsuki was the most frequently executed technique, followed by grabbing and kizami tsuki. The results on the grabbing technique were unexpected and can probably be attributed to the lack of foot movements observed in the study. Both take down and kicking techniques were, however, used seldomly during fights. No other karate techniques emerged as frequently executed techniques during the kumite championships. The body area mostly targeted during kumite was jodan, while the lead front leg shift, followed by the forward lunge and the overstep were the most frequently used foot movements. Poor scoring rates of 9.9% and 12.85% were observed for the female and male karatekas respectively. Furthermore, only 29.3% and 28.5% of the average number of techniques executed by the females and males, respectively were used to initiate attacks during the fights. With regard to time intervals, the recordings showed that female fights lasted 199s compared to male fights that lasted 277.1s. During the different phases which, on average, lasted between 27 and 28.9s for men and women fighters respectively, more or les half of the time was spent on the pre-attack compared to 14.5% and 17.2% respectively spent on interactivities. Breaks lasted between 5.37 (18.5%) and 5.81s (21.5%) per phase. This led to a work:rest ratio of 4.93:1 for females and 3.65:1 for males. From the different work:rest ratio and time intervals, it can be assumed that the aerobic energy system is the primary energy contributor for kumite performances, followed by the anaerobic energy system. In conclusion, the results demonstrated that video analyzing technology can be used effectively to determine the characteristics of kumite.

The second article, titled "Discriminant analyses of kumite characteristics using video analyses during the WKF championship finals" was presented in Chapter 4. The purpose of this article was to determine the kumite characteristics that discriminate significantly between successful and less successful karatekas when making use of video analyses. The kumite characteristics identified by means of the results of Chapter 3 were included in the discriminant analyses functions. The results revealed that gyaku tsuki was the only statistical significant punching technique discriminator for females and, the gyaku tsuki and kizami tsuki for males. The front and back mawashi geri were the only kicking techniques emerging as non-significant discriminators in the male groups while no kicking techniques emerged as a discriminator in the female kumite karatekas in any of the analyses. Both chudan and jodan were identified as significant discriminators for the male karatekas, whereas target area was not identified as a significant discriminator among the female karatekas. With regard to foot movements, the lead front leg shift was identified as a non-significant discriminator in both discriminant analyses and the forward lunge as a non-significant discriminator in the standard discriminant analyses for females. The lead front leg shift, the forward lunge and overstep were only identified by the standard discriminant analyses as non-significant discriminators in the case of the male karatekas. Another variable which emerged as an important discriminator between the different gender groups was the number of initiated attacks. Only the males did, however, reveal a statistically significant result for this variable. To conclude, it was found that the number of initiated attacks, the punching techniques (kizami tsuki and gyaku tsuki) and the target area (jodan and chudan) were the most important discriminators between successful and less successful karateka groups during WKF Championship kumite. Gender differences were also observed with regard to discriminators of successful and less successful karatekas.

Both articles were included in this dissertation and were compiled in accordance with the guidelines of the Journal of Strength and Conditioning Research.

2. CONCLUSIONS

The conclusions drawn from this research are presented in accordance with the set hypotheses in Chapter 1.

- **Hypothesis 1:** Due to the descriptive and explorative nature of the first objective, no hypothesis was set. The researcher will therefore not commentate on the outcome of the first article. It can, however, be concluded that punching techniques are more frequently executed among kumite karatekas during international kumite competitions. Furthermore, it was observed that jodan is the most targeted area and no movement occurred the highest number of times when foot movements were analysed. The importance of the aerobic energy system in contributing to the energy requirements of kumite was highlighted by the calculated work:rest ratio of 4.93:1 and 3.65:1 for the female and male karatekas respectively. The occurrence of short periods (2.57 – 3.44s) of high intensity, explosive type of movements during kumite also accentuated the importance of the anaerobic energy system in contributing to the energy requirements of kumite.

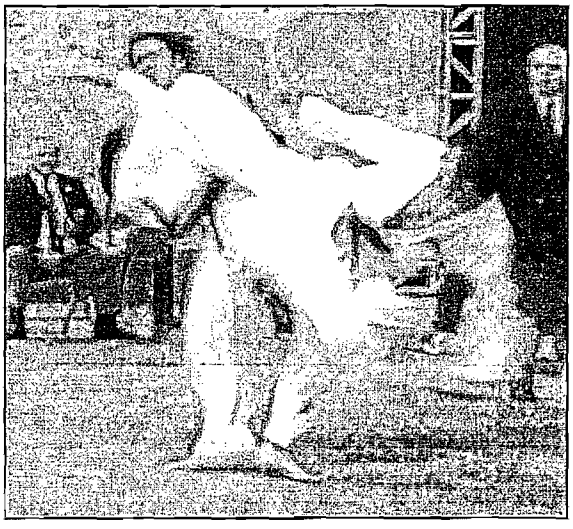
- **Hypothesis 2:** High scoring techniques such as kicks, leg sweeps and take downs as well as the foot movements such as the forward lunge, half step, overstep and lead front leg shift will act as significant discriminators between successful and less successful karatekas. The hypothesis is thus not accepted, based on the research findings that none of the high scoring techniques nor any of the foot movements acted as significant discriminators between successful and less successful karatekas. In contrast to what was predicted, low scoring techniques such as the kizami tsuki and gyaku tsuki as well as body target area (jodan and chudan) and the number of initiated attacks were rather identified as significant discriminators between the groups of karatekas.

