INFLUENCE OF AGE AND MATURATION ON FITNESS DEVELOPMENT, TRAINABILITY AND COMPETITIVE PERFORMANCE IN YOUTH SILAT

Submitted by Mohamad Nizam Mohamed Shapie, to the University of Wales Institute, Cardiff as a thesis for the degree of Doctor of Philosophy in Sports Coaching, September 2011.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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ABSTRACT

Silat Olahraga, also known as Silat, is a popular combat sport, but little is known about the sports in terms of sport science of physiological demands and characteristics. This is particularly true for the adolescent population, with a dearth of research which explains influence of age and maturation on fitness development, trainability and competitive performance in silat youth. A silat match is characterised by high anaerobic and aerobic metabolic responses. Therefore, specific protocols were developed to analyse the demands of youth silat competition to allow the identification and development of suitable silat sport-specific fitness tests which can be used to track the fitness development and trainability of youth silat performers. In order to determine the 'transference' of fitness to competition, a case study research approach has been used to allow detailed analysis on individual responses and transference of fitness to competition.

Time motion analysis was applied in study one to investigate periods of fight time and break time within rounds of 7 international silat matches. Each match was examined twice using the POWER system in order to test the reliability of the method, which found that 2 rounds with good ($0.61 \leq \kappa \leq 0.70$) and remaining 19 rounds with very good ($\kappa \geq 0.81$) strength of agreements between observations. It was found that 62.6% of a silat match involved action periods that ranged from under 6 s to over 12 s, with break periods ranging from under 4 s to over 20 s. The information concluded a valid period of mean the duration of fight and break periods in a silat match with a work:rest ratio of 16:8 s.

Notational analysis was applied in study one in order to analyse the detailed activity that occurs during the fight time of a silat match. The Focus X2 system was used to identify 14 different types of silat actions performed by 2 contestants. The majority of attacking actions were kicks (45.1%) and punches (15.6%), while the defensive actions were blocking (10.9%). However, the percentage of punches (82.6%) that successfully hit the target was greater than kicks (12.9%). The findings of this study complement those of the broad work and rest periods in study one. It was concluded that silat was a type of intermittent sport, where kicks were the most frequent actions but punches were relatively more successful.

Study two developed two new silat-specific fitness tests; 20-kick test (mean CV = 6.83%) and 3-directional jump (3DJ) (mean CV's = 9.00%) which can be used to evaluate athlete's ability to perform rapid kicking and movement agility. Fitness characteristics of 13 to 16 years male and female silat exponents were then evaluated. Females were significantly more advanced, by about 2 years in the estimated age from peak high velocity (PHV) compared to the males (1.1 ± 0.7 versus -0.9 ± 1.1 y from PHV, $p < 0.05$), whereas, male exponents outperformed female exponents for most tests. The fitness characteristics of females did not change with age for any variable (all, $p > 0.05$), while males tended to improve their fitness with advancing age/maturation. Measures of isometric strength (grip strength), upper body power (medicine ball throw) and endurance (push-ups), lower body power (squat-jumps), and endurance (yo-yo test) showed significant (all, $p < 0.05$) gains after 15 year olds in males. Being involved in silat allowed female participants to maintain their fitness, whereas male participants improved their fitness at or post-PHV suggesting a period of accelerated adaptation. The gender-specific differences were attributed to differing maturational processes and the findings may be useful when devising training programmes to maximise fitness development in youth silat.

The third study examined the effect of age and maturation on 6-weeks of silat specific circuit training on 13 and 16-year-old male silat exponents. The older intervention group (N = 21) demonstrated significant (all, $p < 0.05$) gains in endurance (566 ± 4 m), squat jump (1.4 ± 0.5 cm) and push-ups (9 ± 1 reps). The younger intervention group (N = 26) also significantly (all, $p < 0.05$) improved push-up (12 ± 2 reps), together with reactive strength index (RSI) (0.20 ± 0.10) and 3DJ (0.23 ± 0.08 s) performances. Significant (all, $p < 0.05$) improvements in medicine ball throw were observed in the older (28 ± 18 cm) (N = 14) and younger (34 ± 7 cm) (N = 26) control groups, while the older group also improved grip strength (2.6 ± 2.0 kg). Gains in endurance and squat jump were more pronounced in more mature children and might be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in younger children. Both experimental groups were able to improve push-up performance, suggesting similar local muscular adaptation. Improvements following silat-specific circuit training appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power.

In study four, 13 and 16-year-old experimental (E13 and E16) and control (C13 and C16) participants were paired and videoed with fighting before and after training. All individuals demonstrated some meaningful improvements in fitness following the intervention period. However, these responses did not necessarily reflect the group finding in study 3. The E13 increased the frequency of kicking during competition post-training, which is suggested to reflect transference of improved fitness to competition. Both E13 and C13 improved the ability to dodge their opponent attacks, likely reflecting a response to technical coaching. The frequency of actions during competition generally decreased for both older participants, suggesting limited fitness transference to competition. Therefore, fitness gains together with technical coaching may transfer to competition in younger exponents, while alterations in strategy may have been more decisive in the older group.

The research presented was original and have furthered knowledge of the responses of adolescents to silat-sports with the influence of age and maturation. The research have provided further insight of physiological demands and characteristics, fitness development and trainability, and also transference fitness into competitive performance in youth silat which may help to facilitate coaches of the demands and requirements of the combat sport.

This thesis is dedicated to:
my beloved ***wife****, Raja Noor Adilla Raja Mahyaldin,* ***children****, Puteri Elissa Sarah, Mohamad Azraf Luqman and Puteri Eilya Sofea,* ***mother****, Asnah binti Mansor,* ***father****, Mohamed Shapie Mohamed Taib and* ***my mentor****, Allahyarham Anuar Abdul Wahab A.M.N (1945 – 2009, May GOD Bless You) who will always be in my heart…*

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed: ………………………………………………. (Candidate)

Date: ……………………………………………….

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisation.

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Date: …………………………………………………..

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2. Shapie, M.N.M, Oliver, J.L., O'Donoghue, P. & Tong, R. (2009). Activity during action time in international silat competition. Poster presentation, 3rd International Workshop of the International Society of Performance Analysis of Sport, Lincoln, April.

3. Shapie, M.N.M., Oliver, J., O'Donoghue, P.G. and Tong, R. (2011). Fitness characteristics of youth silat performers. Poster presentation for 5^{th} ISN International Sports Medicine and Sports Science Conference 2011, Kuala Lumpur, September.

4. Shapie, M.N.M., Oliver, J., O'Donoghue, P.G. and Tong, R. (2011). Affect of circuit training on fitness development in youth silat. Poster presentation for 5^{th} ISN International Sports Medicine and Sports Science Conference 2011, Kuala Lumpur, September.

LIST OF ABBREVIATIONS

1 RM	One repetition maximum
20KT	20-kick test
3DJ	3-directional jump
3KT	3-kick test
ADP	Adenosine diphosphate
ANOVA	Analysis of Variance
ATP	Adenosine triphosphate
BLa	Blood lactate
BP	Bench Press
C13	Age 13 control group
C16	Age 16 control group
CG	Control group
CNS	Central nervous system
CO_2	Carbon dioxide
CP	Creatine phosphate
CT	Contact time
CV	Coefficient of variation
CWT	Cycle Wingate test
E13	Age 13 control group
E16	Age 16 experimental group
EG	Experimental group
EMG	Electromyography
GCT	Graded cycle treadmill
GTT	Graded treadmill test
HG	Handgrip
HGD	Handgrip dynamometer
HR	Heart rate
La	Lactate
LTAD	Long term athlete development
MEDBALL	Medicine ball throw
MMA	Mixed martial arts
MSACW	Modified seated arm crank Wingate

MUA	Motor unit activation
PHV	Peak height velocity
POWER	Periods of work efforts and recoveries
PWV	Peak weight velocity
RJ	Rebound jump
RJH	Rebound jump height
RSI	Reactive strength index
SD	Standard deviation
SSC	Stretch-shortening cycle
TVT	Treadmill max test
$\dot{V}O_2$ **max**	Maximal oxygen uptake
$\dot{V}O_2$ **peak**	Peak oxygen uptake
Yo-yo IE1	Yo-yo intermittent endurance test level one
Yo-yo IE2	Yo-yo intermittent endurance test level two

CHAPTER ONE

Introduction

1.1 Introduction to Silat Olahraga

Silat is a form of martial art of the Malay race, who are inhabitants the southern part of the Asian continent, covering the Malay Archipelago from the Easter Island in the east to Madagascar Island in the west (Anuar, 2007). The word silat means a kind of sport or game, which consists of quick movements in attacking and defending (Anuar, 1987). Silat olahraga is a sport that existed in the midst of development of thousands of silat schools in Archipelago (Anuar, 1993). Olahraga means the ability for a silat exponent to perform his silat techniques in combat with striking and defensive actions such as punching, kicking, throwing, catching, parrying and blocking and any skill related to silat techniques.

There are three types of silat contests that are championship, showmanship and freestyle. The championship is a contest in which a participant aims to become a district champion, state champion, a national champion or international champion. Several international contests are held, including; World Silat Championship (since 1982), European Championship (since 1985) and South East Asian Games (since 1987). While the showmanship contest is a friendly contest which means to display talents on, for instance, National Day, for charity, even though there will be a winner and loser but the contest is not to choose a champion. The freestyle is a contest for participations of the same silat schools against participation of different martial arts, for example taekwondo, judo, karate and others martial arts (Anuar A.W., 1993).

The sport's world controlling body, the International Pencak Silat Federation includes member countries such as the US, Japan and many European nations (International Pencak Silat Federation, 1999). The sport of silat consists of two categories, artistic and contact. The former focuses on choreographed movements and patterns of silat; this is similar to a karate kata. The latter is a weight-categorised, full-contact, unarmed duel of similar concept to other conventional martial art sports like taekwondo and judo (Aziz *et al.*, 2002), known as silat olahraga. According to new International Pencak Silat (2004) rules and regulation, silat tournaments consist of three divisions according to age, gender and body mass (in kg scale) of the participations.

The first category is **youths aged from 12 to 14-year-old**. The male exponents start from class A (28 – 30 kg) to free class (52 kg above) and for female exponents from class A (28-30 kg) to free class (over 46 kg). Overall, there are 13 classes for male and 12 classes for females in the 12 to 14-year-old category, differentiated by 2 kg for each class. The second category is **teenager aged from 14 to 17-year-old**. The male exponents category starts from class A (39-42 kg) to free class (75 kg above) and for female exponents category from class A (39-42 kg) to free class (over 66 kg). This category is differentiated by 3 kg for each class with 13 classes for males and 10 classes for females. The third category is **Adult category**. In this category, the male exponents starts from class A (45 -50 kg) to free class (over 95 kg) and the female from class A (45-50 kg) to free class (over 75 kg). This category is differentiated by 5 kg for each class with 11 classes of male and 7 classes for female exponents.

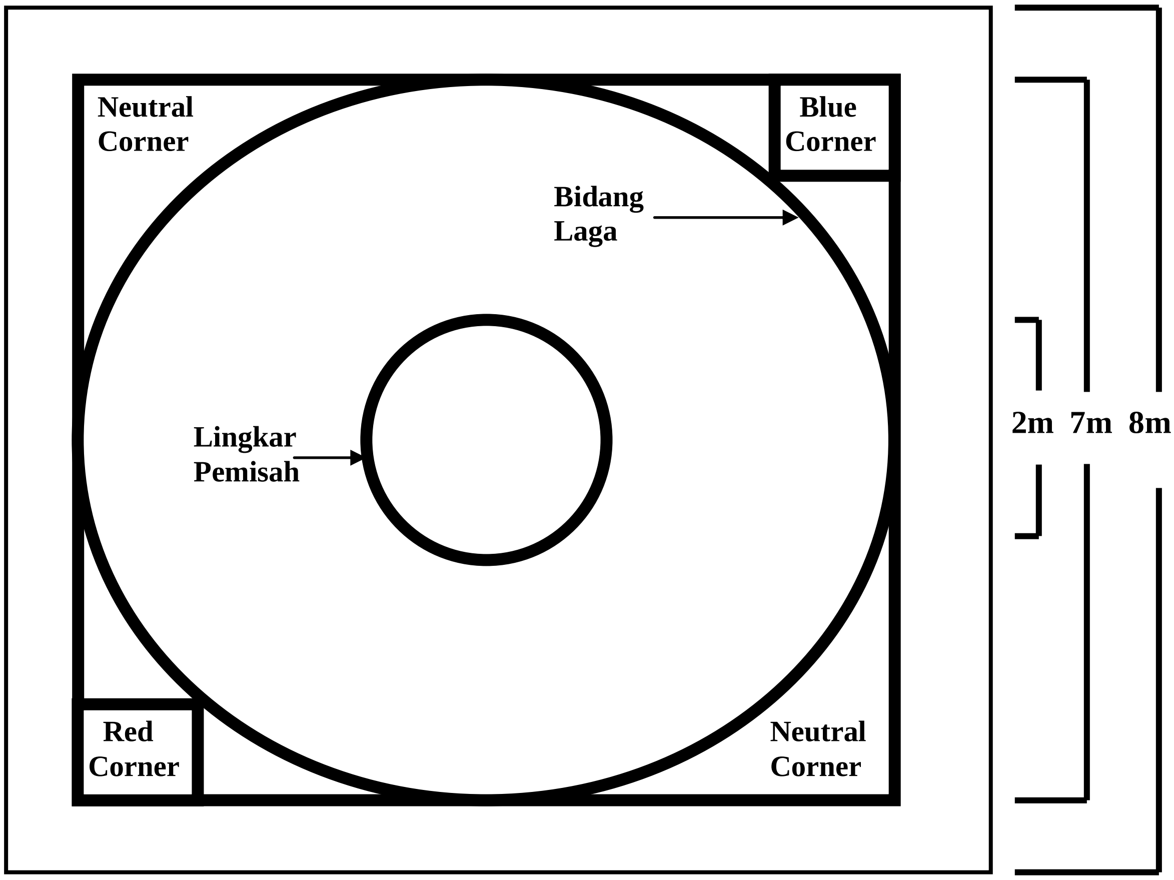


Figure 1.1: The silat arena (Anuar, 1993; pp. 11).

The silat tournament has an arena in which the two silat exponents will compete against each other (see Figure 1.1). The *bidang laga* is a circle measuring seven metres in diameter. It is in this circle that the contest occurs. If a participant steps out of bidang laga during a contest, the contest stops until the participant returns to the bidang laga. The clock will be stopped and resumes once the referee or '*wasit*' instructs the match to proceed. No points will be deducted except if the exponents steps out of the bidang laga regularly with the intention to waste time during the silat match. Meanwhile, the *lingkar pemisah* is the circle measuring two metres in diameter in the middle of bidang laga. This circle separates the two participants before the contest starts.

