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PHYSICAL FITNESS OF TAEKWONDO ATHLETES

by

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CERTIFICATE

This is to certify that the dissertation entitled *'Physical Fitness of Taekwondo Athletes'* is the bonafide record of research work done by *Noorul Husna Binti A.Rashid [89081]* during the period of January [2008] to April [2009] under my supervision. This dissertation submitted in partial fulfillment for the degree of Bachelor of Health Sciences (Exercise & Sport Science). Research work and collection of data belong to Universiti Sains Malaysia.

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ABSTRACT

The purpose of this study was to assess physical fitness in young Kelantanese *taekwondo-in*. The participants were eight male (18.63 ± 1.92 yrs, 168.65 ± 7.36 cm, 68.29 ± 20.69 kg) and ten female (18.10 ± 1.37 yrs, 158.22 ± 4.11 cm, 59.72 ± 10.03 kg) taekwondo athletes. Weight, height and body composition were the anthropometric measurement that were assessed according to ISAK guidelines. The physical fitness characteristics that were evaluated included aerobic endurance by the PACER test, muscular strength and endurance by sit-ups as well as push-ups, explosive power by the vertical jump and flexibility by the modified sit-and-reach test. The females had a higher relative percent total body fat with moderate effect ($p < 0.001$, $eta^2 = 0.566$) while males had more lean body mass ($p = 0.005$) but this difference was small ($eta^2 = 0.399$). There was no difference between males and females in right ($p = 0.355$, $eta^2 = 0.054$) and left leg flexibility ($p = 0.142$, $eta^2 = 0.130$). The males jumped higher than the females ($p = 0.001$) but the effect was small ($eta^2 = 0.476$). The difference became smaller when scaled for height (m^2): 17.39 ± 3.07 cm for males and 14.25 ± 1.66 cm for females ($p = 0.020$, $eta^2 = 0.331$). The theoretical exponent for height controlled for the effect of the body size variable relative to the vertical jump in the males ($r = -0.08$, $p = 0.864$) but not in the females ($r = -0.71$, $p = 0.033$). When the vertical jump was expressed in terms of LBM ($kg^{0.67}$), the difference between males and females disappeared ($p = 0.179$, $eta^2 = 0.125$): 3.52 ± 0.88 cm versus 3.06 ± 0.41 cm. The theoretical exponent for height controlled for the effect of the body size

variable relative to the vertical jump in the males ($r = -0.66$, $p = 0.109$) but not in the females ($r = -0.83$, $p = 0.006$). There was no difference between males and females in push-ups ($p = 0.244$. ES = 0.466) as well as in the sit-ups ($p = 0.809$, ES = 0.127). The males had a higher aerobic endurance ($p = 0.003$, $eta^2 = 0.453$). Male *taekwondo-in* have higher aerobic endurance, higher explosive power and less percent body fat.

ABSTRAK

Tujuan kajian ini adalah untuk menilai tahap kecergasan fizikal kalangan atlet muda taekwondo Negeri Kelantan. Peserta terdiri daripada lapan atlet taekwondo lelaki (18.63 ± 1.92 tahun, 168.65 ± 7.36 cm, 68.29 ± 20.69 kg) dan sepuluh atlet taekwondo perempuan (18.10 ± 1.37 tahun, 158.22 ± 4.11 cm, 59.72 ± 10.03 kg). Berat, tinggi dan komposisi badan adalah ukuran antropometrik yang dinilai mengikut panduan "International Society for the Advancement of Kinanthropometry (ISAK)". Ciri – ciri kecergasan fizikal yang dinilai adalah daya tahan kardiovaskular dengan menggunakan ujian Larian Ulang-alik 20m (20 m multi-stage fitness test), daya tahan dan kekuatan otot dengan menggunakan tekan tubi dan bangkit tubi, kuasa ledakan (explosive power) dengan menggunakan lompatan vertikal, dan juga kelenturan dengan menggunakan ujian duduk dan jangkau yang diubahsuai. Independent t-tests digunakan untuk menilai perbezaan antara atlet lelaki dan perempuan. Korelasi Pearson digunakan untuk menentukan skala alometrik berdasarkan exponent secara teori untuk saiz badan. Tahap signifikan ialah 0.05.