3. RECOMMENDATIONS

To the researcher's knowledge, this is the first study to comprehensively analyse the techniques and movements performed, the attacking areas mainly targeted as well as the time intervals occurring during kumite at the WKF World Karate Senior Championships by making use of video footage and video analysis software. It is probably also the first study that has included the kumite characteristics in a discriminant function in an attempt to identify the main kumite characteristics that act as discriminators between successful and less successful karatekas during such an elite event. The lack of statistically significant results with regard to the discriminators of the two groups of karatekas as well as the fact that the majority of the results related to the profile of kumite karatekas were totally unexpected, suggest that certain shortcomings must, however, be addressed:

- The study was unable to directly measure the intensities of different activities performed during kumite. The use of heart rate data would probably have allowed the researcher to make more accurate analyses of exercise intensities during kumite.
- Despite the fact that foot movements were not executed frequently during the different kumite championships and were also not identified as significant discriminators between the two groups of karatekas, research in general shows that it is indeed an important kumite characteristic. It may therefore be necessary to do an even more detailed analysis of the different foot movements executed during kumite by expanding the list of possible foot movements.
- A number of differences were observed between the discriminant analysis results of the male and female karatekas which may have been caused by the number of fights analysed for each of the genders. Only eight fights of the females were analysed, compared to nineteen for the males. Further research of this nature must therefore attempt to use the same number of analyses for both genders to ensure that difference in the number of analyses between the two genders do not influence the discriminant analysis results.
- The accuracy and relevance of the results of this study may be questioned in view of the fact that only finals were used in the analyses of video footage. The profile of kumite characteristics and the possible discriminators between successful and less successful karatekas will probably differ from the elimination rounds of the WKF World Karate Senior Championships. Hence the elimination rounds should also be included for possible analysis.
- Finally, the results of this study are only related to kumite techniques, attacking areas and movements and not to the physiological requirements or profile of elite kumite karatekas. It would therefore be advisable to also include physiological parameters as variables in a study of this nature.

APPENDIX A



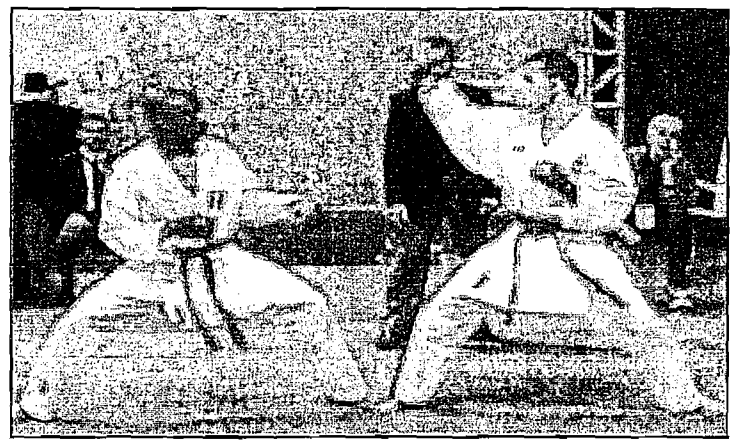
VIDEO ANALYSES DATA SHEET

Video analysis data sheet

Division:																					
RED	Winner					Loser					BLUE	Winner					Loser				
Phase											Phase										
Initiated attacks	1	2	3	4	5	6	7	8	9	10	Initiated attacks	1	2	3	4	5	6	7	8	9	10
Score	1	2	3	4	5	6	7	8	9	10	Score	1	2	3	4	5	6	7	8	9	10
Kizami tsuki	1	2	3	4	5	6	7	8	9	10	Kizami tsuki	1	2	3	4	5	6	7	8	9	10
Gayku tsuki	1	2	3	4	5	6	7	8	9	10	Gayku tsuki	1	2	3	4	5	6	7	8	9	10
Oi tsuki	1	2	3	4	5	6	7	8	9	10	Oi tsuki	1	2	3	4	5	6	7	8	9	10
Front mawashi geri	1	2	3	4	5	6	7	8	9	10	Front mawashi geri	1	2	3	4	5	6	7	8	9	10
Back mawashi geri	1	2	3	4	5	6	7	8	9	10	Back mawashi geri	1	2	3	4	5	6	7	8	9	10
Ushiro mawashi geri	1	2	3	4	5	6	7	8	9	10	Ushiro mawashi geri	1	2	3	4	5	6	7	8	9	10
Mae geri	1	2	3	4	5	6	7	8	9	10	Mae geri	1	2	3	4	5	6	7	8	9	10
Yoko geri	1	2	3	4	5	6	7	8	9	10	Yoko geri	1	2	3	4	5	6	7	8	9	10
Grap	1	2	3	4	5	6	7	8	9	10	Grap	1	2	3	4	5	6	7	8	9	10
Leg sweep	1	2	3	4	5	6	7	8	9	10	Leg sweep	1	2	3	4	5	6	7	8	9	10
Take down	1	2	3	4	5	6	7	8	9	10	Take down	1	2	3	4	5	6	7	8	9	10
Jodan	1	2	3	4	5	6	7	8	9	10	Jodan	1	2	3	4	5	6	7	8	9	10
Chudan	1	2	3	4	5	6	7	8	9	10	Chudan	1	2	3	4	5	6	7	8	9	10
Lead front leg shift	1	2	3	4	5	6	7	8	9	10	Lead front leg shift	1	2	3	4	5	6	7	8	9	10
Forward lunge	1	2	3	4	5	6	7	8	9	10	Forward lunge	1	2	3	4	5	6	7	8	9	10
Half step	1	2	3	4	5	6	7	8	9	10	Half step	1	2	3	4	5	6	7	8	9	10
Moving back	1	2	3	4	5	6	7	8	9	10	Moving back	1	2	3	4	5	6	7	8	9	10
Overstep	1	2	3	4	5	6	7	8	9	10	Overstep	1	2	3	4	5	6	7	8	9	10
No foot movement	1	2	3	4	5	6	7	8	9	10	No foot movement	1	2	3	4	5	6	7	8	9	10
Not clear	1	2	3	4	5	6	7	8	9	10	Not clear	1	2	3	4	5	6	7	8	9	10