In a silat contest, two silat exponents square-off in a 7 m diameter circular area. The match consists of three rounds of two minutes each with one-minute interval between rounds. This is a standard time to all age groups in silat competition. Time stoppages by the referee are not included in the actual bout time, so the actual duration of each round and thus total match time is usually longer than the 3 x 2 minutes scheduled, respectively. Figure 1.2 shows the technical arrangement of silat arena. Points are awarded by the five judges for toppling an opponent, successful defensive blocks, and offensive punches and kicks to the chest, abdomen and flanks, leg sweeps and throws (International Pencak silat Federation, 1999). Only strikes with either the arms or legs are considered legal. Unlike other competitive martial arts, the launch of any attack and defence movement must be initiated with specific co-ordinated silat "step patterns", otherwise points scored will not be valid. The silat step patterns are something that make silat different to other martial arts. Every movement in a silat contest must be in silat posture. It should not be similar like jumping in karate and taekwondo or the silat exponents will be panelised points. Figure 2.03 shows 7 step patterns that are used in silat contests. The exponent scoring the highest number of points or who knocks his opponent out wins (Aziz *et al.*, 2002).

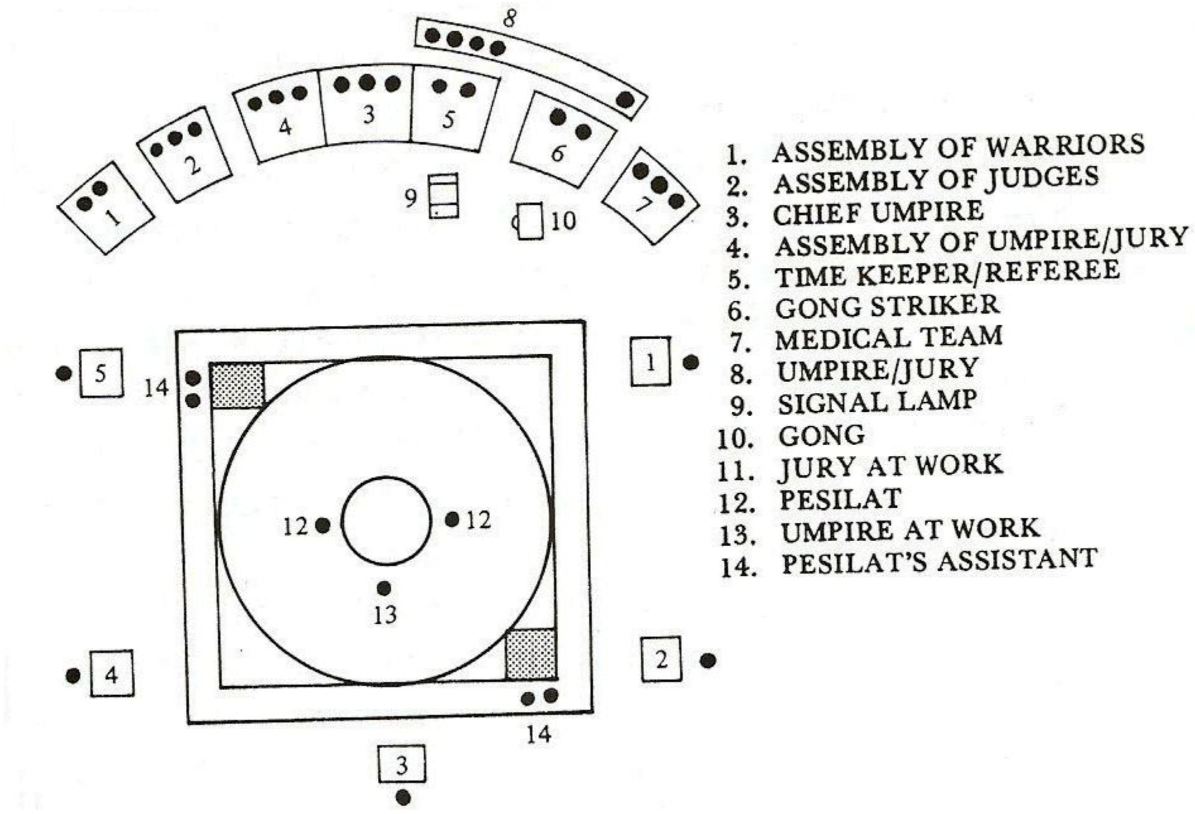


Figure 1.2: Technical arrangement of the silat arena (Anuar, 1993; pp. 14).

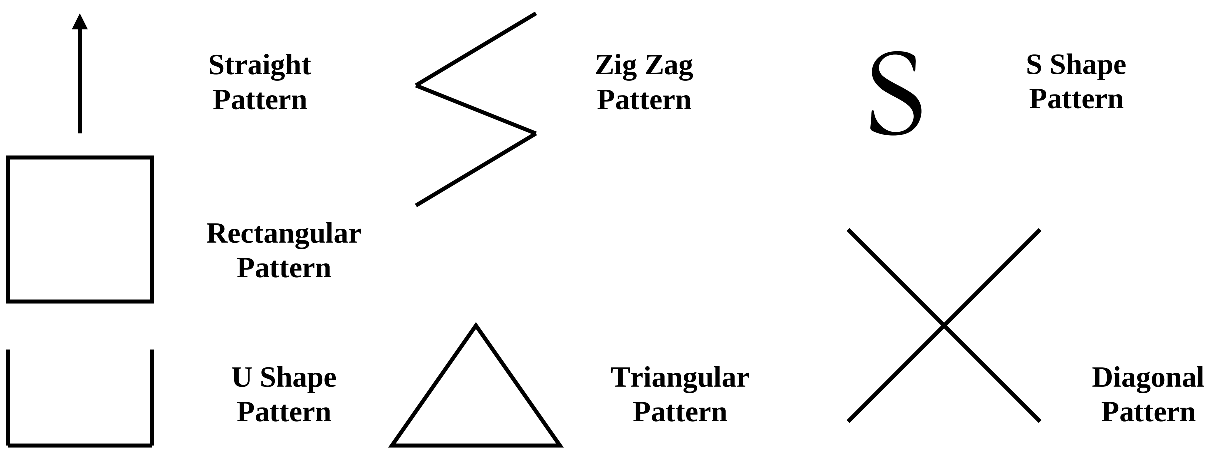


Figure 1.3: Example of silat step patterns (Persilat, 1999; pp. 121).

1.1.1 Issues in Silat Development Relating to Youth Athletes

Silat is one of the arts for Malays self-defense that has been inherited from the Malay's ancestors along the existence of the people known as 'The Malays' (Ministry of Culture, Art and Heritage, 2002). Silat olahraga is a popular combat sport that receives tremendous participation by many young silat exponents in Malaysia. Most of them are actively involved in silat training as part of co-curriculum activities in school. The co-curriculum activity are organised as part of the school timetable and it is compulsory for every student to take part in at least one activity either during or outside school hours. Moreover, many young silat exponents learn silat in school under the supervision of a silat instructor that has a valid certificate in coaching from their own silat institutions who are registered under the Malaysian silat Federation (PESAKA) and Ministry of Education. Ismail (2003) mentioned that there were 3 million silat practitioners in Malaysia. While, Shapie (2004) estimated around 42.5% of the youth population are involved in silat between 12 to 17-year-old. The silat programme in Malaysia is an effort from the Ministry of Art, Culture and Heritage and Ministry of Education in conjunction with National silat Federation (PESAKA) to promote silat among secondary and primary students for the next 15 years, running from 2002 until 2016 through three phases;

First Phase	-	2002 to 2006
Second Phase	-	2007 to 2011
Third Phase	-	2012 to 2016

This kind of programme is similar with the introduction of martial art physical education classes at school level which are conducted around 7 European countries (Theeboom and Knop, 1999). Those authors also suggested that Germany, Netherlands, France, Belgium, Luxemburg and Czech introduced physical education curricula (up to 35 hours) explicitly referring to martial arts during physical education classes in secondary schools.

Silat is growing fast all around the world. The number of countries that participated in the World silat Championship competition has increased from 7 – 25 countries (Anuar, 1993). The increased popularity of silat is reflected by the inclusion of competitors from Austria, Switzerland, Romania, France, Spain, Russian and United Kingdom at the world championships, and the formation of the European Championships. However, further research is required due to the absence of any research related to youth silat particularly on developing young silat performer's fitness and training programme.

1.2 Introduction of the Thesis

Participation of children in martial arts, which constitute a substantial proportion of combat sports, has increased markedly over the past decade (Zetaruk, 2009). In many countries participation in martial arts are among the most popular extra-curricular activities practiced by youths aged between 10 to 15-year-old (De Knop *et al.*, 1996), with participation rates in youth martial arts thought to be on the increase (Woodward, 2009). Moreover, it has been estimated that worldwide approximately 75-120 million children and adults participate in martial arts (Birrer, 1996). With regard to organised sport in particular, martial arts come in second place after soccer and are regarded as one of the most important new trends in sports participation (De Knop *et al*., 1996). It has been shown that strength and flexibility increase in adult or elite martial arts athletes (Callister *et al*., 1991). However, given the popularity of martial arts it is surprising that there is limited research available on the responses of paediatric populations involved in combat sports with most of the research to date tending to focus on adults in Olympic sports such as boxing (Guidetti *et al*., 2002), wrestling (Yoon, 2002), judo (Callister *et al*., 1991; Taylor and Brassard, 1981; Thomas *et al*., 1989) and taekwondo (Lin *et al*., 2004; Heller *et al*., 1998; Thompson and Vinueza, 1991; Markovic *et al*., 2005; Wojtas *et al*., 2007; Kazemi *et al*., 2006).

Silat is a martial art of East Asian origin that can have both artistic and contact variations; with the contact version similar to both judo and taekwondo in that it is weight-classified, unarmed and full contact (Aziz *et al*., 2002), but with unique movement and step-patterns during competition (Anuar, 1993; Anuar, 1987; Anuar, 1992). It is these unique movement patterns, which help define each martial art and make it inappropriate to translate findings from one martial art to another. It has previously been stated that many forms of Asian martial arts are becoming popular in Western Countries (Theebom and De Knop, 1999), which can be observed by the creation of the European and World Silat Championships over two decades ago (Aziz *et al*., 2002) alongside the inclusion of silat in the South East Asia games. These competitions have been held in many non-traditionally silat countries like Austria, Belgium, Netherlands and Thailand, and the fact that global participation in these competitions has increased substantially speaks well of its worldwide following and acceptance (Aziz *et al*., 2002).

The silat competition consists of 3 divisions according to age and weight either in male or female participants; youths (aged 12 to 14-year-old), teenager (aged 14 to 17-year-old) and adults (17-year-old and above) (International Pencak Silat, 2004). By the time silat exponents reach adolescence, it is likely they will be involved in combative competition. Here the adolescence may be in the period when many silat exponents make the transition from junior/teenager competition to compete in senior competition. However, little is known about the physical and physiological characteristics that distinguish younger and older silat competitors, or how these develop with age and maturation. To the authors knowledge there is only one peer-review research publication in silat, which examines the physical responses of adult exponents during competition (Aziz *et al.*, 2002), with no research available in youth silat. The available literature on adult silat competition suggests that a silat match is characterised by a high aerobic and anaerobic metabolic response (Aziz *et al*., 2002). However, that study did not describe details about the demands of silat in terms of typical activity patterns during competition. This is particularly important as the attacking and defensive movement must be initiated with specific co-ordinated silat step-patterns, or the points score will not be valid during the silat match. Thus, identification of work rates and activity patterns within a silat match are important to understand the nature of silat competition. Moreover, identifying sport-specific fitness trends across youth Silat performers will enable identification of fitness traits which are most important to performance, helping to inform training. Other combat sports have been shown to require strength (Thomas *et al*., 1989; Thompson and Vinueza, 1991; Zabukovec and Tiidus, 1995), power (Zabukovec and Tiidus, 1995; Heller *et al*., 1998; Borkowski *et al*., 2001; Thomas *et al*., 1989), speed (Heller *et al*., 1998; Borkowski *et al*., 2001; Thomas *et al*., 1989; Thompson and Vinueza, 1991; Zabukovec and Tiidus, 1995), muscular endurance (Zabukovec and Tiidus, 1995; Francescato *et al*., 1995; Doria *et al*., 2009; Heller *et al*., 1998) and skill (Wojtas, 2007; Kazemi *et al*., 2006; Yoon, 2002). The theory of accelerated adaptation and trainability, as promoted in the long-term athlete development model of Balyi and co-workers (2001, 2004), also suggests that when there is a naturally occurring rapid increase in fitness, a child will be most responsive to training that particular component of fitness. Therefore, identifying such periods may assist with providing a structure to understand the factors that influence fitness and trainability during childhood.

From a biological perspective the period of adolescence includes two major events, the adolescent growth spurt (somatic maturation) and sexual maturation (Malina *et al.*, 2004). Youth enter this phase of growth at varying ages (different timing) and proceed through it at variable rates (differential tempo). Timing refers to the chronological age (CA) at which the spurt occurs, while tempo refers to the rate at which an individual goes through the spurt (Beunen and Malina, 1996). Absolute size changes with growth and maturation are a major confounding factor affecting physical characteristics reflecting individual differences in the timing and tempo of maturation (Silva *et al.*, 2008). In order to appreciate fully individual differences in timing and tempo, a point of reference other than CA is necessary; such indicators of biological maturity include skeletal age, age at appearance of secondary sex characteristics, and age at peak height velocity (PHV). Allowing for this variation, PHV rather than chronological age has been used to characterize changes in size, body composition and performance relative to the adolescent spurt in height (Beunen and Malina, 1988; Beunen *et al.*, 1988; Malina *et al.*, 2004). Improvements in physical performance during childhood are nonlinear, and the variable rates of improvement are reflected in rapid fluctuations in performance (Viru *et al.*, 1999). Moreover, girls on average are in advance in timing of maturation, but tempo overlaps considerably (Thomas and French, 1985; Malina *et al.*, 2004). Other body dimensions, muscular strength, motor performance, and aerobic power show a well-defined adolescent spurt, but the time of the respective spurts varies relative to PHV in both sexes and relative to menarche in girls (Malina *et al.*, 2004).