Atlet perempuan mempunyai jumlah peratus relatif lemak badan yang lebih tinggi dengan perbezaan sederhana ($p < 0.001$, $eta^2 = 0.566$), manakala atlet lelaki mempunyai jisim badan tidak berlemak yang lebih tinggi ($p = 0.005$) tetapi perbezaan ini adalah sedikit. Tiada perbezaan antara atlet lelaki dan wanita bagi kelenturan kaki kanan ($p = 0.355$, $eta^2 = 0.054$) dan kiri ($p = 0.142$, $eta^2 = 0.130$).

Lompatan atlet lelaki lebih tinggi daripada atlet perempuan ($p = 0.001$) secara mutlak, namun perbezaan ini adalah kecil ($eta^2 = 0.476$). Perbezaan ini menjadi semakin kecil apabila diskala untuk tinggi (m^2): 17.39 ± 3.07 cm untuk atlet lelaki dan 14.25 ± 1.66 cm untuk atlet perempuan ($p = 0.020$, $eta^2 = 0.331$). Exponent secara teori untuk tinggi dapat mengawal kesan saiz badan ke atas lompatan vertikal bagi atlet lelaki tetapi tidak untuk atlet perempuan. Tiada perbezaan didapati antara atlet lelaki dan perempuan ($p = 0.179$, $eta^2 = 0.125$): 3.52 ± 0.88 cm versus 3.06 ± 0.41 cm; apabila lompatan vertikal ini dinyatakan dalam bentuk jisim badan tidak berlemak ($kg^{0.67}$). Exponent secara teori untuk jisim badan tidak berlemak dapat mengawal kesan saiz badan ke atas lompatan vertikal bagi atlet lelaki ($r = -0.66$, $p = 0.109$) tetapi tidak untuk atlet perempuan ($r = -0.83$, $p = 0.006$). Tiada perbezaan didapati antara atlet lelaki dan perempuan untuk tekan tubi ($p = 0.335$, ES = 0.283) serta bangkit tubi ($p = 0.809$, ES = 0.006). Atlet lelaki mempunyai ketahanan aerobik yang lebih tinggi daripada atlet perempuan ($p = 0.003$, $eta^2 = 0.453$). Atlet lelaki mempunyai daya tahan kardiovaskular dan kuasa ledakan (explosive power) yang tinggi serta peratus lemak badan yang rendah.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Taekwondo has its origins in Korea and is one of the martial art sports. It is well-developed and spread out over the world as it became one of the sports with global participation among children and adolescents (Kazemi *et al.*, 2006). It is the Korean art of self-defense (Taaffe and Pieter, 1990), which also is categorized as a combat sport. Taekwondo competition consists of three rounds of 2 minutes with a 1-minute rest period between rounds. Thus, it is also classified as an intermittent sport, such as boxing and badminton. Just like karate, taekwondo also does not involve or use any weapons. Instead, it only uses hands and legs in attacking and defending. Taekwondo has a grading level which is marked by colors that divide the participants according to their skill. This grading is known as "kŭp" and "dan" which come from Korean. The lowest level of the "kŭp" grade is the white belt, whereas the highest "dan" grade is the black belt, which is divided into several degrees (Ferrie, 1999).

Taekwondo consists of a few disciplines. However, one of the most often used in competition, whether at national or international level, is sparring. Sparring is a discipline where two opponents fight each other according to the rules. One side represents red and the other side, blue. Sparring involves kicking and punching the opponent at certain areas of the body to score points. There are two different rules of sparring in taekwondo competition, which are controlled by two international organizations: the World Taekwondo Federation (WTF), established in 1973, as well as the International Taekwondo Federation (ITF), which was founded in 1966. Many competitions use the rules of sparring by the WTF, such as at the Olympic Games or SUKMA (Malaysian Games).

Full-contact taekwondo was conceived at the end of the 1960s-beginning of the 1970s and eventually became a demonstration sport at the Olympic Games in Seoul, 1988, as well as in Barcelona, 1992 before officially becoming an medal sport at the Olympic Games in Sydney, 2000. Taekwondo, as a new sport in the Olympic Games, has not been studied yet on a large scale basis (Markovic *et al.*, 2005). Although the ITF claims that it is promoting "traditional" taekwondo, it is actually based on Japanese karate, especially Shotokan karate. Olympic taekwondo is Korean based, in that it was developed by Koreans with a different training approach than the Japanese based version practiced by the ITF. In other words, full-contact taekwondo is more "traditional" Korean than ITF semi-contact taekwondo (Capener, 1995; Pieter, 2009).