Time intervals						
Division:						
Phase	Attempt	Pre-attack (sec)	Interactivity (sec)	Post-attack (sec)	Break (sec)	Phase time (sec)

APPENDIX B



EXAMPLE OF AN ARTICLE THAT HAS BEEN PUBLISHED IN THE JOURNAL OF STRENGTH AND CONDITIONING RESEARCH

Physiological Responses of Simulated Karate Sparring Matches in Young Men and Boys

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Abstract

The purpose of this study was to investigate the duration of each series of offensive and defensive techniques and the cardiovascular, metabolic, and perceptual responses during 2- and 3-minute bouts of simulated karate sparring. Six young men (age, 18–20 years) and 6 boys (age, 16–17 years) participated in this study. We teamed 3 pairs of men and 3 pairs of boys to create a demanding competitive environment. After a rest period, each pair performed a 2-minute bout of sparring, and quietly for 60 minutes, and then performed 3-minute bout of sparring. We measured oxygen uptake ($\dot{V}o_2$), heart rate (HR), and blood lactate responses and ascertained the rate of perceived exertion (RPE) and energy expenditure (EE) during these sparring bouts. The ventilatory threshold was estimated from ventilatory equivalent and $\dot{V}o_2$ obtained during the treadmill test. The duration of each series of offensive and defensive techniques was videotaped. During the 2- and 3-minute bouts of sparring, the duration of longest series of offensive and/or defensive combination techniques performed were 2.1 ± 1.0 and 1.9 ± 0.4 seconds, respectively; the mean total times of performing offensive and defensive techniques were 13.3 ± 3.3 and 19.4 ± 5.5 seconds, respectively. The mean oxygen uptake ($\dot{V}o_2$), the percentage of maximum oxygen uptake (%$\dot{V}o_2$max), HR, percentage of maximum HR, RPE, and EE for a 3-minute bout of sparring were significantly higher than for a 2-minute bout of sparring. The mean %$\dot{V}o_2$max values for these bouts of sparring were below the ventilatory threshold. It is recommended that karate practitioners perform more specific weight training, plyometric exercises, and interval training to increase the ability to buffer acid muscle and blood concentrations and to build lean body mass, strength, and power to develop the specific motor skills required in sparring.

Key Words: heart rate, maximal oxygen uptake, rate of perceived exertion, blood lactate, energy expenditure

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Journal of Strength and Conditioning Research

Introduction

Karate training involves basic techniques, kata, and sparring. Basic techniques such as *punching, kicking, blocking, and striking* are practiced either in the stationary position (stationary basics) or with body movements in various formal stances (movement basics). The stationary basics and movement basics are very formal and systematic and combined with kata, which are set forms in pre-established sequences of defensive and offensive techniques and movements. Sparring is the execution of defensive and offensive techniques while one is freely moving against an opponent that is frequently associated with injuries. Instead, more often, sparring techniques are performed without an opponent (sparring TECH I) or against an opponent (sparring TECH II).

Traditional Japanese karate tournament consists of kata and sparring competitions. Because competition is the focal point of athletic training, a better understanding of the duration of each series of offensive and defensive techniques and the physiological responses during competition would be desirable to develop *training programs for achieving optimal performance and avoiding injuries.* For sport nutritionists, it is also important to know the energy expenditure (EE) during competition to advise athletes to consume adequate energy from a variety of foods to avoid injuries and problems that may arise due to nutritional deficiencies. Some studies reported only heart rate (HR) responses (15,17) or both oxygen uptake ($\dot{V}o_2$) and HR responses (16,25) of karate practitioners performing kata. However, only 1 study (20) reported HR responses, without measuring $\dot{V}o_2$ during a 3-minute bout of simulated karate sparring (3-minute bout of sparring). They estimated the percentage of maximum $\dot{V}o_2$ (%$\dot{V}o_2$max) of 3-minute bout of sparring from the HR obtained during the bout and HR-$\dot{V}o_2$ curve obtained from an incremental test to volitional exhaustion on a bicycle ergometer. However, these results need to be cautiously approached because higher HR responses were elicited for a given %$\dot{V}o_2$max during 5 types of karate exercises (*stationary basics, movement basics, sparring* TECH I, *sparring* TECH II, and kata) when compared with that for a cycle ergometer or treadmill (9,16,25).