Sporting performance depends on the combination of physical (physiological), functional (mechanical) and behavioural characteristics and sport-specific skills (Silva *et al.*, 2008; Bar-Or and Rowland, 2004). Physical performance is an important component of the behavioural repertoire of children and adolescents, perhaps more so for boys than for girls, although the recent acceptance of girls and women in the role of elite athletes may influence the views and the values attached to physical performance in girls (Beunen and Malina, 1996). The assessment of physiological (fitness testing) and physical changes during growth is essential for the valid interpretation of human performance (Stratton and Williams, 2007). Moreover, exercise adaptations to strength, anaerobic and aerobic training have been extensively studied in adults, however, young people appear to respond differently to such exercise stimulus in comparison to adults (Matos and Winsley, 2007). Furthermore, many functional characteristics have their own growth spurts, including aerobic capacity, strength, power, and speed, which vary in timing relative to the growth spurt in body size (Malina *et al.* 2004). Thus, the development of proficiency in a variety of movements is a major task of childhood (Malina, 2000). Motor performance is most often measured in a variety of gross motor tasks which require abilities such as speed, balance, flexibility, explosive strength, and local muscular endurance, while muscular strength is traditionally measured by static dynamometric tests such as gripping, pulling and pushing (Beunen and Malina, 1996). It has been reported that children show considerable increases in performance of some skills between 5 and 8 years of age (running speed and the shuttle run) but show steady, more gradual increase in performance of other skills from 5 years of age through childhood (jumping, throwing, and strength) (Malina *et al.*, 2004). Performance of girls, on average, on a variety of tasks (dash, standing long jump, vertical jump, shuttle run, and others) improve more or less linearly from 6 to about 14 years of age, followed by a slight increase in some tasks or a plateau in others. There is much overlap between the sexes during the childhood (Malina *et al.*, 2004; Beunen and Malina, 1996). In boys, isometric strength increases linearly with age from early childhood to approximately the age of 13-year-old, when there is a clear adolescent spurt (an acceleration in strength development); whereas in girls, strength increases linearly until 15 year old in several studies though there is less evidence of a clear adolescent spurt (Beunen and Malina, 1996). With the exception of flexibility, males tend to attain, on average, higher performances than females in standard tests of speed (dashes), power and coordination (vertical jump, standing long jump, throw for distance), muscular endurance (flexed arm hang) and agility (shuttle runs) from about 8 years of age on and the difference between sexes increases during adolescence (Malina *et al.*, 2004).

Performance in a variety of motor tasks such as speed, explosive strength, local muscular endurance, flexibility and balance show an improvement, on average, from childhood through adolescence in boys (Beunen and Malina, 1996). Moreover, changes in body size, physique and body composition associated with growth and maturation are important factors that affect strength and motor performance (Malina *et al.*, 2004; Beunen and Malina, 1996; Malina, 2000; Viru, 1999), particularly in boys where the sex differences might relate to size advantage in boys. Age is positively related to strength and motor performance even when stature and weight are controlled (Malina *et al.*, 2004), which this positive relation suggests an important role of neuromuscular maturation and experience in performance on strength and motor tasks. During childhood and adolescence boys tend to have greater strength per unit body size, especially in the upper body and trunk, than girls (Beunen and Malina, 1996). A study by Malina *et al.* (2005) reported that the observations on both elite divers and distance runners (Eisenmann and Malina, 2003) suggest that sex differences in motor performance are negligible until late adolescence, when the male adolescent spurts in muscle mass, specifically upper body musculature and in strength and power contribute to sex differences in several performance items at this time (vertical jumps, medicine ball throw). The changes occur after PHV (Mirwald *et al.*, 2002). In early adolescence, motor performance of girls fall, on average, within 1 standard deviation (SD) below average performance of boys, however, after 14-year-old, average performance of girls are consistently beyond the bounds of 1 SD below the means of boys in most tasks (Beunen *et al.*, 1989; Malina *et al.*, 2004). Furthermore, strength and motor performance are also influenced by motivational factors, opportunity for practice, exposure to appropriate instruction, habitual physical activity and perhaps in the cultural environment, which suggests that these variables may be especially relevant in the context of examining sex differences in performance (Malina *et al.*, 2004). Although age, gender and maturation associated variation in the motor performances of children and adolescents are well documented in research literature on physical activity and sport (Malina *et al.*, 2005; Malina, 2000; Naughton *et al.*, 2000; Augustsson *et al.*, 2009; Beunen and Malina, 1988; Thomas and French, 1985; Viru *et al.*, 1999) there is a paucity of research which reports if being involved in martial arts will help to promote fitness development during childhood, with no research available in youth silat.

The development of performance in competition is achieved through a training process that is designed to induce automation of motor skills and enhance structural and metabolic functions (Smith, 2003). Moreover, many young athletes are being encouraged to train intensely for sporting competitions from an early age (Naughton *et al*., 2000). Nevertheless, compared with studies in adults, less is known about the physiological trainability of adolescents. It has been reported that a child will be most sensitive to additional stimulus in training during a specific term that is known as a period of accelerated adaptation or window of opportunity (Balyi and Hamilton, 2004). Therefore, the ability to identify periods of accelerated adaptation is paramount to further understand potential physical adaptation during childhood and into adulthood to maximize the athletic potential of young performers (Lloyd *et al*., 2011). It has been considered that the initial prepubertal window of opportunity is related to CA-related enhancement in neuromuscular efficiency, while the second circa- or postpubertal window is attributable to maturity-related increases in hormonal levels, muscle fibre-type and muscle mass (Viru *et al*., 1999). This theory has been used in the development of the popular "Long Term Athlete Development" (LTAD) model (Balyi and Hamilton, 2004), which has been proposed by a variety of national governing bodies to offer a first step to considering the approach to talent development. The model was based on research of the natural development of physical components throughout childhood, such as speed (Kotzamanidis, 2006; Fournier *et al*., 1982), strength (Ramsay *et al*., 1990; Ozmun *et al*., 1994; Hetzler *et al*., 1997; Granacher *et al*., 2010; Mahon and Vaccaro, 1989), aerobic endurance (Obert *et al*., 2001; Fournier *et al*., 1982) and muscular power (Beunen *et al*. 1988) Although the implementation of the model, and its derivatives, has provided a more structured approach to athlete-centred programming, there is arguably a lack of empirical evidence for the development of the components of the original model (Ford *et al*., 2011; Lloyd *et al*., 2011). Specifically, it is not known if periods of naturally occurring accelerated adaptation during childhood do indeed lead to enhanced trainability. Further research is required into the potential benefits associated with training for fitness development in youth, particularly in youth martial arts and silat where little empirical evidence currently exists.

The physiology of exercise can be defined as the study of how the body responds and adapts to exercise and the identification of physiological characteristics that explain rather than simply describe performance (Winter *et al*., 2007). Bird and Davidson (1997) stated seven reasons for undertaking physiological tests including the importance of the information gathered from the tests will assist in selection or identify readiness to resume training or competition. Furthermore, the development of any fitness prescriptions will develop knowledge and understanding of a sport or activity for the benefits of coaches, future athletes and scientists within specific-sports *per se*. Several criteria have been raised to make sure protocols are effective, including that the assessment should be specific and valid and that resulting measures should be reproducible and sensitive to changes in performance (Winter *et al*., 2007). Thus, much of literature across team-sports (Taskin, 2009; Izumi *et al*., 1996), individual-sports (David *et al*., 1996; Keren and Epstein, 1981; Mosher *et al*., 1994; Spurss *et al*., 2003; Rahami and Behpur, 2005; Hunter *et al*., 1987; Fournier *et al*., 1982) and combat-sports (Teng *et al*., 2008; Baudry and Roux, 2009; Turner, 2009; Bounty *et al*., 2011; Melhim, 2001; Kraemer *et al*., 2004; Amtmann and Cotton, 2005; Buse and Santana, 2008; Amtmann and Berry, 2003; Amtmann *et al*., 2008; Violan *et al*., 1997) have been published in order to facilitate the development of sport-specific training and testing programmes, although no such information exists for silat. In published training studies most of the improvements observed in fitness following a training programme are based on group responses (Taskin, 2009; Izumi *et al*., 1996; Teng *et al*., 2008; Baudry and Roux, 2009; Turner, 2009; Bounty *et al*., 2011; Melhim, 2001), which is understandable given the design of experimental research. However, most research (Kraemer *et al*., 2004; Amtmann and Cotton, 2005; Buse and Santana, 2008; Amtmann and Berry, 2003; Amtmann *et al*., 2008; Violan *et al*., 1997) tends to focus on group responses and ignore the benefits for the individual athlete and transference of fitness improvement into competition. Bompa and Haff (2009) stated that the goal of training is to optimise fitness performance into sport-specific competitions throughout the training year. Therefore objective measures are needed to confirm whether or not training is benefiting competitive performance. This is important in silat, which is an individual sport; any significant improvements observed in fitness following a training programme from a group analysis does not mean that all individuals would gain similar improvements in fitness or transfer this improved fitness to competitive performance. Thus, an objective measurement is required to provide the silat coach with information on whether individual improvements in fitness may have a positive impact on combative performance.

To facilitate the coaching process there is a need for systematic research that increases understanding of the demands of silat and how young silat athletes develop. This requires a multidisciplinary approach to develop appropriate methodologies that allow the collection of worthwhile and objective evidence that can aid both scientists and the coaching community. Figure 1.4 shows the interlinking relationship of the various studies contained within the thesis. Performance analysis techniques developed in Study 1 are utilised to develop test batteries in Study 2 and monitor competitive performance in Study 4, whilst fitness data in Study 2 is used to test the theory of accelerated adaptation and trainability in Study 3, with Study 4 examining any transference of improved fitness to competition.

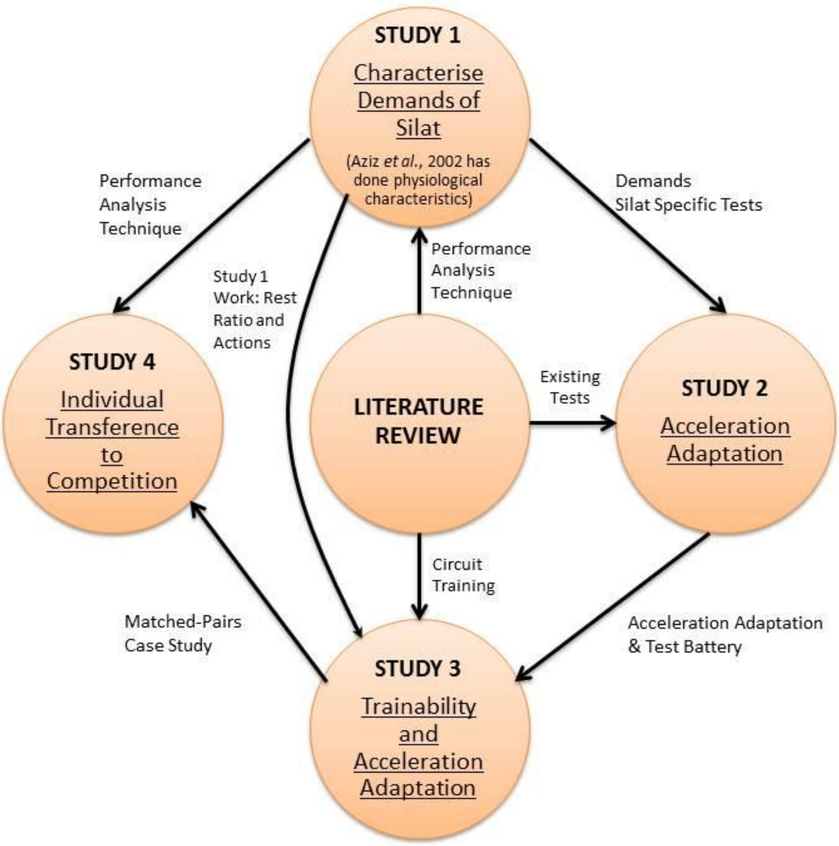


Figure 1.4: The interdisciplinary perspectives between studies in the thesis.

The specific aims or objectives of the thesis are given below.

1.3 Objectives of the Thesis

- To identify periods of fight time (work) and break time (rest) within rounds of international silat matches. (Study 1 [a])
- To analyse the activity pattern of individual exponents during the fight time of a silat match. (Study 1 [b])
- To establish the reliability of newly developed silat-specific fitness tests. (Study 2)
- To profile the fitness characteristics of male and female youth silat athletes across ages 13 to 16-year-old. (Study 2)
- To determine whether a 6-week circuit training intervention can promote fitness development in male youth silat athletes. (Study 3)
- To determine whether acute training responses differ between 13 and 16-year-old male silat performers. (Study 3)
- To analyse the activity pattern of individual exponents aged 13 and 16-year-old during competitive fights completed before and after a 6 week circuit training programme. (Study 4)

CHAPTER TWO

Literature Review

2.1 Introduction of Performance Analysis

In order to better understand silat and the role of performance analysis in this thesis, it is necessary to have a brief overview of both subject area development and some important points of history in order for the reader to get the greater insight into the complexities of determining notational system for the sport of silat olahraga.

Performance analysis is a discipline that typically involves analysis of actual sporting performance rather than fitness test or questionnaire data (Wojtas *et al.*, 2007). It can be undertaken as part of an academic investigation into sports performances or as part of applied activities in coaching, media or judging contexts. What distinguishes performance analysis from other disciplines is that it is concerned with actual sports performance rather than activity undertaken in laboratory settings or data gathered from self reports such as questionnaires or interviews (O'Donoghue, 2008). Performance analysis can be broken down into two separate but related disciplines:

1) Notational analysis or match analysis, where individual or team performance is analysed using a number of different indicators (e.g. the distance cover by a single player in football match).
2) Skill analysis where any skill or activity performance is analysed based on the key points of the skill (e.g. the type of strike/skill needed to get point in martial art competition).

This view is supported by the work of Hughes (1998). Five major purposes of notation have been delineated:

1) Analysis of movement

2) Tactical evaluation

3) Technical evaluation

4) Performance modelling

5) Coach and player education

Most research using notation or indeed any practical application working directly with coaches and athletes will span more than one of these purposes. The sophistication of data manipulation procedures available can aid a coach in their efforts to ameliorate performance. The advent of online computer facilities overcomes many error possibilities such as operator errors, hardware or software errors. The sports game could be digitally represented first via data collection directly into computer and then documented via the response to queries pertaining to the game (Hughes, 2008).

2.1.1 The Development of Sport-Specific Notational Analysis

Notational analysis is not a new phenomenon as a general perspective, rudimentary and unsophisticated forms of notation have existed for centuries (Hughes and Franks, 1997). Traditionally, large number of studies in notational analysis were completed in soccer and squash (Reilly and Thomas, 1976; Hughes, 1985) but more recently this has changed because a lot of publications can now be found on a variety of sports including mixed martial art (William and O'Donoghue, 2006) and taekwondo (Wojtas *et al.*, 2007). Early research on movement systems was limited to variety and details. But this system gradually diversified into game analysis and into sport-specific analysis.

One of the first attempts to devise a hand notation system specifically for sport analysis was that of Messersmith and Bucher (1939), who attempted to notate the distance covered by basketball players during a match. The use of pen and paper made hand notation systems inexpensive and easily portable and they could also be used in 'real life' situations (Hughes and Franks, 1997). However for certain sports such as boxing which could involve a number of fast combinations of hand strikes, analysis of such events in 'real time' were still impossible from an analytical perspective (Hughes and Franks, 2004).