Physical fitness is one of the factors that determine performance in all sports, including taekwondo, beside psychological, technical, skill and tactical considerations. Therefore, having an excellent physical fitness level will help young athletes to improve their skill and performance so that they are prepared to compete internationally (Bompa, 1999; McArdle *et al.*, 2001). It is counter-productive to have very skillful and fast movements but lacking the strength and stamina to keep going until the end of a match (Ferrie, 1999). A lack or low level of physical fitness makes it difficult for athletes to improve their performance. Low fitness may also more easily lead to defeat when faced with an opponent who is better conditioned.

Physical fitness consists of several variables to determine the health and performance level of individuals according to the specific sport that the person is involved in. In taekwondo, aerobic endurance, body composition, muscular strength and endurance, power and flexibility are very important. A high level of aerobic endurance will be an advantage to them as they can recover more rapidly and therefore can resist fatigue quickly and longer where this situation may impair performance (Markovic *et al.*, 2005., Taaffe and Pieter, 1990., Yiau *et al.*, 2004).

Body composition is important because taekwondo competition is held according to weight categories. Muscular strength and endurance as well as power are required mostly in the arms, abdomen and legs as the limbs are the main keys for punching and kicking during competition, whereas the abdominal area is crucial

in terms of core stability. Flexibility also is a necessary element as it will allow the limbs to move in a wide range of motion.

Taekwondo is a sport that is practiced by children and adolescents in Malaysia. Therefore, it is important for them to have an optimal level of physical fitness to be able to compete at the elite international level, usually achieved by the age of 24 to 26 years when peak performance commonly occurs (Markovic *et al.*, 2005., Taaffe and Pieter, 1990).

Local newspapers typically report that young Malaysian athletes are not fit enough for competition. For example, Glen Peters stated that "Most of the athletes were out of breath, even before they started the final events, in the Kuala Lumpur Schools Sports Council (MSSKL) athletics meet at the National Stadium last week" (New Straits Times, 5/1/2001). This may be prohibitive in preparing them for international meets. As also reported by Izham Shuhaimi Ahmad, J.C. Francis Carvalho who is the founder and pioneer of 'EITP Fitness Sports Image' outfit based in Petaling Jaya, noted that "Malaysia has a big pool of youngsters, sports experts, first class sports infrastructure and offers excellent rewards compared to many other developing nations, thus there is no reason why the national athletes could not succeed. However, this dream cannot be achieved if the administrators do not plan well the programs" (Bernama News, 30/12/2008). Therefore, the purpose of this study was to assess the physical fitness in young Kelantan taekwondo athletes.

1.2 Statement of the Research Problem

The physiological aspects of combat sports have been studied before (e.g., Aziz *et al.*, 2002; Imamura *et al.*, 2002). However, there are few studies on taekwondo. Moreover, they also focus on physiological changes in response to training and matches. Many studies that are related to the physical preparation and physiological aspects are mainly focused on the energy system. They are more aimed at assessing the relationship of blood lactate and heart rate (Bouhlel *et al.*, 2006; Butios *et al.*, 2007). There are fewer studies that focused on physical fitness in combat sports, especially in taekwondo athletes. Those that deal with the physiological profile and physical fitness of young and adolescent athletes in other intermittent sports are widely done (e.g., Apostolidis *et al.*, 2004., Aziz *et al.*, 2007; Gabbett., 2007., Tsunawake *et al.*, 2003). Yet, studies which focus on young athletes in taekwondo are scarce and they rarely involve Malaysian taekwondo athletes.

1.3 Research Objective

1.3.1 General Objective

The general objective of this study was to describe the physical fitness of both male and female Kelantan SUKMA (Malaysian Games) taekwondo athletes.

1.3.2 Specific Objective

The specific objective of this study was to compare the physical fitness of male and female Kelantan SUKMA taekwondo athletes.