The purpose of this study was to investigate the duration of each series of offensive and defensive techniques, $\dot{V}o_2$, HR

and blood lactate responses, rate of perceived exertion (RPE), EE during a 3-minute bout of simulated karate sparring (2-minute bout of sparring) and 3-minute bouts of sparring.

Methods

Experimental Approach to the Problem

Because the duration of a sparring competition is usually 2 minutes for elimination matches and 3 minutes for semifinal and final matches, we performed 2- and 3-minute bouts of sparring in the same order. Each match was formally refereed and scored. To create a demanding competitive environment, each match was contested with an opponent of similar age, skills, training background, and body weight to simulate competition. At the start of a sparring match, the referee stood 2 meters from the center of the competition area. The contestants faced and stood 3 meters away from each other and at right angles to the referee. Each bout of sparring was started or stopped when the referee calls *hajime*, which means to start or *yame*, which means to stop. Attacks were 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. No contact was allowed with the head, face, and neck. Full contact with the abdomen was allowed. A score was awarded when a technique was performed according to the following criteria for a scoring area: good form, sporting attitude, vigorous application, good timing, and correct distance (23). During the match, the referee stayed a few meters away from the players to minimize any interference. However, every time 1 player scored, the referee stopped the fight and made the contestants moving back to the starting position. Then the referee awarded 3, 2, or 1 point according to the rules set by the World Karate Federation (23). This usually occurred within a few seconds to minimize any interference. Thus, the fight was stopped as many times as each contestant scored during the match, which is the official rules set by the World Karate Federation (23).

Because one purpose of this study was to estimate EE during 2- and 3-minute bouts of sparring, expired gas was collected using the Douglas bag for the entire period of each bout. Although the Douglas bag was affixed to the subjects' back with tape as much as possible, this could be inhibitory to performing some of the techniques. However, only straight punches are allowed, and other punches such as hook and upper punches are prohibited in the traditional Japanese karate sparring competitions. Also, most of kicks used in the competition are front and roundhouse kicks. These techniques could be performed with the Douglas bag much more easily than with a spinning back kick, which is also prohibited. Prior to the study, subjects were familiarized with how to spar while wearing the Douglas bag until they feel comfortable enough with this equipment to be able to spar. Each bout was videotaped, and the duration of each series of offensive and defensive techniques was estimated to the nearest 0.01 second from the videotape with a digital timer on the screen. However, in some cases, it was very difficult to determine when an offensive or defensive move began and ended to the nearest 0.01 second, so that the data were presented to the nearest 0.1 second. The duration of each series of techniques was defined as from the start to the end of total body movements when actual offensive and defensive techniques were performed so that feints and just reacting to an opponent's feint were not included. Two of the investigators have been official referees for the Federation of All Japan Karate Organizations. They observed the videotape and commented that these subjects competed quite well wearing the equipment.

Subjects

Seven young men (age 18–20 years) and 6 boys (age 16–17 years) volunteered for this study. With the subjects, we formed 3 pairs of men and 3 pairs of boys to create a demanding competitive environment as stated previously. One man was excluded from the data because he fought against one of the investigators, who were middle age. So, the data included in each bout of sparring were the measurements of 12 subjects. They hold a black belt from the Federation of All Japan Karate Organizations, which unified major styles (Shotokan, Wado, Goju, and Shito styles), and many other styles in Japan. The mean (± *SD*) age, height, body weight, and karate experience of the subjects were 18.0 ± 1.7 years, 167.6 ± 7.3 cm, 60.7 ± 7.3 kg, and 4.6 ± 3.5 years, respectively. Karate was the only form of training at least for 2 years for all subjects. The study protocol was approved by the Ethics Committee of the Nakamura Gakuen University, and informed consent was obtained from each subject. Informed consent was also obtained from a parent of the 6 boys.

Procedures

Three to 7 days before the experiment started, each subject performed a incremental test to volitional exhaustion on a Woodway treadmill (Tokyo, Japan) using a modified Bruce protocol, which consisted of 3-minute work stages, starting with 1.7 miles·h^{-1} and the percentage of grade, after which the treadmill speed and grade were increased according to the protocol of Bruce (3). The test was conducted in air-conditioned facilities with the temperature set at 22°C. Ventilatory measurements were made by standard open-circuit calorimetry (Sensormedics Vmax, Yorba Linda, CA) with 30-second sampling intervals. The ventilatory threshold was estimated from the ventilatory equivalent and $\dot{V}o_2$ obtained during the treadmill test and was defined as the $\dot{V}o_2$, which occurred during the workload before ventilatory equivalent increased out of proportion to $\dot{V}o_2$, and a concomitant increase in the fraction of O_2 in expired air was observed (22). The system was calibrated against a known mixture of gases before each experiment. The electrocardiogram (ECG), using a bipolar CM5 lead configuration, was monitored via radio telemetry (Nihon Koden, Tokyo, Japan). Exercise HR was recorded for 10 seconds during the final minute of each stage.