The development of recording technologies both in audio and visual was to play a crucial role in the consequent evolution of post-event hand notation systems. Reilly and Thomas (1976) analysed individual players in terms of their movement patterns during match play in football. Importantly, the distances covered were measured using audio equipment and the use of a hand notation system. With this system they were able to specify work rates of the different positions, distances covered and the percentage time of each position spent in the various movement classifications (Hughes and Franks, 1997). A further important development was the use of video in notational analysis. The video as a tool, allows a permanent record for post-event analysis of sports that traditionally would be impossible to hand notate due to the speed of individuals movements (Hughes and Franks, 2004; Hughes and Franks, 1997).

Withers *et al.* (1982) attempted to determine the movement patterns of football players using videotaped games in an analysis that had implications for the specificity of fitness training in football. They classified players into four categories: full backs, central defenders, midfield and forwards (n=5 in each group of player positions). Players were videotaped while playing; at the end of the match they were informed that they were the subject and were then required to ‘calibrate’ the different classifications of motion. The subject was videotaped while covering the centre circle as follows from a walking start of 3–5 m: walking, jogging, striding, sprinting, moving sideways, walking backwards and jogging backwards. The average stride length was then calculated for each of these types of locomotion. The data produced by Withers *et al.* agreed to a great extent with that of Reilly and Thomas (1976): both studies showed that players spend 98% of the match without the ball, and were in agreement in most of the rest of the data, the only difference being that the English First Division players (Reilly and Thomas) were stationary a great deal more (143 s) than the Australian players (45 s). Withers *et al.* went on to link their analysis with training methods specific to the game and position. Later, the use of post-event video analysis with hand notation systems was being employed in a number of the post-event video analysis such as netball (Miller and Winter, 1984) and field hockey (Miller and Edwards, 1983). The use of video in notational analysis offers more than augmented information. It allows for a macro-analysis of performance and the micro-analysis of individual elements or actions which may be performed at speeds greater than can be observed and notated accurately (Hughes and Franks, 1997).

Currently as mentioned above, notational analysis consists of four major areas consisting of movement analysis, tactical analysis, technical evaluation and statistical compilation using statistical databases in an attempt to enable more accurate predictions for outcomes in sporting competitions (Hughes and Franks, 1997; Hughes and Franks, 2004). The area of statistical databases compilation includes profiling and modelling and is an important aspect of notational analysis with respect to combat sports when attempting to establish normative or average performance (Hughes *et al.*, 2001; Hughes and Potter, 2001). The use of modelling has been used in a number of sports with examples such as rugby union (Parsons and Hughes, 2001), and squash (Lynch *et al*., 2001) and can be used as a coaching tool for pinpointing strengths and weaknesses and designing training strategies.

The use of notational analysis in sport is a relatively new development, yet the real future lies in the growing awareness by coaches, athletes and sports scientists of its potential application to all sports. Various technologies have been employed in the process of post-event analysis and have been pivotal in objective performance measures which then serve as the basis of future planning in any coaching process (Hughes and Franks, 2004). The priority when devising hand notation or computer based notation systems is to devise simple recording methods that are both efficient and easy to learn (Franks and Goodman, 1984) and can provide accurate and precise feedback; the role of which is fundamental in the coaching process and central in the improvement of performance (Hughes, 2004).

A characteristic of most combat sports is the throwing of a number of strikes in short bursts of actions between the two contestants, making it almost impossible to notate a fight in 'real time' (Harris, 2005). For fast moving combat sports the use of a hand notation system needs to be used in conjunction with video playback facilities and is essential for the logical analysis of the form and function of the events taking place in such a sport and is necessary before further analysis can take place (Hughes and Franks, 2004).

Several dissertations have attempted to address the need to design hand notation systems in order to analyse other forms of competition fighting (Davis, 1986 and Sand, 2000). An unpublished dissertation by Sands (2000) using a specialised hand notation system, was able to show significant differences between grade and style of fighting from the analysis of karate kumite contests. The published work of McCann *et al.* (1996) was successful in comprehensively recording and evaluating karate tournaments using a modification of the Davis (1986) hand notation system. While, William and O'Donoghue (2006) successfully showed the different strikes used by the winning and losing fighters in mixed martial competition that can aspire mixed martial art competitors and coaches to design a better training programmes using this useful descriptive data.

Hughes and Franks (2004) described a system for analysis of punch types in professional boxing. A simple hand notation system for boxing was devised in identifying types of punches and offensive actions. As described by the authors, the hand notation system required the use of video for post-event analysis. Even though the system was in itself somewhat crude and simple (Hughes and Franks, 2004) and was unable to record many essential aspects of a fight such as defensive information, positional information and subjective measures of power and accuracy, the data was able to give some very simple and basic information clearly maps the progress of the fight and gives a quantitative analysis of the two boxers during the bout (Hughes and Franks, 1997).

Investigating combat sports, O'Donoghue (2008) stated that where a technique is important within a sport and cannot be analysed during competition, laboratory based analysis of the technique still falls under the umbrella of performance analysis. This is because the technique that is being analysed is clearly one that is often performed within competition. Thus, Wojtas *et al.* (2007) describe the influence of several physical factors, motor abilities and technical skills on the performance level in taekwondo using data's from 16 female taekwondo competitors such as height, body mass, BMI, ranking and the results of general and special fitness tests in taekwondo. The result indicated that the top athlete from 16 female taekwondo competitors has developed all abilities and skills to a very high level, generally higher than other subjects in the study and shows that a better athlete was able to connect good level of technical skills and motor abilities. Clearly this is important and the results are generally in line with previous results by Heller *et al.*, (1998), Toskovic *et al.* (2004), Markovic *et al.* (2005) and Kazemi *et al.* (2006) that elite taekwondo competitors requires both a high level of "dynamic" motor ability and the ability to perform major techniques at high speed (Wojtas *et al.*, 2007).

2.1.2 Time Motion Analysis

The process of bridging the gap between research and practice, so that scientific knowledge about sports can be discussed and put into practice has been an ongoing problem (Reilly, 1996). Understanding the demands of competitive sport is essential when designing the conditioning elements of training programmes, estimating energy requirements and reducing injuries (O'Donoghue and Parker, 2002). However, without an understanding of the physiological demands of the sport, valid and effective training sessions cannot be developed (Hawley and Burke, 1998). It is also important to be able to integrate knowledge such as between performance analysis and physiology. To understand or appreciate physiological demands linked to the performance it would also need some measure of intensity or at least appreciation of this. Detailed information on the movements in a sport provides comprehensive assessment of the demands of competition and assists in developing specific training regimes (Duthie *et al.*, 2005).

Performance analysis has been integrated to provide objective assessment of live performance and its physiological requirements in a non-intrusive manner (Lyons, 2003). Most studies in sport that have used time motion analysis aim to quantify the movement patterns of various playing position such as in rugby (Duthie *et al.*, 2005), football (O'Donoghue *et al.*, 2005b), hockey (MacLeod *et al*, 2007), netball (O'Donoghue, 2004b) and Gaelic football (O'Donoghue and King, 2005). Here, analysis of movement is a purpose of performance analysis that is concerned with entire in-game activity and work-rate rather than tactical and technical aspects of competition. Analysis of movement has been undertaken using a variety of different methods, each promoting different sets of performance indicators to describe athlete activity (O'Donoghue *et al*, 2005b). Some methods have monitored the locations and path of player movement within the playing area during match time. Such methods range from manual methods supported by audio-video equipment (Liddle and Murphy, 1996) to automated player tracking systems described by Liebermann *et al.* (2002). Notational and match analysis, has attempted to create a valid and reliable record of performance of soccer, by comparing the activity profiles of different positional roles in terms of the distribution of match time among a variety of activities (Withers *et al.*, 1982., Bangsbo *et al.*, 1991 and O'Donoghue *et al.*, 2001).

Time-motion analysis produces information about activity profile and work-rate during competitive sport (O'Donoghue *et al.*, 2005a). Calculating the frequency, mean duration and total time spent in activities is fundamental in time motion analysis. Time-motion analysis studies which measure the duration and frequency of, and distance covered in, different motion categories over the duration of a sport, provide essential information used to estimate the contribution of each energy system to match play (Reilly and Thomas, 1976; Withers *et al.*, 1982). Time-motion analysis studies have developed since initial investigations conducted by Reilly and Thomas (1976) and the advent of computerised notation systems has reduced the time it takes to analyse data and has improved the way in which data can be presented.

2.1.3 Work and Rest Ratio / Intermittent Exercise

Time-motion analysis is an objective observational analysis technique used to investigate work-rate in sport and exercise (O'Donoghue, 2008). The POWER (Periods of Work Efforts and Recoveries) system is the simplest computerised analysis system that records periods of work and rest and was developed by O'Donoghue *et al.* (2005a). This system is specifically focuses on the analysis of work to rest ratios to the exclusion of other time-motion data such as distance covered and performance of different types of work (such as running and sport related activity) and different types of recovery activity (such as standing, walking and jogging). The classification enables the observer to enter the sequence of activity performed by players into the POWER system during observation of video-recorded performance (O'Donoghue *et al.*, 2005b). The computerised system used F1 function key to record the beginning of each work period and F2 to record the beginning of each rest period (O'Donoghue and Parker, 2001).

The POWER system has been predominantly used in team sports especially in ball sports (Table 2.01). This system has evolved through its use in previous research studies (O'Donoghue and Parker, 2001; King and O'Donoghue, 2003; O'Donoghue, 2004a). In football, O'Donoghue and Parker (2001) used only two broad movement classes, "work" and "rest" during their investigation of work:rest ratio during ball-in-play time for football players in 3 different positions in FA Premier League competition. Their study provided the following output for a player once the timed sequence of movements had been entered:

1. The number of periods of "work" and "rest" performed. These two values would differ by no more than 1 for any match period as periods of work and rest alternated.

2. The percentage of observation time spent performing periods of work and rest. These two values always add up to 100% of the observation time.
3. The mean duration of work periods as well as the mean duration of rest periods.

All of these performance indicators were included in the output provided by the POWER system even though the frequency of rest periods and the percentage of observation time spent performing rest were considered not so important. They were functionally dependent on the frequency of work periods and the percentage of observation time spent performing work respectively.

Table 2.01: Selected studies of time motion analysis using POWER system in difference sports.

Reference	**Title**	**Sports**	**Target group**
O'Donoghue *et al.*, (2005b)	Repeated work activity in English FA Premier League soccer	Football	226 Football players
O'Donoghue (2002)	Time-motion analysis of work-rate in English FA Premier League soccer.	Football	52 football matches targeted to 6 players
O'Donoghue (2004b)	Activity profile of senior netball competition	Netball	36 subjects from netball players targeted to 7 positions.
O'Donoghue and King (2005)	Activity Profile of Men's Gaelic Football	Gaelic Football	55 seniors male players targeted to 4 different position
O'Donoghue and Parker (2001)	Time-motion analysis of FA Premier League soccer competition	Football	21 matches were observed targeted to 6 players
O'Donoghue (2003)	Analysis of the duration of periods of high-intensity activity and low-intensity recovery performance during English FA Premier League soccer	Football	34 English FA Premier League matches targeted to 6 players

King and O’Donoghue (2003) recognised that not all periods of work were of the average duration but could vary widely. Similarly, not all rest periods would be of the average rest duration either. Thus the frequency of work periods of 7 different duration ranges as well as the frequency of rest periods of 8 different duration ranges was reported by them. This allowed them to determine whether the duration of a rest period was independent of the duration of the work period that preceded it. The POWER system uses the same ranges of durations as in King and O’Donoghue’s (2003) investigation and O’Donoghue’s (2003) investigation, providing the following variables:

1. The number of work periods of 0 s-under 2 s, 2 s-under 4 s, 4 s-under 6 s, 6 s-under 8 s, 8 s-under 10 s, 10 s-under 12 s and 12 s or longer.
2. The number of rest periods of 0 s-under 2 s, 2 s-under 4 s, 4 s-under 8 s, 8 s-under 12 s, 12 s-under 20 s, 20 s-under 45 s, 45 s-under 90 s and 90 s or longer.
3. The number of work periods of each work duration range of interest (0 s-under 2 s to 12 s or longer) that are followed by rest periods of each rest duration range of interest (0 s-under 2 s to 90 s or longer).

Time-motion analysis studies of soccer have provided valuable information about player activity during the match in terms of work to rest ratios, the percentage of match time spent performing high intensity activity and the duration of the average high intensity bursts (Bangsbo *et al.*, 1991; Withers *et al.*, 1982). However, not all high intensity bursts are of the average duration and the recovery periods that follow them also can vary in duration (King and O’Donoghue, 2003). When Huey *et al.*

(2001) used average burst and recovery durations observed in competition to develop a specific intermittent training session for field hockey players, the session did not cause a significant improvement in relevant fitness test performances in comparison to undertaking non-specific aerobic endurance training. O'Donoghue and Cassidy (2002) evaluated a specific training session for netball players based on work to rest ratios observed in competition, fixed repetition and recovery times, there was no significant difference in improvement in relevant fitness test performance between those players that did the session and those players that did not.

Spencer *et al.* (2002) have analysed activity in field hockey using "repeated sprint bouts". They define a repeated sprint bout as a period of 3 or more sprints where the sprints are separated by non-sprint periods averaging less than 21s. The POWER system deals with periods of work rather than sprints specifically, but the ideas developed by Spencer *et al.* (2002) was utilised in the POWER system. For example 25% of recoveries in netball (O'Donoghue, 2004b), 30% of recoveries in Ladies' soccer (O'Donoghue *et al.*, 2004), 40% of recoveries in men's soccer (O'Donoghue, 2003) and 10% of recoveries in men's Gaelic football (King and O'Donoghue, 2003) last under 2s showing that these team sports required to perform repeated bursts of high intensity activity with very short recovery. However, the work:rest ratio periods and variability of these in marital arts has not been reported before.

This POWER system has been applied to a series of investigations of work rate in netball (O'Donoghue, 2004b), Gaelic football (O'Donoghue and King, 2005) and soccer (O'Donoghue, 2003; O'Donoghue 2004a). Table 2.01 showed several selected team sports that used the POWER system to establish their work-to-rest ratios throughout a match. The knowledge of the different types of high intensity exercise performed by the players of different positions during ball-in-play would be beneficial to coaches and players, supporting decisions relating to conditioning elements of training programmes. Whilst it has predominately been used in the team sports its application could be utilised in combat sports, including silat. As there is little work of work-rate to identify periods of fight time and break time within rounds of International contests, therefore it is important to look at several martial arts sports that have used performance analysis in their research.