1.4 Research Questions

1.4.1 What is the physical fitness level of Kelantan Sukan Malaysia (Sukma) taekwondo athletes?

1.4.2 What are the differences in physical fitness between male and female Kelantan Sukma Taekwondo athletes?

1.5 Significance of the Study

Scientific information on taekwondo in Malaysia is limited. More research related to physical fitness of Malaysian athletes needs to be done. The significance of this study, then, is to give information about the physical fitness of taekwondo athletes to the Kelantan Taekwondo Association as part of an ongoing sports science support project. It will assist sport scientists and coaches in Kelantan and, by extension, Malaysia, in planning training programs (Aziz *et al.*, 2002). This will lead to a more optimal and productive use of the available training time. It will also help in reducing the susceptibility of taekwondo athletes to sustain injuries during training or competition (Pieter and Heijmans, 2000).

1.6 Definition of Terms

1.6.1 Physical fitness

"Physical fitness which is also known as physical performance ability, is referred to as an umbrella concept covering a series of qualities related to how well an individual performs physical activity" (Åstrand *et al.*, 2003; page: 269-271).

On the other hand, it may also be explained by "a total dynamic physiological state of body functions and abilities, which means the capacities of the heart, lungs and muscles to function at optimum efficiency and effectively relative to sport performance" (Robergs and Keteyian, 2003, page: 3-4).

In this study, the components of physical fitness include aerobic endurance, body composition, muscular strength, muscular endurance, muscular power and flexibility.

1.6.1.1 Aerobic Endurance

Aerobic or cardio-respiratory endurance is defined as "the capability of the heart and lungs to consume and use oxygen as maximally as possible during intense activities" (Robergs and Keteyian, 2003, page: 3-4).

1.6.1.2 Body Composition

Body composition refers to the structure of our body, which consists of many components like bone, muscle, body water, organs, connective tissues, fat tissues and others. Body composition refers to the relative proportion of body fat and lean body mass to overall body weight (Baumgartner *et al.*, 2003., Grosvenor and Smolin, 2002., Tritschler, 2000).

1.6.1.3 Muscular Strength

Muscular strength refers to "the ability of the muscle to exert maximum force when contracting" (Robergs and Keteyian, 2003, page: 3-4).

1.6.1.4 Muscular Endurance

Muscular endurance is defined as "the ability of the muscle to repeat movements and sustain the contraction for a long period" (Robergs and Keteyian, 2003, page: 3-4).

1.6.1.2 Explosive Power

Explosive power refers to "the ability of muscles to generate explosive burst-like force during fast and short movements" (Robergs and Keteyian, 2003, page: 3-4).

1.6.1.4 Flexibility

Muscular flexibility is needed "as it is the ability of muscles and joints to move through a wide range of motion" (Robergs and Keteyian, 2003, page: 3-4).

1.6.2 Athlete

An athlete refers to "a person who is involved in and good at a sport of his or her choice as well as takes part in competitions" (Macmillan Dictionary, page: 73).

1.7 Limitations of the Study

The small sample size influenced the effect sizes.

The presentation of the current investigation refers to a descriptive study of recreationally active adolescent taekwondo athletes (*taekwondo-in*), who were preparing themselves to compete in the Malaysian Games.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Knowledge of sports science is widely used in many sports nowadays. Many sports people are aware of the importance of sports science to be applied in almost all sports. This also includes martial art sports. For years, researchers have shown an interest in studying martial art sports from various sub-disciplines of sport science, such as biomechanics, sport psychology, kinanthropometry and sport physiology (e.g., Hong, 1998, 1997, Pieter, 1991, Pieter *et al.*, 1990).

In line with the view that sport physiology is one of the contributing factors to successful performance in martial art sports (Pieter, 1991., Imamura *et al.*, 2002), a number of studies have been done in this field (e.g., Aziz *et al.*, 2002., Hong, 1997., Pieter *et al.*, 1990). They include field and laboratory investigations to gain more knowledge in relation to martial art sports in terms of the physiological aspects.

For instance, Falk and Mor (1996) investigated the effect of a 12-week training program on the motor performance of pre-pubertal boys by comparing an experimental and control group. The experimental group participated in a training program twice a week for 12 weeks. Both groups were tested before and after the intervention. The children were assessed relative to their muscle endurance, flexibility and motor performance. The tests included sit-ups in 20 seconds for abdominal muscular endurance, seated two-handed medicine ball put for upper body explosive power, standing long jump for lower body explosive power, sit-and-reach for flexibility as well as the shuttle run for agility.