Alcohol intake and physical exercise were not allowed 1 day before each experiment. The participants reported to the laboratory at 7:00 AM after an overnight fast. They were transported by a car to avoid unnecessary physical activity before each experiment. They finished eating breakfast by 7:30 AM. The caloric content for the breakfast was approximately 42 kJ·kg^{-1} (10 kcal·kg^{-1}) with 59%, 15%, and 26% energy derived from carbohydrate, protein, and fat, respectively. The subjects changed into their karate uniform after ECG surface electrodes were taped and sat quietly until 8:30 AM, after which the resting measurements were taken. They sat quietly for 60 minutes after performing a 2-minute bout of sparring. By the end of this rest period, HR and $\dot{V}o_2$ returned to the resting values obtained prior to the 2-minute bout of sparring. Then they stretched again for 10 minutes and performed a 3-minute bout of sparring.

Expired gas was collected by the Douglas bag method for the entire period of each bout. The volume of gas was measured in a wet gas meter (Sinagawa Corp., Tokyo, Japan). Analyses for O_2 and CO_2 were performed on the system as described above. Blood lactate sample was taken in the sitting position in a chair before and immediately after the performance of each bout. Shortly after the 5 μl of blood was drawn from an earlobe, it was analyzed with the Lactate Pro Analyzer (Arkray, Tokyo, Japan). The Lactate Pro is supplied with a check strip to confirm that the analyzer is operating correctly and a calibration strip that provides a nonquantitative indication of instrument accuracy. The reported correlations between the Lactate Pro and the ABL 700 Series Acid-Base Analyzer YSI 2300 and Accusport were r = 0.98, r = 0.99, and r = 0.97, respectively (14). The ECG as described above was monitored with 4-channel radio telemetry (Fukuda Denshi, Tokyo, Japan). The subjects' HR was recorded for 10 seconds at the end of the 10-minute sitting rest and every minute thereafter. The percentage of maximum HR (%HRmax) and $\%\dot{V}o_2max$ were calculated by dividing exercise HR or exercise $\dot{V}o_2$ by HRmax or $\dot{V}o_2max$ obtained from maximal treadmill exercise, respectively. RPE using Borg's scale from 6 to 20 was obtained immediately after the performance of each bout (1). The EE was calculated from $\dot{V}o_2$ and respiratory exchange ratio (RER) according to the following formula: EE = $\dot{V}o_2$ · (15.480 + 5.550 × RER) (5).

Statistical Analyses

The SPSS statistical software 10.0J (Chicago, IL) was used to analyze the data. Descriptive statistics included mean and *SD*. Data were analyzed using repeated-measures analysis of variance and subsequently Tukey's test for post hoc analysis. Significance was defined as a $p \leq 0.05$.

Results

The mean $\dot{V}o_2max$, HRmax, RER, and $\%\dot{V}o_2max$ at ventilatory threshold measured by the treadmill run were 51.2 ± 4.3 ml·kg^{-1}·min^{-1}, 188.3 ± 2.4 beats·min^{-1}, 1.10 ± 0.10, and 66.5 ± 7.0%, respectively.

The duration of performing the shortest offensive and/or defensive technique was 0.3 ± 0.1 second for both 2- and 3-minute bouts of sparring. The duration of longest series of performing offensive and/or defensive combination techniques during 2- and 3-minute bouts of sparring were 2.1 ± 1.0 and 1.8 ± 0.4 sec, respectively. The mean total times of performing offensive and defensive techniques during 2- and 3-minute bouts of sparring were 13.3 ± 3.3 and 19.4 ± 5.5 seconds, respectively.

The physiological responses, calculated values, and RPE of 2- and 3-minute bouts of sparring are shown in Table 1. The mean $\dot{V}o_2$, $\%\dot{V}o_2max$, HR, %HRmax, RPE, and EE for a 3-minute bout of sparring were significantly higher than for a 2-minute bout. Blood lactate levels were elevated above the resting value, but there was no significant difference between the 2- and 3-minute bouts of sparring.

The relationship between %HRmax and $\%\dot{V}o_2max$ is shown in Figure 1. Higher HR responses were elicited during 2- and 3-minute bouts of sparring studied for given $\%\dot{V}o_2max$ than during the treadmill run.

The estimated $\%\dot{V}o_2max$ values during the 2- and 3-minute bouts of sparring from the HR obtained during these bouts and HR-$\%\dot{V}o_2$ curve obtained from a maximal treadmill test were 77.3 ± 9.8% and 84.9 ± 8.1%, respectively. The corresponding $\%\dot{V}o_2max$ values calculated from $\dot{V}o_2$

Table 1. Physiological responses and training intensities of simulated karate sparring.