Some notational analysis research has been done on individual combat sports such as boxing (Mullan and O'Donoghue, 2001; Hughes and Franks, 2004; Coalter *et. al*, 1998) and wrestling (Pekas and Hraski; 2006). Hughes and Franks (2004) described a system for analysis of punch types used while in amateur boxing. Coalter *et al.* (1998) investigated the validity of the computerised scoring system used. Other combat sports where performance analysis has investigated the action of competitors include Taekwondo (Wojtas *et al.*, 2007) and mixed martial arts (Williams and O'Donoghue, 2006), but to date there are no studies on silat. Wojtas *et al.* (2007) has described the chosen physical factors, motor abilities and technical skills for female international taekwondo competitors. The results showed the top athlete has higher technical skills and motor abilities than other athletes. The distinction of the very best athlete and other athletes allowed a deeper analysis concerning the influences of general and sport-specific fitness on performance level in taekwondo. The profile of skills performed by competitors in individual and team games gives an indication of playing style and preferred tactics. To understand the intermittent nature in silat or martial art, it is necessary to determine the work and rest ratio especially in identifying the profile of high intensity bursts and low intensity recovery of different duration during occur in competition. Therefore, there is a need to use notational analysis to describe the work to rest ratio that will have implications for the type of metabolic training of the energy system required in international silat competition.

2.1.4 Notational Analysis of Movement Patterns

The analysis of movement can be performed through two distinct methodologies. Fine and discrete movements are assessed through cinematographic analysis involving computerised frame by frame analysis of isolated movements providing accurate and detailed biomechanical results (Winter, 1979). Gross and continuous movements are recorded through notational analysis which provides a wider overview of performance and has developed from the use of hand notation or dictated notes (Reilly and Thomas, 1976), to sophisticated computerised video analysis (Krustrup *et al.*, 2003). Although not as detailed as cinematographic analysis, the use of video and computerised notational analysis techniques enhances the manipulation and presentation of data as it is able to process large amounts of data quickly and easily allowing for detailed statistical analyses to be compiled on the performance or player (Hughes, 1996; Rienzi *et al.*, 2000; Olsen and Larson, 1997). Through time-motion analyses, the pattern of exercise in multiple-sprint invasion sports (i.e. soccer) has been identified as intermittent and involves frequent alternations of activities such as standing, walking, jogging, cruising/running, sprinting, and backwards and sideways moving (e.g. Reilly and Thomas, 1976; Withers *et al.*, 1982; Van Gool *et al.*, 1988). Since the Reilly and Thomas (1976) study, motion classification systems have developed to include jumping (Mayhew and Wenger, 1985) and running has been classified as low, moderate or high speed (Bangsbo *et al.*, 1991). More recently, shuffling and match (‘on the ball’) activity classifications have been included in the analysis (O'Donoghue *et al.*, 2001).

In recent years, the development of sport specific movement abilities has become important in the training of players in team games. Speed, agility and quickness (SAQ) training programmes with associated equipment are being used in attempt to make conditioning training more specific to the demands of the games. The POWER system would not provide the necessary information about turns, swerves, lunges, jumps, leaps, breaking movement or direction. Bloomfield embarked on a programme of research to investigate the SAQ demands of activity performed during professional soccer competition (O’Donoghue, 2008). The Bloomfield Movement Classification (BMC) was designed after several preliminary observations of performances of individual players in multiple-sprint invasion sports (soccer, field hockey, rugby union, rugby league, basketball and netball). It is a detailed time-motion analysis technique that allows sports behaviour to be characterised by the profile of locomotive movements performed, direction of movement, turns, swerves, on-the-ball movement and intensity of movement (Bloomfield *et al.*, 2004). Thus, BMC is an important step forward in the more specific analysis of sport.

The BMC may give some perspective of movements used in combat sports. This includes the patterns of movement that are used in competition, which may inform training and testing. The ability to determine the movement that involve in competition will help the coaches to train the specific training for their fighter’s. A fundamental requirement for designing any sport specific training programme is having an understanding of the physical demands placed upon players during competition (Miller and Bartlett, 1994). In silat, the movement patterns were elaborated theoretically by Anuar (1992) and Anuar (1993). He showed the all the step patterns involved in silat while moving freely or during the actual event of attacking and defensive movements. The common movements that happened in the silat competition were similar with those William and O'Donoghue (2005) observed in modifying BMC. The fighter can move forwards, backwards, sidewards (left or right), diagonal, arced and in circle patterns while moving, parrying, catching, clinching or jumping. However, these step patterns also depending on the position of the opponent and the distance between each fighter. Also the fighter posture or '*sikap pesilat*' at the time the fighter is facing each other.

2.1.5 Skills and Movement Patterns in Silat Olahraga

The development of notational analysis has been a key in describing the system used in several individual combat sports such as boxing and mixed martial arts (Mullan and O'Donoghue, 2001; Hughes and Franks, 2004 and William and O'Donoghue, 2006). However, there is no research that characterise strikes and movements in silat competition. The profile of skills performed by competitors in combat sports gives an indication of fighting style and preferred tactics. Strike rate and type within a round has great significance to the eventual outcome of a fight. Most of the current published literature available with regards of notational analysis of combat sport has been directed at boxing, with the emphasis on the scoring system used by the judges officiating boxing matches (Mullan and O'Donoghue, 2001; Coalter *et al.*, 1998). These studies are important due to controversy surrounding the decisions of judges when observing and officiating fights but do not offer immediate and useful feedback to the individuals about their performance.

In silat olahraga there are several types of strikes athletes can use during competition. The assessment of winning or losing is determined by the standard of attack, the defence, the falls and clinching that takes place in the competition (Anuar, 1993). The fighters are judged on the prestige of their techniques and the beauty of silat that is portrayed. They are assessed on the following aspects:

(a) The prestige of the techniques used:

Assessment 1:

- Every act of parrying which results in attack of the target.
- A strike of the hand on the target.

Assessment 2: The kick that hits the target.

Assessment 3: A fall of the opponent onto the floor. Part of his body must touch the floor. The fighter must still be able to defend himself.

Assessment 4: Clinching of the opponent (for five counts) until he is not able to move.

(b) The beauty of techniques used:

The orderliness and the beauty of the techniques in the contest are based on the postures adopted and the coordination of the movements in attacking and defending. The fighters are allowed the freedom to develop their individual methods. The beauty of the techniques must be shown in every round. The lowest mark given is two and the highest five (Anuar, 1993).

Figure 2.1 shows the target areas that are allowed and not allowed to score points in silat competition. The point for attacking and defensive movements was given in Appendix A.

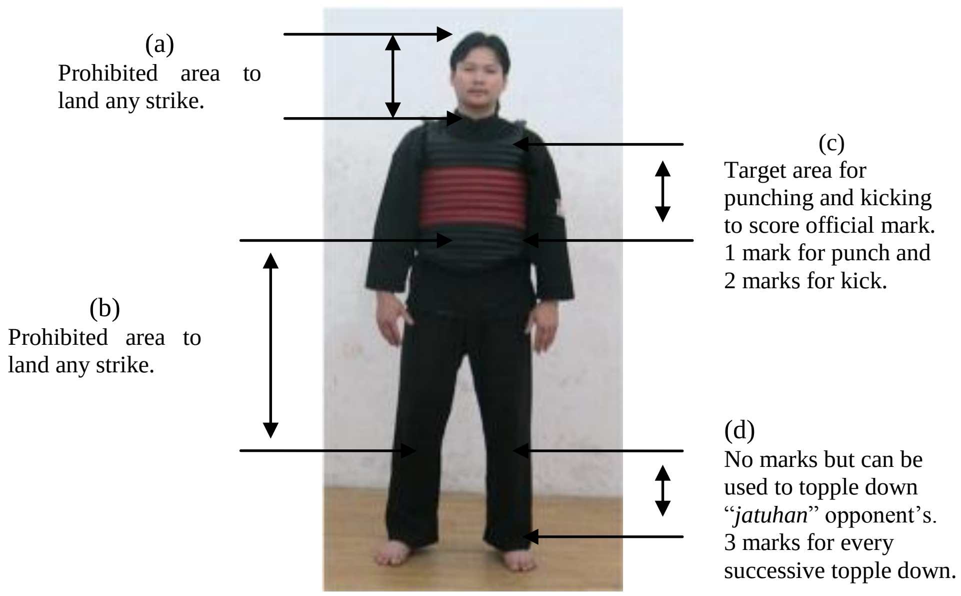


Figure 2.1: Area that are allowed and not allowed to attack by silat exponent.

There are several skills that contribute to success in silat performance where every aspect of these skills will contribute to success of the fighter. There are: punch, kick, swipe, block, dodge/evade, catch, self release, topple down (i.e. scissors skills "*guntingan*"), jump, fake punch, fake kick, and fake swipe. All of these skills will contribute on the attacking and defensive movements made by each fighter during the competition (Figure 2.2). As this is a subjective sport, it is important for each fighter to make a clear strike that can be observed by the judges. Thus, several factors will also influence the game such as injury and error of marking.

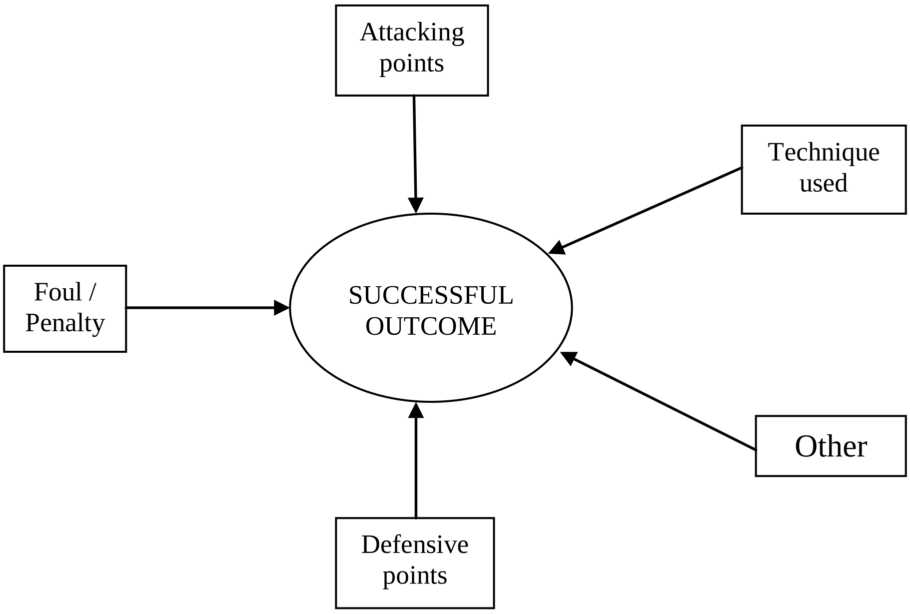


Figure 2.2: Factors that attribute to success or improved performance in silat competition.

There are occasions when juries fail to record the exact points because of the intensity of the strikes of both fighters. Weinberg and Richarson (1990) stated that the judges that officiate at sporting events have been recognised as a factor that can affect the overall outcome of sporting contest. Thus, most of coaches tend to use clear strikes, such as kicks and toppling down, to score points. However, to get a clear strike the fighter should master the concept of distance in martial art; with > 1 m distance between the both fighters, the best defensive movement when under attack is dodging or avoiding the strike and follow up by counter strike. While, for a distance < 1 m between fighters the best defensive skills when under attack is parrying or blocking that follow-up with counter strike. This means the closer the opponent the more specific technique (dodge/avoid, dodge/block or catch) the fighter must apply when being attack in the competition (Anuar, 1992). However this depends on the technical and tactics between coach and fighter. Sometimes, fighter tends to come close to his opponent to make sure they are not in distance to be kicked and have the ability to block the kick and topple down the opponent. Hughes and Franks (2004) found that in a boxing match between Mike Tyson and Frank Bruno, Bruno made 41% of his punches while holding, compared with Tyson's 4%. This is probably a reflection of Bruno trying to punch 'inside' Tyson i.e. by staying close you have less chance of being knocked out with one punch, which was characteristic of Tyson's fight. This concept is similar in any combat sports.

Silat competition rules state that an exponent is allowed up to four consecutive punches and/or kicks to the opponent during a single attack, upon which the referee immediately breaks off the confrontation (International Pencak Silat Federation, 1999). This suggests that silat exponents are accustomed to numerous bursts of high force production for 2-5 s, alternating with relatively lower-intensity movements throughout match (Aziz *et al.*, 2002). The high intensity in silat involves kick, punch, catches, topple-down, sweeping or scissors technique, parry, dodge or jumping to avoid strikes. While, the low intensity movements are specific co-ordinated silat ''step patterns'' before launching any attack and defensive movements. The information regarding skills and performance of successful fighters is important in order to determine the most critical skills needed in the competition. Hughes and Franks (2004) showed that in a match between Tyson-Bruno, although the data from the fight did not address many essential aspects of the fight, positional information, defensive information or subjective measures of power and accuracy but it did still describe the basic techniques employed by a boxer during the match. Also some very simple and basic information clearly maps the progress of the fight and gives a quantitative analysis of the progress of the two boxers during a bout. Athletes may exhibit a unique performance signature which can be used to predict future performance from past observation (Franks *et al.*, 1998; Hughes and Potter, 2001). Thus this information can be useful when attempting to develop strategies in combat sports.

2.1.6 Reliability Issues of Work and Rest Analysis

Reliability of measurement is important in all disciplines of sports and exercise science particularly in performance analysis. This is because most performance analysis methods do not involve fully automated data capture techniques. Therefore, reliability evaluation is essential so that the information produced by performance analysis can be interpreted with a full understanding of measurement error involved (O'Donoghue, 2007). In performance analysis of sport, reliability of measurement is a common feature of work in both notational analysis and biomechanics (Bartlett, 2001). There are different types of performance indicators used in performance analysis of sport ranging from timings measured on a ratio scale (Liddle and O'Donoghue, 1998; Brown and O'Donoghue, 2007) to event types, playing areas, players involved and event outcomes that are measured on nominal scales (Edwards and O'Donoghue, 2004).

Hughes *et al.* (2001) surveyed published performance analysis research finding many investigations where the reliability of data collection was not reported and other investigations where the reliability test made inappropriate use of statistical techniques. Many performance analysts find reliability testing a difficult area, particularly the use of statistical analysis techniques in order to evaluate reliability (O'Donoghue, 2007). Guidance on reliability statistics has been limited to percentage error (Hughes *et al.*, 2004) and confidence intervals (Cooper, 2006). O'Donoghue

(2007) discussed seven recommendations during developing and operating a performance analysis system:

1. Identify the performance indicators of interest and define these as precisely as possible. Where the performance indicator represents a complex pattern that is difficult to define in words, example video sequences for each value of the indicator may be required to train operators.
2. Identify the values of performance indicators for different types of performances (tactically, technically or in terms of energy systems).
3. Select a reliability statistic that will have construct validity.
4. Determine what value of this performance indicator represents an acceptable level of reliability (based on step 2 of these recommendations).
5. Train the operators using intra-operator reliability studies.
6. Undertake an inter-operator reliability study. This stage could be to compare reliability of performance indicators using a system with those published in media or internet sources.
7. If the level of reliability achieved by the operators is poor, consider using a less precise categorical version of the performance indicator.