The researchers found that the experimental group significantly improved their upper and lower body explosive power. Other motor performance indicators, such as abdominal muscular endurance, flexibility and agility, showed some improvement, however they did not reach statistical significance. Falk and Mor (1996) also reported that their results agreed with those of previous resistance-training studies. Therefore, the researchers concluded there is a relationship between resistance training and strength and performance.

Research has also been done in the field of physiological profiling of taekwondo athletes. Taaffe and Pieter (1990) investigated physical and physiological characteristic of elite taekwondo athletes. The subjects, with a mean age of 24.3 years for men and 25.6 years for women, were US national taekwondo team members and taekwondo permanent residents at the US Olympic Training Center in Colorado Springs. Physical characteristics assessed included the Heath-

Carter somatotype and body composition; whereas the physiological components measured were aerobic and anaerobic power. Aerobic fitness was tested on a treadmill, while anaerobic power was estimated using the Wingate Anaerobic Cycling Test (Inbar *et al.*, 1996).

The researchers found that the men were taller, heavier, and had a higher lean body mass, lower body fat and were more mesomorphic compared to their female counterparts. Males had a higher VO_2 max, and mean anaerobic power when expressed in absolute and relative terms. The men also had a greater peak anaerobic power when expressed in absolute terms, but there was no significant difference when expressed in relative terms. Based on these results, the researchers concluded that elite taekwondo athletes have physical and physiological characteristics similar to those of other highly trained combative sports athletes. Therefore, it is important to assess their physiological profile, which is currently lacking as far as Malaysian counterparts are concerned.

2.2 Muscular Strength and Endurance

Strength is one of the areas of sport physiology that has received much attention from researchers. Studies typically focus on isokinetic peak torque and grip strength in martial art sports.

Aziz *et al.* (2002) investigated grip strength of elite pencak silat athletes. The subjects were tested using an electronic dynamometer. The authors reported that the silat athletes had lower absolute grip strength when compared to taekwondo

and judo competitors. The researchers concluded that this might be because silat competitors score points through non-grasping movements like kicking. They also argued that a tight grip in silat is not as important as in taekwondo and judo. The authors seem to have overlooked the importance of kicking in taekwondo competition in which punches are hardly scored (Moon, 2003).

Pieter *et al.* (1989) conducted one of the first studies that focused on gravity-corrected isokinetic strength in taekwondo. The main purpose of this investigation was to assess isokinetic peak torque during extension and flexion of the leg by comparing two groups, which consisted of taekwondo practitioners and non-taekwondo athletes. Subjects were tested on an Orthotron II at angular velocities of 120°, 180° and 250°/ sec. The researchers found that the control group scored higher on knee extension peak torque at all angular velocities, whereas the taekwondo practitioners recorded higher knee flexion peak torques.

Isokinetic strength of American elite senior male and female taekwondo athletes was investigated by Pieter and Taaffe (1990) at 120°, 180°, 240° and 300°/sec during leg extension and flexion at the knee joint. Peak torque was corrected for the effect of gravity. When peak torque of the males was compared with that of the females relative to body weight and lean body mass per ratio standard, the males still recorded higher values but the differences became smaller.

Thompson and Vinueza (1991) investigated the physiological profile of recreational taekwondo practitioners, which included isometric leg and back strength. The results revealed that it was generally poorer compared to a sedentary but healthy population of the same age and sex. The authors concluded that this was due to no emphasis being placed on strength development in training.

Markovic *et al.* (2005) assessed whether there were any differences in muscular strength and endurance between successful and less successful female taekwondo athletes. The subjects were divided into two groups. Group A was labeled as the successful one as it consisted of athletes, who had won at least one medal in World Championships or Olympic Games, while Group B was categorized as less successful as its members had never won any medals at international competitions.

The researchers used maximal number of push-ups in 60 seconds and maximal number of sit-ups in 60 seconds to assess muscular strength and endurance. Although Group A scored better than Group B, the differences were not statistically significant. Markovic *et al.* (2005) stated that the small differences between the two groups showed that abdominal muscular strength and endurance played an important role in improving sport performance and to prevent injury. They concluded that core strength and endurance is one of the primary factors that contribute to performance in female taekwondo athletes.