Parameters	Simulated karate sparring matches		
	Rest	2-min bout	3-min bout
$\dot{V}O_2$ (ml·min^{-1})	225 ± 59	1292 ± 236*	1466 ± 198*†
$\%\dot{V}O_2max$	7.3 ± 1.9	42.8 ± 10.0*	47.8 ± 8.0*†
RER	0.85 ± 0.07	0.84 ± 0.06*	0.89 ± 0.05*†
HR (beats·min^{-1})	66.4 ± 7.7	160.0 ± 12.8*	169.9 ± 9.1*†
%HRmax	33.4 ± 2.9	85.2 ± 6.5*	93.2 ± 4.4*†
LA (mmol·L^{-1})	1.4 ± 0.3	3.1 ± 1.0*	3.4 ± 1.0*†
RPE	6.0 ± 0.0	13.5 ± 1.8*	15.3 ± 1.7*†
EE (kJ·min^{-1})	4.5 ± 1.2	26.0 ± 5.1*	29.9 ± 4.0*†

RER = respiratory exchange ratio; HRmax = maximal heart rate; LA = lactic acid; RPE, rate of perceived exertion; EE, energy expenditure.
*p < 0.05 compared with rest.
†p < 0.05 compared with the 2-minute bout of simulated karate sparring matches.

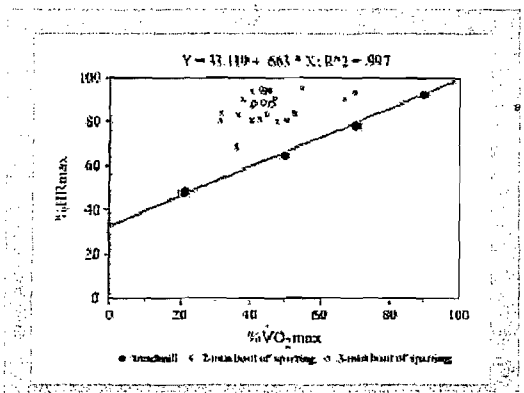

Figure 1. Relationship between percentage of maximal heart rate (%HRmax) and percentage of maximal oxygen uptake (%V̇O2max) during karate exercises.

measured during these bouts were 42.3 ± 10.0% and 47.8 ± 8.0%, respectively (Table 1), which were below the ventilatory threshold measured by treadmill running.

Discussion

Some studies reported only HR responses (15,17) or both $\dot{V}O_2$ and HR responses (16,25) of karate practitioners performing kata. However, these studies are performed from a physical fitness point of view because karate training in general and karate kata in particular have been claimed to contribute to increasing general physical fitness and/or cardiovascular fitness (9). None of the studies have reported physiological responses of simulated karate competitions except 1 study (20), which reported HR responses, without measuring $\dot{V}O_2$, during a 3-minute bout of sparring. The authors estimated $\%\dot{V}O_2max$ during the bout from the HR obtained during the bout and HR-$\dot{V}O_2$ curve obtained from an incremental test to volitional exhaustion on a bicycle ergometer. The estimated mean $\%\dot{V}O_2max$ of a 3-minute bout of sparring was 72.5%. However, the results need to be cautiously approached because higher HR responses were elicited during the 5 types of karate exercises studied (stationary basics, movement basics, sparring TECH I, sparring TECH II, and kata) for given $\%\dot{V}O_2max$ than during the treadmill run (9,16,25). Similar results were obtained in the present study measuring both $\dot{V}O_2$ and HR during 2- and 3-minute bouts of sparring. To make a valid comparison between the study by Toyoshima et al. (20) and the present study, we estimated $\%\dot{V}O_2max$ during the 2- and 3-minute bouts of sparring from the HR obtained during these bouts and HR-$\dot{V}O_2$ curve obtained from a maximal treadmill test. The estimated mean $\%\dot{V}O_2max$ values of 2- and 3-minute bouts of sparring were 77.3 ± 9.8% and 84.9 ± 8.1%, respectively. The corresponding $\%\dot{V}O_2max$ values calculated from $\dot{V}O_2$ measured during 2- and 3-minute bouts of sparring were 42.3 ± 10.0% and 47.8 ± 8.0%, respectively. Thus, the estimated mean $\%\dot{V}O_2max$ of a 3-minute bout of sparring in the Toyoshima et al. study might be questionable. Shaw and Deutsch (16) suggested that the explanation for higher HR responses were elicited during karate exercises studied for given $\%\dot{V}O_2max$ than during the treadmill run could be due to the static nature of the arm movements involved in these activities, the arm movements themselves, or the combined effects of this type of exercise performed by the arms. Upper body exercises have been shown to induce a greater HR at a given $\dot{V}O_2$ than lower body exercises (7,19).