An investigation of reliability observation in football match was performed by O'Donoghue *et al.* (2005b). They analysed 6 football players on two occasions each for a 15 minute period. The observation time for each player varied and, therefore, each frequency variable was scaled to the frequency per 15 minutes of observation time. The POWER system was used to enter timed work and rest periods performed by the player. The data was collected by four of the authors. Thus, to investigate the reliability of the observation process, these four operators were organized into two pairs of two operators. Each pair of operators used a different video recorded match during the reliability study. Each operator within a pair of operators independently analysed the video for that pair. The video containing the activity of 6 English FA Premier League football players covered by Sky Television's PlayerCam facility for approximately 15 minutes each. The two operators analysed the video on 3 occasions each using the POWER system. The classification of movement was subjective with work being classified according to observer perception of high intensity effort (i.e. running, sprinting and shuffling movements). It was therefore essential to establish the strength of agreement associated with the method when applied to football. Table 2.02 (a) shows the kappa values achieved by the first pair of observers for the 6 players they observed while Table 2.02 (b) shows the kappa values achieved by the second pair of observers. The kappa values represented a good to very good reliability throughout the three observations performed by the two pairs of observers (Altman, 1991).

Table 2.02 (a): Kappa values for first pair of observers (O'Donoghue *et al.*, 2005b).

Player	Observation Time	Observation		
		1st	2nd	3rd
Player 1	15 min 13s	0.7830	0.7369	0.7579
Player 2	14 min 50s	0.9327	0.8554	0.8905
Player 3	16 min 50s	0.7707	0.7832	0.7954
Player 4	15 min 10s	0.8136	0.7693	0.8203
Player 5	14 min 31s	0.7391	0.7028	0.7548
Player 6	20 min 29s	0.7381	0.7479	0.7402

Table 2.02 (b): Kappa values for second pair of observers (O'Donoghue *et al.*, 2005b).

Player	Observation Time	Observation		
		1st	2nd	3rd
Player 1	15 min 20s	0.7334	0.8160	0.8027
Player 2	16 min 27s	0.8510	0.8263	0.9024
Player 3	16 min 28s	0.7781	0.7202	0.8088
Player 4	14 min 45s	0.7816	0.8685	0.8237
Player 5	15 min 05s	0.8118	0.8511	0.7588
Player 6	18 min 34s	0.7682	0.9205	0.7211

Kappa was used to measure the strength of agreement between independent observations. Kappa is a statistic that has been used to evaluate the reliability of independent assessments in medicine (Altman, 1991) where each assessment is a decision of which nominal category should be applied (Cohen, 1960). Kappa determines the proportion of cases where the independent observers agree excluding the proportion where they could have agreed by chance. This has made kappa a useful reliability statistic to use with the nominal variables that are often used in notational analysis of sport (Robinson and O'Donoghue. 2007). The POWER system implements an algorithm to apply the kappa statistic to the times movement sequence recorded (O'Donoghue, 2005). This algorithm determines the proportion of observation time where 2 independent observations agree on the activity being performed, addressing the proportion of time where the observations would be expected to agree by guessing. Table 2.02 (a) shows the kappa values achieved by the first pair of observers (O'Donoghue *et al.,* 2005b) for the 6 players they observed while Table 2.02 (b) shows the kappa values achieved by the second pair of observers. Kappa values are interpreted as a very good strength of agreement if over 0.8, good if between 0.6 and 0.8, moderate if between 0.4 and 0.6, fair if between 0.2 and 0.4 and poor strength of agreement if between 0.0 and 0.2 (Altman, 1991). It is mathematically possible for kappa values to be below 0.0 where the level of agreement is lower than would be expected if the two observers guessed the activity being performed for entire duration of the observation. Values of kappa below 0.0 are classified as very poor (O'Donoghue *et. al.*, 2005a).

The study showed that the use of the kappa statistic to evaluate reliability of work-rate is recommended when using the POWER system. Kappa was shown to have a greater degree of construct validity for reliability assessment than percentage error, chi square and Pearson's *r* (O'Donoghue *et. al.*, 2005a). When O'Donoghue *et al.* (2005a) developed the POWER system for time-motion analysis, they found that values of Pearson's r, percentage error and chi square produced when analyzing different subjects could be greater than when the same subject was being analysed by an experienced observer. However, the kappa statistic achieved construct validity with values of under 0.2 (very poor to poor strength of agreement) being obtained when analysing completely different performances and values of over 0.6 (good to very good strength of agreement) being obtained when the same performance was analysed by an experienced user. Kappa might not be the best reliability statistic for all systems and performance indicators. However, it is recommended that efforts are made to use statistical procedures for reliability that do exhibit construct validity. This can be tested by applying them to pairs of observations where the same performance is being observed and pairs of observations from completely different performances. Any reliability statistic showing the "known group difference" between these two different types of pair of observation with no overlap in values can be deemed to have the property of construct validity as a reliability statistic.

2.1.7 Summary of Performance Analysis

Determining those characteristics of competitors and those techniques that have the greatest construct validity is important in silat. These involve the description of the influence of some physical factors, motor abilities, technical skills and movement patterns in silat competition. This is because the techniques or skills being used in intermittent sport specific training is often performed within competition. The need to make training specific to silat competition is essential so that it can be replicated accurately in training sessions. This involves the ability to execute match related skills such as tactical awareness, agility, flexibility, speed, anaerobic power, endurance and the ability to perform repeated burst of high intensity activity either in defensive or offensive situations.

Time motion analysis provides an objective method for quantifying work rate during a silat fight and is proposed to be the most effective method of assessing the physiological demands placed on each fighter. Several methods have been employed to monitor movement patterns in various team sports including rugby league (Duthie *et al.*, 2005) rugby union (McLean, 1992) football (Krustrup *et al.*, 2005), gaelic football (King and O'Donoghue, 2003) and basketball (Bishop and Wright, 2006). Time motion analysis has been found to be effective and accurate in determining and quantifying player behaviour and the component parts of the sport in a competitive environment (Duthie *et al.*, 2003). It is applicable to use the movement analysis to characterize the details of a silat fighter's distribution of action periods within competition. Furthermore, the need for further analysis that examines the relationship between movement patterns performed in a fight compared to those used in training.

Therefore determining the defensive and offensive movements is essential to quantify the movement patterns demonstrated by silat fighters.

Several combat sports (Table 2.03) have been notated such as karate (Davis, 1986; McCann *et al.*, 1996; Sands, 2000), boxing (Hughes and Franks, 1997), mixed martial art (Williams and O'Donoghue, 2006) and Muay Thai (Harris, 2005). The profile of skills performed by each fighter in an individual match gives an indication of fighting style and preferred tactics in competition. Using notational analysis to describe the striking techniques used in competition will help coaches to determine the training methodology to be implemented. However, the speed of the match should be considered (e.g. boxing, it is impossible to notate a fight live, Hughes and Frank, 2004). Therefore, the use of video and playback is essential for post-match analysis.

Table 2.03: Selected studies of performance analysis in combat sports.

Reference	Title	Sports	Objective
William and O'Donoghue (2006)	Technique used in mixed-martial arts competition	Mixed-Martial Arts	Notational analysis of striking techniques in mixed martial art
Mullan and O'Donoghue (2001)	An alternative computerised scoring system for amateur boxing	Boxing	Comparing alternative scoring system with existing system used in amateur boxing
Wojtas *et al.* (2007)	Fitness and skill performance characteristics of Polish female national taekwondo squad members	Taekwondo	Describing the influence of some physical factors, motor abilities and technical skills of performance level in taekwondo
Harris (2005) *(unpublished thesis)*	A hand notation system designed to record strike type and strike frequencies in Muay Thai (Thai Boxing)	Muay Thai	Notational analysis of striking techniques in Muay Thai
Sands (2000) *(unpublished thesis)*	Design of a hand notation system for the analysis of Karate Kumite	Karate	Comparing the differences between grade and fighting style of karate kumite contest

2.2 Physiological Demands of Combat Sport

2.2.1 Heart Rate (HR) and Blood Lactate

Measurement of HR has frequently been used as a reliable index of average exercise intensity during intermittent exercise (Ali and Farrally, 1991; Heller *et al.*, 1998). The measurement of HR provides a convenient method to monitor the response of the cardiovascular system in a match situation, allowing an estimation of the overall physiological workload imposed on a martial art exponent. Heller *et al.* (1998) pointed out that Taekwondo could not only improve human cardio respiratory endurance but also enhance practitioners' martial arts psychology and form good exercise and self-defense exercise. It also is classified as a high-strength anaerobic capacity exercise (Heller, *et al.*, 1998).

Table 2.04: Heart rate (HR) and blood lactate (BLa) response of different age groups during competitive combat sports.

References	**Combat Sports**	**Situation**	**Mean Age (y)**	**Gender**	**Mean HR (b.min^{-1})**			**BLa Post match (mMol^{-1})**
					Rd 1	**Rd 2**	**Rd 3**	
Aziz *et al.* (2002)	Silat	National Competitive match	22.6 23.1	Males Females	174 165	186 174	190 181	12.5 (2.1) 13.1 (4.0)
Heller *et al* (1998)	Taekwondo	National Competitive match	20.9 -	Males Females	184 -	186 -	- -	11.4 (3.2) -
Khana *et al* (2006)	Boxing	National Competitive trials	17.5 -	Males Females	170 -	177 -	183 -	7.4 (1.3) -

Astrand and Rodhal (1970) reported that heart rate increases with an increase in work intensity and shows a linear relationship with work rate. At the submaximal versus maximal, the relationship may become non-linear as the work intensity reaches maximum. The heart rates reported in Table 2.04 gives an indication of physiological demands experienced in combat sports including boxing. Lin and Kuo (2000) found during a taekwondo match, the athlete's heart rate would increase to 165 $b.min^{-1}$ and some may reach as high as 192 $b.min^{-1}$. This shows that martial art sports are a high intensity exercise, placing a significant impact on circulation and respiratory systems. Combat sports require significant anaerobic fitness to operate within a well-develop aerobic system. Even though the movement and pattern of the various combat sports are different, these sports involve a similar duration in competition. Many combat sports involve 2 minute bouts separated by 1 minute recovery periods. Amateur boxing competition consists of four rounds, silat olahraga with three rounds, while taekwondo (matsogi) has two (Heller *et al.*, 1998). A study by Lin and Ryder (2004) showed that the heart rate of 10 male taekwondo athletes during training and competition were similar between training and competition (188.7±2.8 $b.min^{-1}$ vs. 189.6 ± 1.6 $b.min^{-1}$, $p > 0.05$). Combat sports require significant anaerobic fitness to operate within a well-develop aerobic system.

Using the predicted heart rate maximum formula (HR_{max} = 220 - age), it is possible to estimate the percentage of exercise intensity in real competition. For example, the mean age for the male silat exponents in Table 2.04 is 23-year-old. So, the maximum heart rate is 220-23 = 197 $b.min^{-1}$. Actual competition shows that at round three the mean heart rate for male silat exponent is 190 $b.min^{-1}$. This shows that the male silat exponent is operating at 96% of HR_{max} during round three. Thus, this result shows that silat olahraga is a very high intensity sport. This is supported by the mean HR, which indicated that the male and female silat exponents were operating between 89-97% and 84-92% of HR_{max} respectively, throughout the match (Aziz *et al.*, 2002).

There is a similarity between amateur boxing and silat competition. Both sports involve more than 2 rounds of action and appear to have an increased in HR over the three rounds, with a significant increase between rounds 1 and 2 in boxing ($p < 0.05$) (Khanna and Manna, 2006). Both sports are totally different in fighting style but the intensity of the match was similar. Compare to silat exponents, a boxer is steadily reaching the 90% of mean maximum heart rate. However there was lower amount of blood lactate (7.4 $\pm$ 1.3 $mmol.L^{-1}$) compared to silat (12.5 $\pm$ 2.1 $mmol.L^{-1}$). This particularly reflects the reliance on arms in boxing which representing a lower muscle mass (Khanna and Manna, 2006) compared to more whole-body involvement in the martial arts (Heller *et al*., 1998 and Aziz *et al.*, 2002).

In addition, Lin and Kuo (2000) found that during Taekwondo competition, athlete's heart rates increased to 165 $b.min^{-1}$ with some individual reaching 192 $b.min^{-1}$. While, Guidetti *et al*. (2002) reported eight elite amateur boxers' produced HR_{max} at 195±7 $b.min^{-1}$ during training. The measurement of maximum heart rate is important because it is often used to determine the intensity of cardiovascular training zone. In reality, a larger size athlete would tend to have a lower HR_{max} value than the predicted value (McArdle *et al.*, 2001). Based on the Table 2.04 all three combat sports such as silat, taekwondo and boxing showed a high value of mean heart rate during competition. The mean heart rate is operating above 85% HR_{max} which resulted from the time-limited rounds. Each exponent will attempt to score as many points as possible resulting in frequent fight-contacts with very short recovery duration. Consequently, there will be a large reliance on anaerobic glycolysis and phosphocreatine to supply the energy requirements throughout the match. This is clearly supported by the high value of mean post-match [La] data in all combative sports (Table 2.04).

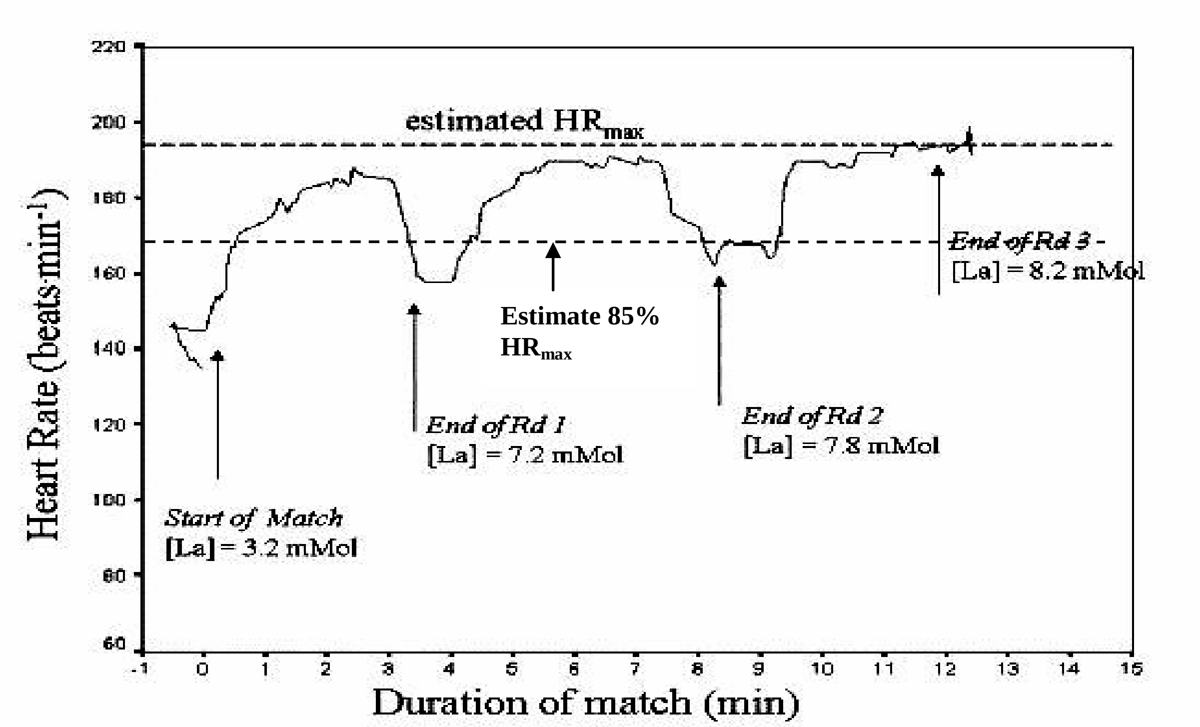


Figure 2.3: Typical heart rate and blood lactate response during a competitive match of an adult male silat exponent. Rd = round, [La] = capillary blood lactate concentration (Aziz *et al.*, 2002: pp. 151).