Toskovic *et al.* (2004) assessed abdominal muscular strength and endurance in taekwondo athletes with a 1-minute bent-knee sit-ups test. The main objective of this study was to examine whether there was any effect of gender and taekwondo experience on muscular strength and endurance performance. The subjects were divided into four groups: experienced men, experienced women, novice men and novice women. The authors reported that male athletes scored higher than their female colleagues, while experienced athletes scored better than their novice counterparts. Overall, male experienced taekwondo athletes scored highest compared to the other three groups. Therefore, the researchers concluded that taekwondo exercise may improve motor abilities.

2.3 Muscular Strength and Endurance in Malaysian Taekwondo Athletes

The first study on strength and endurance in young (19 years) Malaysian taekwondo athletes was conducted by Yiau *et al.* (2004). The authors found no differences in sit-ups and push-ups between the winners and losers in both genders. No difference in push-ups ($eta^2 = 0.116$) was found between child male and female taekwondo athletes (Erie and Pieter, 2008). However, they did differ in sit-ups ($eta^2 = 0.741$) with the boys scoring higher: 45 vs. 35 repetitions.

The effect of training was assessed on general motor abilities in young Malaysian male (16.81 years) and female (15.52 years) taekwondo athletes. The boys did more sit-ups than the girls during the posttest (median: 37 vs. 26 repetitions), but there was no difference in push-ups at the posttest (median: 49 vs. 47 repetitions). Both boys (median: 37.5 vs. 49.0 repetitions) and girls (median:

33.0 vs. 47 repetitions) could do more push-ups from pre- to posttest. Regardless of gender, general motor abilities tended to improve over time as a result of training (Suzana and Pieter, 2006).

Collapsed over angular velocity (120°/sec and 300°/sec) and movement (leg extension and flexion at the knee joint), Malaysian young (17.43 years) male taekwondo athletes recorded a higher peak torque than their female colleagues (16.77 years) (116.05 Nm vs. 88.94 Nm, eta^2 = 0.473). When scaled to $height^2$, relative peak torque was still higher for the boys (41.54 Nm/m^2 vs. 35.87 Nm/m^2) but the difference became smaller (eta^2 = 0.379) (Aiwa and Pieter, 2007a).

2.4 Explosive Power

Explosive power in the lower limbs is important in combat sport as it is used in kicking. Aziz *et al.* (2002) also included explosive power in their profile of elite silat athletes using the vertical jump. The researchers maintained that silat athletes have greater absolute explosive leg power than elite judo and taekwondo athletes. They suggested that the nature of different combat sports might have repercussions for explosive leg power. Their study seems to suggest that explosive power is one of the important motor performance indicators in martial art sports.

Toskovic *et al.* (2004) also included explosive leg power as one of the variables in their study. They used the vertical jump to assess explosive power of novice and experienced taekwondo athletes. The authors showed that, in absolute terms, male athletes scored higher than their female counterparts and that

collapsed over gender, experienced athletes recorded a better score. Overall, their study showed that male experienced athletes performed best.

2.5 Explosive Power in Malaysian Taekwondo Athletes

To assess the relationship between general physical fitness and performance in young Malaysian taekwondo athletes, Yiau *et al.* (2004) reported that the female winners collapsed over weight division jumped higher (39.10 cm) than the losers (35.13 cm) in absolute terms.

In absolute terms, junior boys jumped significantly higher than the girls (56.30 vs. 37.72 cm) when collapsed over time ($eta^2 = 0.751$) (Suzana and Pieter, 2006). After allometrically scaling using the empirical exponent for body mass and height as a co-variate, the boys still jumped higher than the girls: 6.32 $cm.kg^{-0.314}$ versus 5.58 $cm.kg^{-0.314}$ ($eta^2 = 0.702$).

Using adolescent taekwondo athletes, Erie *et al.* (2007) reported that, in absolute terms, the boys jumped higher than the girls ($eta^2 = 0.643$). However, the difference became smaller when jump height was scaled to $height^2$ (12.79 cm/m^2 and 10.45 cm/m^2 for the boys and girls, respectively, $eta^2 = 0.497$).