A review in a lay magazine (12) raises some arguments about training methods and nutritional strategies in karate. First, some karate instructors claim that practicing the stationary basics, movement basics, and kata exclusively will improve their sparring ability. However, sparring competitions are performed very rapidly and indeterminately and depend on an opponent's movements and skill level. The highly specialized nature of sparring requires that training develop the specific skills used in sparring. In a previous study from our laboratory (9), we reported physiological demands of 5 types of karate exercises in young men (age, 21 years; weight, 62.1 kg; height, 169.9 cm). The mean $\%\dot{V}O_2max$ values were 29.3 ± 7.3% for the stationary basics, 53.9 ± 9.2% for the movement basics, 54.8 ± 7.6% for sparring TECH I, 53.9 ± 9.2% for sparring TECH II, and 44.1 ± 3.7% for kata. Of these exercises, the stationary basics, movement basics, and kata are very formal and systematic unlike sparring. Because competition is the focal point of athletic training, any training program should mimic the competition and reflect the desired adaptation. The techniques and movements practiced in the sparring TECH I and sparring TECH II are very similar to sparring competitions. Also, the mean $\%\dot{V}O_2max$ values of sparring TECH I and sparring TECH II are above those of the 2- and 3-minute bouts of sparring obtained in the present study (42.3 ± 10.0% and 47.8 ± 8.0%, respectively), which might be necessary to overload a system to cause the body to respond and adapt. Thus, it is recommended that a sparring competitor practice longer duration of sparring TECH I and sparring TECH II than the stationary basics, movement basics, and kata.

The second argument is that some instructors claim that long distance running is important to increase cardiovascular endurance for sparring competitors and believe that strength training decreases flexibility and reduces the speed of techniques. The conditioning specialists may have to educate these instructors about how properly designed plyometric exercises and strength and ballistic training will not have this effect, but may increase punching and kicking speed, or power (13,21). Much of the power in various techniques, not only kicking techniques but also even hand techniques in karate, is generated through the hip rotation and related leg actions. To optimize power generated through the hip rotation, twisting crunches and other variations of rotary movements should be

used, and also power exercises such as cleans and snatches should be used to increase power generated through the legs (8). Although resistance training does not appear to decrease flexibility, it has been suggested that flexibility training may be needed to increase the range of motion (6).

In comparison with top-level athletes in various sports, the mean $\dot{V}O_2max$ (51.2 ± 4.3 mL·kg^{-1}·min^{-1}) of the subjects in the present study was much lower than long and middle distance runners and were similar to volleyball players and sprinters (11). Our findings indicate that the subjects in the present study were nonendurance athletes. In addition, it has been reported that lean body mass and strength are indicative of highly competitive karate players (2 world champions and 5 prize winners in international competitions in sparring were included in the subjects: age 21 years; weight, 66.3 kg; height, 172.9 cm), whose mean $\dot{V}O_2max$ was also in the range of nonendurance athletes (10). The karate players may perform cardiovascular conditioning 3 days per week for short period of time (e.g., 20 minutes) to assist anaerobic recovery (6). However, because the high oxidative stress accompanying high-volume or high-intensity endurance training appears to negatively affect power development, they should limit high-intensity aerobic training (6).

In the present study, the duration of the longest series of performing offensive and/or defensive combination techniques during 2- and 3-minute bouts of sparring were 2.1 ± 1.0 and 1.8 ± 0.4 seconds, respectively, and the mean total time of performing offensive and defensive techniques during the 2- and 3-minute bouts of sparring were 13.3 ± 3.3 and 19.4 ± 5.5 seconds, respectively. Toyoshima et al. (20) reported similar results. Thus, the 2- and 3-minute bouts of sparring are characterized by short spells of high-intensity exercises, which are interrupted by less intense periods such as preparation for attack and/or defense and suspension by the referee and appear to be anaerobic. For rapid exercises lasting from a few seconds to approximately 1 minute, muscle depends mainly on immediate energy sources and glycolytic energy sources (2). Although blood lactate levels were moderate after performing 2- and 3-minute bouts of sparring (5.1 ± 1.0 and 3.4 ± 1.0 mmol·L^{-1}, respectively), they were elevated above resting values. Thus, increasing the ability to buffer acid muscle and blood concentrations in order to demonstrate optimal strength and power during training and competition might be important. Performing resistance training with short rest intervals, traditional cardiovascular interval training, and/or punching and kicking as quickly as possible with short rest intervals are recommended to increase the buffering ability.

The third argument is that although some instructors recognize that nutritional strategies are an integral component of the overall goal of improving karate performance, it has been reported that highly competitive collegiate karate players may be at risk of suboptimal nutrient intake (18). In this study, daily EE was estimated from the basal metabolic rate, body surface area, and time and relative metabolic rate of various activities. The relative metabolic rates during karate exercises were calculated from the result of a previous study from our laboratory (9). We reported EE for 5 types of karate exercises in young men who hold a black belt. The mean values in kJ·kg·min^{-1} were 0.343 for the stationary basics, 0.632 for the movement basics, 0.649 for sparring TECH I, 0.640 for sparring TECH II, and 0.510 for kata. Physiological responses of 2- and 3-minute bouts of sparring were not measured in this study because these 5 types of karate exercises are typically practiced during a regular workout. However, karateists practice 2- and 3-minute bouts of sparring quite often before a tournament. They usually practice at least several rounds, so that it seems reasonable to use the EE obtained during 3-minute bout of sparring in the present study (0.500 kJ·kg·min^{-1}) to estimate the EE for simulated karate sparring during a regular workout. Adding this EE value to the EE for 5 types of exercises, nutritionists can estimate the EE during the entire workout.

The common injuries in karate are sprains and bruises of the fingers, toes, and limbs. Most of these injuries could be prevented by hand, foot, and shin protectors. The significant injury sites are the head, neck, shoulder, and lower back (4,24). The strength training program in karate would include the neck, rotator cuff, and core stability and flexibility exercises. In addition to these exercises, the ballistic muscle contractions essential to various karate techniques necessitate development of agonist/antagonist muscle balance (8).