Figure 2.3 shows that even though silat olahraga match is typically "start stop" in nature and despite the wide fluctuations in intensity between work and pause periods during a bout, the HR profile does not appear to exemplify this intermittent pattern. The HR increased rapidly at the start of each round and was oscillating close to the silat exponent's estimated HR_{max} without any substantial decline throughout match, except for the in-between rounds break (Aziz *et al.*, 2002). This HR trend of relatively constant "steady-state" is usually observed during continuous-type exercise can also be found in other intermittent-type of exercise with very short work (< 15 s) to rest period (Saltin *et al.*, 1994) as well as in taekwondo matches (Heller *et al.*, 1998). This shows that combat sport exponents require a well-develop cardio-respiratory system that will be working at near maximum. Limitations of HR analyses are no research explains the activity that occurs during the low-intensity periods, which affect the outcome of a match. Moreover, is important to determine the non-contact activities during the silat olahraga match in order to recognize what are the most important physiological and performance parameters in silat. Further research is needed to fill this current gap in knowledge in martial arts.

The blood lactate concentration in wrestlers has been recently used as an indicator of anaerobic power and capacity in successful wrestlers (Yoon, 2002) with values of 10 to 15 $mmol.L^{-1}$. Heller *et al.* (1998) reported that in male international taekwondo competitions, peak blood lactate reached 11.4 $mmol.L^{-1}$ at the end of the match. The change in the blood lactate in silat is similar to taekwondo. Lin and Ryder (2004) reported that the change in blood lactate has a close relationship with the taekwondo competition intensity and competition performance. Research by Aschenbach *et al.* (2000) showed that successful wrestlers may be more tolerant of lactate as well as more capable of blood buffering for muscular endurance. This also has been suggested to the case with team sport players during a set of repeated sprints where improvements in both intracellular and extracellular buffer capacity may therefore improve repeated-sprint ability in sports by helping to resist changes in muscle pH (Bishop *et al.*, 2005). Accumulation of blood lactate reflects the difference in production (anaerobic glycolysis) and clearance (ability to buffer and utilise lactate) (Edge *et al.*, 2006). When the intensity of the activity increases, production of lactic acid in the muscle increases (resulting in high lactate accumulation in muscle), which has been suggest to lead to fatigue (Khanna and Manna, 2006). Well trained athletes are less sensitive to lactate accumulation and better able to tolerate higher levels of acidosis than average athletes. It is possible that they also learn to withstand and even ignore the pain threshold, which is surpassed with high lactate levels (Yoon, 2002).

Intense muscle contractions are associated with large ionic change within the muscle, including accumulation of hydrogen ions (H^+), which suggest an improvement in muscle buffer capacity should delay the accumulation of H+. Thus, increased intracellular buffer capacity should help to resist changes in muscle pH, while increases in extracellular buffer capacity may increase H+ efflux out of muscle cell (Bishop *et al.*, 2005). Nevertheless, while there is some evidence to suggest that training intensity may determine changes in muscle buffer capacity, further research is required (Edge *et al.*, 2006). However, it is speculated that training to improve lactate/ H^+ buffering and tolerance will aid the silat exponent.

There are several factors that undetermine the differences of blood lactate responses between combat sports, such as difference in the intensities of actions, difference of weight class between the research results and also active muscle mass that functions during the competitive match. Furthermore, it was reported that between 6.7 to 18.7 $mmol.L^{-1}$ of post-round blood lactate samples were taken during the silat olahraga competition (n=60) (Aziz *et al.*, 2002). Although there are clear differences in the fight pattern between the various martial art forms, the [La] levels observed during silat matches were similar to competitive taekwondo and judo matches (Heller *et al.*, 1998; Sikorski *et al.*, 1989). The rise in mean lactate suggests an accumulation of lactate due to increase in activity and/or an inability to remove lactate. Towards the end of a match the athletes are possibly intensifying their efforts to score as many points possible to influence the match outcome; however, research is needed to confirm this. The comparable mean HR (expressed as % estimated HRmax) and [La] between male and female exponents suggest that male and females work with similar intensity (Table 2.04 and 2.05).

Table 2.05: Blood lactate response of different sports during competitive combat sports.

Sports	Situation	Gender	Blood Lactate (m.mol^{-1})						
			Pre-M	**Post-Rd 1**	**Rd 2**	**Rd 3**	**Post-5**	**p-30**	**p-60**
Silat		**Males**	**(n=14)**						
Aziz et. al. (2002)	Singapore National Competition	Mean (SD)	2.2 (0.7)	8.8 (1.3)	11.2 (1.6)	12.5 (2.1)	-	-	-
		Females	**(n=6)**						
		Mean (SD)	1.9 (0.5)	9.7 (2.3)	12.8 (3.5)	13.1 (4.0)	-	-	-
Taekwando		**Males**	**(n=11)**						
Heller *et al.* (1998)	Chez National Competition	Mean (SD)	-	-	11.4 (3.2)	-	-	-	-
Taekwando		**Males**	**(n=10)**						
Lin and Ryder (2004)	University Competition	Mean (SD)	0.8 (0.0)	-	-	-	7.0 (1.3)	3.3 (0.7)	0.9 (0.1)
Boxing		**Males (Light Weight)**		**(n=7)**					
Khanna and Manna (2006)	Indian Competitive Trials	Mean (SD)	-	5.5 (1.5)	6.2 (1.1)	7.1 (1.2)	-	-	-
		Males (Medium Weight)		**(n=7)**					
		Mean (SD)	-	5.0 (1.1)	6.5 (1.5)	7.4 (1.3)	-	-	-
		Males (Heavy Weight)		**(n=7)**					
		Mean (SD)	-	6.9 (1.9)	8.1 (1.6)	9.9 (1.5)	-	-	-

Rd=round; Pre-Match = pre-match; Post-5=post- 5 minutes

2.2.2 Fitness Testing in Combat Sport

Combat sports have been shown to require strength (Thomas *et al.*, 1989; Thompson and Vinueza, 1991; Zabukovec and Tiidus, 1995), power (Zabukovec and Tiidus, 1995; Heller *et al.*, 1998; Borkowski *et al.*, 2001; Thomas *et al.*, 1989), speed (Heller *et al.*, 1998; Borkowski *et al.*, 2001; Thomas *et al.*, 1989; Thompson and Vinueza, 1991; Zabukovec and Tiidus, 1995), muscular endurance (Zabukovec and Tiidus, 1995; Francescato *et al.*, 1995; Doria *et al.*, 2009; Heller *et al.*, 1998) and skill

(Wojtas, 2007; Kazemi *et al.*, 2006; Yoon, 2002). But few have been accomplished in the order to obtain a specific test to evaluate the physiological preparation of combat sports athletes. This is particularly true because there is no established test battery in combat sports, thus various tests have been used across many studies in combat sports as shown in the Table 2.06 and 2.07.

Table 2.06: Aerobic fitness ($\dot{V}O_2$ max, $mL\cdot kg^{-1}\cdot min^{-1}$), comparative data of silat exponents with athletes from taekwondo and judo. Data are meaning (SD).

	N	**$\dot{V}O_2$ max**	**References**
Males			
Silat, Singapore National	10	52.1 (4.4)	Aziz *et al.*, 2002
Taekwondo, USA Club	14	44.0 (6.8)	Thompson and Vinueza, 1991
Taekwondo, Czech National	11	53.9 (4.4)‡	Heller *et al.*, 1998
Taekwondo, USA Olympic	na	55.8 (3.9)	Pieter, 1991
Judo, Canada Provincial	17	53.8 (5.6)	Little, 1991
Judo, Poland National[a]	58	57.6 (4.6)	Borkowski *et al.*, 2001
Judo, Poland National[b]	17	55.6 (3.2)	Borkowski *et al.*, 2001
Judo, Korea National	10	62.8 (5.9)	Kim *et al.*, 1996
Judo, USA National	18	55.6 (1.8)	Callister *et al.*, 1991
Females			
Silat, Singapore National	5	43.1 (3.3)	Aziz *et al.*, 2002
Taekwondo, Czech National	12	41.6 (4.2)‡	Heller *et al.*, 1998
Taekwondo, USA Olympic	na	47.0 (7.8)	Pieter, 1991
Judo, Canada Provincial	8	43.7 (3.5)	Little, 1991
Judo, Poland National[a]	49	50.7 (5.5)	Borkowski *et al.*, 2001
Judo, Poland National[b]	18	49.9 (4.8)	Borkowski *et al.*, 2001
Judo, Korea National	10	50.5 (6.9)	Kim *et al.*, 1996
Judo, USA National	9	52.0 (1.4)	Callister *et al.*, 1991

$\dot{V}O_2$ max = maximal oxygen uptake; **na** = data not available; ‡on a cycle ergometer; **a**athletes representing Poland from 1994-1997; **b**athletes representing Poland from 1998-1999

Table 2.07: Studies on physiological and performance characteristics in combat sports.

Reference	Target group	Performance characteristics					
		Aerobic	**Anaerobic**	**Strength**	**Muscular Endurance**	**Flexibility**	**Reflex**
Taylor *et al*. (1981)	19 Judo exponents	$\dot{V}O_2$ max	Lower Body: - Anaerobic run at 8 m/h at 20% grade	Lower Body: - Cybex leg strength	Tests: - Push-up, - Sit up, - Chest raises, - Leg raises, - Side leg raises, - Sitting tucks	Tests: - Trunk flexion / sit & reach, - Trunk extension/back extension - Shoulder flexion	-
Thomas *et al*. (1989)	22 males Judo exponents	$\dot{V}O_2$ max - Treadmill Upper Body : - Arm cranking exercise	Upper Body & Lower Body : - Wingate cycle ergometer tests	Lower Body: - Vertical jump test Upper Body : - Right grip - Left grip - 1RM bench press	-	- Sit & Reach, - Head rotation, - Shoulder hypertension, - Shoulder internal rotation, - Shoulder external rotation, - Hip flexion	-
Callister *et al*. (1991)	18 males & 9 females Judo exponents	$\dot{V}O_2$ max - Treadmill	-	- Knee & Elbow extensors and flexors using Cybex II dynamometer	-	-	-
Thompson *et al*. (1991)	14 males Taekwondo exponents	$\dot{V}O_2$ max - Treadmill	-	Lower Body: - Leg and back strength Upper Body : - Handgrip strength	- Sit up test	-	-

Heller *et al.* (1998)	11 males & 12 females of Taekwondo exponents	$\dot{V}O_2$ max - Cycle ergometer	Lower Body: - Wingate cycle ergometer tests	Lower Body:: Vertical jump test Muscular Strength: - Arm flexion - Knee extension - Handgrip	-	- Sit & Reach	Upper Body: & Lower Body: : Visual reaction time
Aziz *et al.* (2002)	30 Singaporean Silat exponents	$\dot{V}O_2$ max - Treadmill	Lower Body: - Wingate cycle ergometer tests	Lower Body: Vertical jump test Upper Body: - Handgrip strength	-	-	-
Lin and Ryder (2004)	10 males Taekwondo athletes	$\dot{V}O_2$ max - cycle ergometer	Lower Body: cycle ergometer tests	-	-	-	-
Chia *et al.* (2006)	20 males Taekwondo athletes	$\dot{V}O_2$ max - treadmill	-	-	-	-	-
Khanna and Manna (2006)	Second study: 21 male Indian Junior national Boxer	$\dot{V}O_2$ max - treadmill - graded exercise	-	-	-	-	-

Table 2.07 shows several performance characteristics in combat sports. However, some tests may be lacked ecological validity to the specific nature of combat sports, such as the use of cycle ergometer. Even though the protocol of cycle ergometer may explain the anaerobic performance, the protocol did not reflect the activities applied in fight/spar during combat sport match. Moreover, many studies as stated in Table 2.07 and 2.08 tend to use generic fitness tests, rather than anything that is sport-specific and reflects the actions used in combat. Furthermore, most of the data presented in Table 2.06, 2.07 and 2.08 is on adult populations with only Khanna and Manna, 2006 characterised the physiological responses of young-elite boxers to boxing (Table 2.08). With a limited data in youth combat sports, the author found that there is a need to identify sport-specific fitness trends in silat in order to understand the important parameters that influence fitness during childhood. Commonly, majority of the combat sports studies (Table 2.06 and 2.07) reporting maximal oxygen uptake ($\dot{V}O_2$ max) to measure the aerobic performance. Maximal oxygen uptake is the volume of oxygen that can be utilised per minute to perform work (Yoon, 2002). It has found that the maximum oxygen consumption volume was 57.0 $mL \cdot kg^{-1} \cdot min^{-1}$ in Spanish international Taekwondo athletes and 53.8 $mL \cdot kg^{-1} \cdot min^{-1}$ in Czech international Taekwondo athletes (Heller *et al.*, 1998). Drobnic (1995) found that recreational Taekwondo athletes had a mean $\dot{V}O_2$ max about 44.0 $mL \cdot kg^{-1} \cdot min^{-1}$; however, the $\dot{V}O_2$ max values for elite athletes are substantially higher than for athletes of recreational level (Table 2.9).

The mean $\dot{V}O_2$ max value of the Korean National Team, the perennial dominant power of taekwondo, was 59.56 $mL \cdot kg^{-1} \cdot min^{-1}$ (Hong, 1997). It has been reported that the $\dot{V}O_2$ max of national and international wrestlers is about 53 to 56 $mL \cdot kg^{-1} \cdot min^{-1}$,

Table 2.08: Details on physical and physiological characteristics in combat sports.