Using the theoretical exponent, Erie and Pieter (2008) found that when expressed relative to lean body mass (LBM) ($kg^{0.67}$), the difference between boys and girls decreased further as compared with scaling the jump to height (m^2): 2.79 $cm/kg^{0.67}$ versus 2.37 $cm/kg^{0.67}$, respectively ($eta^2 = 0.246$) in younger children (13

years). The authors reported no difference in jump height between boys and girls after allometric scaling, which might be due to the age of the children, i.e., they had not yet entered puberty (Malina *et al.*, 2004).

2.6 Aerobic Endurance

A high level of aerobic endurance provides an advantage to the athletes as they can recover faster and therefore can resist fatigue longer where it may impair their performance. This is because a higher cardio-respiratory endurance removes oxygen from the circulating blood vessels more rapidly to utilize it in the working muscles (Robergs and Keteyian, 2003).

Olympic taekwondo typically involves full-contact free sparring conducted over three rounds of two minutes each with a one-minute rest between rounds. Significant demands are placed on both aerobic and anaerobic energy production pathways as short bursts of high work output are interspersed throughout the rounds (Taaffe *et al.*, 1991).

Markovic *et al.* (2005) assessed aerobic capacity to examine whether there were any differences between successful and less successful taekwondo combatants. The researchers estimated aerobic endurance using a treadmill. They found that the successful athletes attained a significantly higher maximum running speed compared to the other group. They also had a higher VO_2 max. However, this difference was not statistically significant. The authors suggested that it is important to have a high aerobic capacity so that the athletes will be able to

recover fast between rounds and fights. High aerobic capacity facilitates better performance during martial art sports competitions.

Toskovic *et al.* (2004) also used a graded exercise treadmill test to assess cardiovascular endurance of novice and experienced taekwondo athletes. The authors reported that male athletes scored better compared to their female counterparts, while experienced athletes scored higher than beginners. In general, male experienced athletes showed the highest aerobic endurance compared to the other groups. The study seems to suggest that training in taekwondo might influence aerobic endurance, which is suggested to be related to improved performance in competition.

2.7 Aerobic Endurance in Malaysian Taekwondo Athletes

No difference in aerobic endurance was found between winners and losers in young Malaysian male (49.12 vs. 48.61 $ml.kg^{-1}.min^{-1}$) and female (38.67 vs. 37.49 $ml.kg^{-1}.min^{-1}$) taekwondo athletes (Yiau *et al.*, 2004). Malaysian young (17 years) boys had greater aerobic endurance than girls of the same age: 49.03 $ml.kg^{-1}.min^{-1}$ vs. 39.54 $ml.kg^{-1}.min^{-1}$ ($eta^2 = 0.760$). The difference persisted when height was used as a co-variate: 48.40 $ml.kg^{-1}.min^{-1}$ for the boys and 40.17 $ml.kg^{-1}.min^{-1}$ for the girls ($eta^2 = 0.603$) (Erie *et al.*, 2007).

Malaysian developmental taekwondo athletes (13 years) were studied by Erie and Pieter (2008). The authors reported that the boys (41.34 vs. 33.45 $ml.kg^{-1}.min^{-1}$) had a moderately higher aerobic endurance ($eta^2 = 0.351$), even after controlling for height ($eta^2 = 0.329$).

2.8 Flexibility

Muscular flexibility is needed as it is important to taekwondo athletes to execute high kicks that score more points as well as enabling them to use the full range of motion when kicking. Heller *et al.* (1998) aimed to assess whether flexibility was one of the physiological parameters that might be important to successful taekwondo athletes. Members of the Czech national team performed the conventional sit-and-reach test. The authors found that both male and female taekwondo athletes performed above average compared to the general population. Female athletes were more flexible compared to their male counterparts. Compared to other studies, however, the Czech taekwondo athletes scored lower. Heller *et al.* (1998) stated that flexibility is important to taekwondo practitioners, as more flexible athletes are expected to perform better.

Thompson and Vinueza (1991) reported that black belt taekwondo athletes were more flexible compared to those from a sedentary but healthy population of the same age and sex. The researchers suggested that this might be due to the nature of taekwondo, which emphasizes flexibility. The studies reviewed above show that flexibility is one of the main components of physical fitness that influences athletes' performance in taekwondo.