Practical Applications

Because competition is the focal point of athletic training, any training program should mimic the competition and reflect the desired adaptation. Thus, it is recommended that a sparring competitor practice a longer duration of sparring TECH I or sparring TECH II than the stationary basics, movement basics, and kata. Because much of the power in various techniques in karate is generated through the hip rotation and related leg actions, twisting crunches and other variations of rotary movements and power exercises such as cleans and snatches should be included in the strength training. Although resistance training does not appear to decrease flexibility, flexibility training may be needed to enhance the range of motion. Performing resistance training with short rest intervals, traditional cardiovascular interval training, and punching and kicking as quickly as possible with short rest intervals are recommended to increase the ability to buffer acid muscle and blood concentrations. Although long-distance running is not recommended, the competitors may perform cardiovascular conditioning 3 days per week for short period of time to assist anaerobic recovery. It seems reasonable to use the EE obtained during 3-minute bout of sparring in the present study (0.500 kJ·kg·min^{-1}) to estimate the EE for simulated karate sparring during a regular workout. Adding this EE value to the EE for 5 types of exercises, nutritionists can estimate the EE during the entire workout. To avoid or prevent athletic injuries, the strength training program in karate would include the neck,

rotator cuff, and core stability and flexibility exercises. In addition to these exercises, the ballistic muscle contractions essential to various karate techniques necessitate development of agonist/antagonist muscle balance.

Acknowledgments

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APPENDIX C

MANUSCRIPT SUBMISSION GUIDELINES

Manuscript Submission Guidelines

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You must submit the cover letter, copyright release, and manuscript separately to separate identifying information from the manuscript.

Manuscript must match JSCR formatting, including terminology use and units.

Please attempt to keep all figures and tables in a single file (instead of submitted as separate attachments). We prefer that each diagram be pasted into a PowerPoint presentation. Ensure all figures are labeled and referenced in the manuscript.

IRB approval must be mentioned.

If you use Microsoft Word, save in the .doc format.

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The text must contain the following sections with titles in ALL CAPS in this exact order:

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This section is a careful development of the hypotheses of the study leading to the purpose of the investigation. Limit information that is "chapter like" in nature as this is not an exhaustive review of the topic. Focus the studies lending support to your hypothesis(es) and giving the proper context to the problem being studied. In most cases use no subheadings in this section and try to limit it to 4 – 6 concisely written paragraphs.

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Within the METHODS section, the following subheadings are required in the following order: "Experimental Approach to the Problem," where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; "Subjects," where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; "Procedures," in this section the methods used are presented with the concept of "replication of the study" kept in mind. After reading this section another investigator should be able to replicate your study. Under this subheading you can add others but please limit their use to that which makes the methods clear and in order of the investigation (e.g., Biochemical Assays or EMG Analyses); "Statistical Analyses," here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g., $P < 0.05$). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited

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Journal Article
Hartung, GH, Blanco, RJ, Lally, DA, and Krock, LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. *Med Sci Sports Exerc* 27: 452-457, 1995.

Book
Lohman, TG. Advances in Body Composition Assessment. Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book
Yahara, ML. The shoulder. In: Clinical Orthopedic Physical Therapy. Richardson, JK and Iglarsh, ZA, eds. Philadelphia: Saunders, 1994. pp. 159-199. <BR
Software
Howard, A. Moments [software]. University of Queensland, 1992.

Proceedings
Viru, A, Viru, M, Harris, R, Oopik, V, Nurmekivi, A, Medijainen, L, and Timpmann, S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. Tenenbaum, G and Raz-Liebermann, T, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22 - 30.

Dissertation/Thesis
Bartholmew, SA. Plyometric and vertical jump training. Master's thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgements

In this section you can place the information related to Identification of funding sources; Current contact information of corresponding author; and gratitude to other people involved with the conduct of the experiment. In this part of the paper the conflict of interest information must be included. Authors are required to state in the acknowledgments all funding sources, and the

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Title Page

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Abstract and Key Words

Introduction

Methods

Results

Discussion

Practical Applications

References

Acknowledgements

Figure Legends

Figures

Tables

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The units of measurement shall be Système International d'Unités (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the *British Medical Journal* (1:1334 – 1336, 1978) and the *Annals of Internal Medicine* (106:114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., $mL \cdot min^{-1} \cdot kg^{-1}$.

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Selected conversion factors:

1 N = 0.102 kg (force);

1 J = 1 N·m = 0.000239 kcal = 0.102 kg·m;

1 kJ = 1000 N·m = 0.239 kcal = 102 kg·m;

1 W = 1 J·s-1 = 6.118 kg·m·min-1.

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1994) indicates that type IIb fibers contain type IIx myosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate IIb fibers in theie manuscripts.

Smerdu, V., Karsch-Mizrachi I., Campione M., Leinwand L., Schiaffino S. Type IIx myosin heavy chain transcripts are expressed in type IIb fibers of human skeletal muscle. Am J. Physiol. 267 (6 Pt 1):C1723-1728, 1994.