2.9 Flexibility in Malaysian Taekwondo Athletes

Suzana and Pieter (2006) reported that, collapsed over gender, adolescent taekwondo athletes improved in conventional sit-and-reach flexibility (20.20 cm and 25.20 cm for the pre- and posttest, respectively) (eta^2 = 0.617). No difference in flexibility was found in child taekwondo athletes between boys and girls for the modified flexibility test for the right (eta^2 < 0.001) and left legs (eta^2 = 0.001) (Erie and Pieter, 2008). No difference was also found in flexibility of bent- (eta^2 = 0.152) and straight-leg (eta^2 = 0.062) hip flexion between boy and girl adolescent taekwondo athletes (Erie *et al.*, 2007).

2.10 Body Composition

Body composition also is an important aspect of physical fitness in taekwondo. Athletes should have a suitable level of body mass and body fat because these two factors can affect their performance. Generally, excess body fat leads to low aerobic fitness and it also affects jumping activity (Okely *et al.*, 2004, Baumgartner *et al.*, 2003).

Hong (1997) assessed body composition in world level taekwondo athletes using anthropometric measurements. The researcher found that there was no significant difference between boxers, taekwondo and track and field athletes. The study showed that taekwondo athletes had a similar body composition compared to athletes in other sports.

Body composition is widely studied in anthropometric profiling. Heller *et al.* (1998) investigated anthropometric characteristics of elite Czech taekwondo athletes. The researchers measured body height, mass, circumferences, diameters and ten skinfolds. They revealed that the athletes had low estimated body fat percentages and increased amounts of lean body mass. Body fat of male athletes was about 8.2%, while that of the females was 15.4%. These values were similar to those reported in other studies (e.g., Taaffe and Pieter, 1990).

2.11 Body Composition in Malaysian Taekwondo Athletes

Body composition in Malaysian taekwondo athletes was first reported by Aiwa and Pieter (2007). The authors found male adolescent (17.40 years) taekwondo athletes to have an estimated 19.88% of total body fat and their female colleagues (18.09 years), 32.21%. In a follow-up study, male taekwondo athletes (17.30 years) had less fat (19.58%) than their female (17.35 years) counterparts (31.13%, $eta^2 = 0.848$) (Erie *et al.*, 2007).

This difference was also apparent in younger taekwondo athletes. Members of the Malaysian developmental team recorded values of 18.58% for boys (13.17 years) and 29.78% for girls (13.33 years, $eta^2 = 0.608$) (Erie and Pieter, 2008).

CHAPTER 3

METHODOLOGY

3.1 Sample

3.1.1 Sample Size

The subjects were 18 *taekwondo-in* (taekwondo athletes) that consisted of eight males and ten females with an age range of 16 to 21 years They represented Kelantan state in SUKMA competition that was held in Terengganu in June 2008.

3.1.2 Sample

The study was done using a non-probability purposive sample. This is because this research was part of a sports science support project for the Kelantan Taekwondo Association.

3.1.3 Population and Location

This study was carried out with taekwondo athletes from the Kelantan Taekwondo Association in Kota Bharu. The tests were held in the Pusat Pengajian Sains Kesihatan (PPSK) Sports Science Laboratory, Universiti Sains Malaysia (USM), Kubang Kerian, Kelantan.

3.2 Testing Instruments and Procedures

3.2.1 Anthropometric Measurements

The anthropometric measurements in this study included height, weight and body composition. Height and weight were taken twice unless the difference between the two measurements exceeded 5%, in which case a third measurement was taken. The mean was used when two measurements were taken and the median if a third one was necessary (International Society for the Advancement of Kinanthropometry, 2001).

3.2.1.1 Weight and Height

Height was measured using a wall-mounted wooden stadiometer (Lafayette Instrument Co. USA, Lafayette, IN, USA). The technique that was used to measure height was the stretch stature (International Society for the Advancement of Kinanthropometry, 2001). The measurement was taken to the nearest to 0.01 cm and, just like weight, was taken in the morning. The subject stood in front of the stadiometer with the feet and heels placed together but the buttocks and spine touching the stadiometer. Then, the head was adjusted to the Frankfort plane position (see Figure 3.1) after which height was taken at the Vertex point.