Protocol	Reference	Sport	Subject	Mean Age (year)	Standard (athletes level)	Sample Size (N)	Performance characteristics	Range of mean values or mean ±SD
Anthropometry								
Body composition	Aziz *et al.* (2002)	Silat	Male	24.4 ± 4.4	Singapore National	10	Skinfold (%)	11.3±5.4
			Female	24.6 ±3.9	Singapore National	5	Skinfold (%)	23.4±3.6
	Callister *et al.* (1991)	Judo	Male	24.4 ± 0.9	U.S. National	18	Skinfold (%)	8.3±1.0
			Female	23.8 ± 1.5	U.S. National	9	Skinfold (%)	15.2±1.0
	Thompson *et al.* (1991)	Taekwondo	Male	27.4 ± 3.8	Taekwondo Academies	14	Skinfold (%)	18.9±10
	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Skinfold (%)	8.2±3.1
			Female	18.5 ± 2.6	Czech National	12	Skinfold (%)	15.4±5.1
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	Skinfold (%)	9.3±2.1
	Khanna and Manna (2006)	Boxing	Male (Junior) - Light weight	17.4 ± 2.6	Indian National	7	Skinfold (%)	12.2±1.1
			Male (Junior) - Medium weight	17.5 ± 1.5	Indian National	7	Skinfold (%)	11.6±0.9
			Male (Junior) - Medium heavy weight	18.1 ± 1.5	Indian National	7	Skinfold (%)	11.2±1.2
	Guidetti *et al.* (2002)	Boxing	Male -middleweight	22.3 ± 1.5	Elite Italian Amateur	8	Skinfold (%)	14.5±1.5

Isometric strength Grip	Aziz *et al.* (2002)	Silat	Male	24.4 ± 4.4	Singapore National	10	HGD (N)	435±79
			Female	24.6 ±3.9	Singapore National	5	HGD (N)	271±58
	Thompson *et al.* (1991)	Taekwondo	Male	27.4 ± 3.8	Taekwondo Academies	14	HGD (N) - dominant hand	 508±81
	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	HGD (N)	555±76
			Female	18.5 ± 2.6	Czech National	12	HGD (N)	369±45
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	HGD (N) - right hand - left hand	 553±65 546±65
	Khanna and Manna (2006)	Boxing	Male (Junior) - Light weight	17.4 ± 2.6	Indian National	7	HGD (N) - right hand - left hand	 433±51 430±49
			Male (Junior) - Medium weight	17.5 ± 1.5	Indian National	7	HGD (N) - right hand - left hand	 497±29 478±41
			Male (Junior) - Medium heavy weight	18.1 ± 1.5	Indian National	7	HGD (N) - right hand - left hand	 516±50 491±58
	Guidetti *et al.* (2002)	Boxing	Male - Middleweight	22.3 ± 1.5	Elite Italian Amateur	8	Boxing (N) - dominant hand	 571±68
Upper body	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	1RM BP (kg)	100 ± 21
Lower body	Thompson *et al.* (1991)	Taekwondo	Male	27.4 ± 3.8	Taekwondo Academies	14	Back and Leg dynamometer (kg)	151.3±7.4

Isometric strength								
Lower body	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Knee extension (N)	629±150
			Female	18.5 ± 2.6	Czech National	12	Knee extension (N)	488±152
Upper body	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Arm flexion (N)	331±67.7
			Female	18.5 ± 2.6	Czech National	12	Arm flexion (N)	196±34.3
Strength endurance								
Upper body	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	BP at 70% 1RM (max. reps)	16 ± 3
Abdominal muscular endurance	Thompson *et al.* (1991)	Taekwondo	Male	27.4 ± 3.8	Taekwondo Academies	14	1-minute sit-up (rep) - sit-up test	53.7±3.2
Reaction time								
Upper body	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Upper limbs (ms)	196±16.4
			Female	18.5 ± 2.6	Czech National	12	Upper limbs (ms)	198±24.1
Lower body	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Lower limbs (ms)	224±16.4
			Female	18.5 ± 2.6	Czech National	12	Lower limbs (ms)	243±30.6
Power								
Lower body	Aziz *et al.* (2002)	Silat	Male	24.4 ± 4.4	Singapore National	10	Vertical jump (cm)	59.9±5.8
			Female	24.6 ±3.9	Singapore National	5	Vertical jump (cm)	40.8±4.0
	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Vertical jump (cm)	45.5±4.5
			Female	18.5 ± 2.6	Czech National	12	Vertical jump (cm)	29.8±4.0
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	Vertical jump (cm) Vertical jump (W)	55.0 (no SD) 1227±211

Flexibility								
Lower body	Thompson *et al.* (1991)	Taekwondo	Male	27.4 ± 3.8	Taekwondo Academies	14	Sit and reach (cm)	53.2±6.6
	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	Sit and reach (cm)	36.9±4.5
			Female	18.5 ± 2.6	Czech National	12	Sit and reach (cm)	37.9±3.4
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	Sit and reach (cm)	43.2±6.3
Aerobic capacity – heart rate (HR) measurements	Aziz *et al.* (2002)	Silat	Male	22.6 ± 3.3	Singaporean National	16	Mean during 6 min silat match (b.min^{-1})	174 -190
			Female	23.1± 3.1	Singaporean National	6	Mean during 6 min silat match (b.min^{-1})	165 -181
	Thomas *et al.* (1989)	Taekwondo	Male	24.0 ± 4.0	Canadian National	22	Mean during 4 min taekwondo match (b.min^{-1})	191±9.6
Anaerobic capacity								
Upper body peak power	Aziz *et al.* (2002),	Silat	Male	24.4 ± 4.4	Singaporean National	10	MSACW (W.kg^{-1})	6.2±0.6
			Female	24.6 ±3.9	Singaporean National	5	MSACW (W.kg^{-1})	4.1±0.5
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	MSACW (W.kg^{-1})	11.3±0.8
Lower body peak power	Aziz *et al.* (2002),	Silat	Male	24.4 ± 4.4	Singapore National	10	CWT (W.kg^{-1})	12.3±0.8
			Female	24.6 ±3.9	Singapore National	5	CWT (W.kg^{-1})	9.7 ±0.7
	Heller *et al.* (1998)	Taekwondo	Male	20.9 ± 2.2	Czech National	11	CWT (W.kg^{-1})	14.7±1.3
			Female	18.5 ± 2.6	Czech National	12	CWT (W.kg^{-1})	10.1±1.2
	Thomas *et al.* (1989)	Judo	Male	24.0 ± 4.0	Canadian National	22	CWT (W.kg^{-1})	13.7±1.1
	Khanna and Manna	Boxing	Male (Junior)	17.6 ±2.9	Indian National	30	CWT (W.kg^{-1} BW)	4.9±0.7

	(2006)						
		Male (Senior)	22.1± 3.1	Indian National	30	CWT ($W.kg^{-1}$ BW)	6.5±0.5
Peak lactate measurements	Aziz *et al.* (2002),	Male	22.6 ± 3.3	Singapore National	16	1 min post-round 1,2,3 silat matches ($m.mol^{-1}$)	8.8,11.2,12.5
		Female	23.1± 3.1	Singapore National	6	1 min post-round 1,2,3 silat matches ($m.mol^{-1}$)	9.7,12.8,13.1
	Lin and Ryder (2004)	Male	19.5 ± 0.5	University	10	5 min post- 3 round of 2min taekwondo match ($m.mol^{-1}$)	7.0±1.3
	Heller *et al.* (1998)	Male	20.9 ± 2.2	Czech National	11	CWT, La_{peak} ($m.mol^{-1}$)	12.5±1.6
		Female	18.5 ± 2.6	Czech National	12	CWT, La_{peak} ($m.mol^{-1}$)	11.6±0.8
		Male	20.9 ± 2.2	Czech National	11	3 min post- 2 round of 2min taekwondo matches ($m.mol^{-1}$)	11.4±3.2
	Thomas *et al.* (1989)	Male	24.0 ± 4.0	Canadian National	22	MSACW ($m.mol^{-1}$)	14.5±1.7
						CWT ($m.mol^{-1}$)	15.2±1.8
	Khanna and Manna (2006)	Male (Light weight)	17.4 ± 2.6	Indian National	7	TVT ($m.mol^{-1}$)	11.4±1.9
		Male (Medium weight)	17.5 ± 1.5	Indian National	7	TVT ($m.mol^{-1}$)	10.8±1.4
		Male (Medium heavy weight)	18.1 ± 1.5	Indian National	7	TVT ($m.mol^{-1}$)	13.1±0.9
	Guidetti *et al.* (2002)	Male - Middleweight	22.3 ± 1.5	Elite Italian Amateur	8	TVT ($m.mol^{-1}$)	9.1±1.8

Key, HGD = Handgrip dynamometer, BP = Bench Press, GTT = graded treadmill test, GCT = graded cycle treadmill, MSACW = Modified seated arm crank Wingate, CWT =cycle Wingate test, TVT = treadmill $\dot{V}O_2$ max test which is not exceptional for any well trained athlete (Yoon, 2002). This range was not high compared with that of elite endurance runners who are measured at 70 to 80 $mL \cdot kg^{-1} \cdot min^{-1}$ (Schultz, 1997). Given the $\dot{V}O_2$ max scores that are moderate, it suggests that silat is a predominantly an anaerobic sport, which can be supported by high HR and BLa during competition. However, as an intermittent type-exercise which is interspersed with off- fight period (low intensity actions), the ability to recover and to reproduce a high explosive power output in subsequent bursts is an important fitness requirement of silat sports. Therefore, while silat is classified as predominately anaerobic sport, aerobic metabolism will be important to aid recovery. Although data in Table 2.06 show that the $\dot{V}O_2$ max of martial art athletes is not remarkable, this may suggest that aerobic power is of less importance in martial arts. Alternatively the use of continuous protocols may limit the validity of the findings, with progressive intermittent tests (e.g. yo-yo intermittent test) shown to better relate to intermittent performance (Aziz *et al.*, 2005; Bangsbo, 1996).

Aziz *et al.* (2002) also reported that silat exponents mean $\dot{V}O_2$ max is similar to the taekwondo and judo club-level athletes (Table 2.06), but is clearly lower when compared to the martial arts' national level. Past research reported that with excellent aerobic exercises and training, taekwondo exponents can enhance their physical endurance during the match (Lin and Ryder, 2004). Furthermore, intensive aerobic training could improve the physiological functions of highly trained sport contestants (Cooke *et al.*, 1997). Table 2.07 and 2.08 shows details of physiological and performance test used in previous research of combat sports. All studies (Table 2.06 and 2.07) emphasise that the maximal oxygen uptakes test is the prominent test for determining the relation of cardiovascular performance and performance in competition even though this review suggests this test is not remarkable with martial artists.

2.3 Growth, Development and Maturation of Physical Activity

2.3.1 Growth, Development and Maturation in Childhood

Growth, development and maturation are the terms used to describe changes that occur in the body starting at conception and continuing through adulthood. Growth refers to the increase in the size of the body as a whole and of its parts (Malina, 2000). As children grow, they become taller and heavier; they increase in lean and fat tissues, and their organs increase in size. For example heart volume and mass follows the growth pattern of body mass while lungs and lung functions grow proportionally to height. Changes in size are outcomes of three underlying cellular processes; (1) an increase in cell number (hyperplasia); (2) an increase in cell size (hypertrophy); and (3) an increase in intercellular substances, or accretion. Hyperplasia, hypertrophy and accretion all occur during growth, but the predominance of one or another process varies with age and the tissues involved (Malina *et al*, 2004).

Development refers to the differentiation of cells along specialized lines of function, so it reflects the functional changes that occur with growth (Wilmore *et al.*, 2008). As children experience life at home, school, recreation, sports and other community activities, they develop intellectual, social, emotional, morally and so on. Maturation is a process of becoming mature or progressing toward the mature state. Maturation is a process; maturity is a state (Malina *et al*, 2004). Studies of children and adolescents often focus on skeletal, sexual and somatic maturation (Malina, 2000). For example skeletal maturity refers to having a full developed skeletal system, on which all bones have completed normal growth and ossification, whereas sexual maturity refers to having fully functional reproductive system (Wilmore *et al*, 2008).

Maturation can be viewed into two contexts which are timing and tempo. Timing refers to when specific maturational events occur (Beunen and Malina, 1988). For example, age at the appearance of pubic hair in boys and girls, or the age at maximum growth during the adolescent growth spurt. While, tempo refers to the rate at which maturation progresses or rate of speed at which the individual goes through the spurt (Beunen and Malina, 1988), for example, how quickly or slowly the youngster passes from initial stages of sexual maturation to the mature state (Malina, 2000). Both are vary considerably among individuals. Children and adolescents are unique and must not be regarded as miniature version of adults. They are different at each stage of their development. The growth and development of their bones, muscles, nerves, and organs largely dictate their physiological and performance capacities particularly on motor ability, strength, cardiovascular and respiratory function, and aerobic and anaerobic capacity. As children's size increases, so does almost all of their functional capacity (Malina, 2000).

2.3.2 Somatic Growth

Somatic growth is rapid in infancy and early childhood, rather steady during middle childhood, rapid during the adolescent spurt, and then slow as adult stature is detained (Beunen and Malina, 2008). The adolescent growth spurt in height refers to the acceleration in growth at this time. In girls, it starts, on average, at about 9 or 10 years of age, peaks about 12 years of age, and stops at about 16 year of age. In boys, the acceleration begins, on average, at about 10 or 11 years of age, peaks at about 14 years of age, and stops about 18 years of age (Malina *et al.*, 2004). The growth rate of stature is highest during the first year of life then gradually declines until the onset (take-off) of the adolescent growth spurt (about 10 years in girls and 12 years in boys). With the spurt, growth increases, reaching a peak (peak height velocity, PHV) at about 12 years in girls and 14 years in boys, and then gradually declines and eventually ceases with the attainment of adult stature (Tanner 1962; Malina *et al.*, 2004). Malina (2000) reported one of the features of height provides the basis for assessment of somatic maturation is age at peak height velocity.

2.3.3 Age at Peak Height Velocity (PHV)

Peak height velocity refers to the maximum rate of growth in stature during the adolescent spurt, and the age when PHV occurs is an indicator of somatic maturity (Malina, 2000). Although age at menarche is a widely used maturity indicator in studies of female adolescence, it is rather late maturational event that occurs most often after PHV (Beunen and Malina, 1988). Furthermore, it does not have corresponding maturity indicator in males; while, age at PHV on the other hand is a maturity indicator that can be used in both sexes. Longitudinal data are necessary to estimate age at PHV and related parameters of the adolescent growth (Malina, 2000; Beunen and Malina, 1988). However, Tanner (1989) suggested that either cross sectional or longitudinal studies have their uses, but they do not give the same information and cannot be dealt with the same way. The spurt in stature refers to the acceleration in stature which in boys begins at about 10-11 years, peaks at about 14 years, and stops at about 18 years (Malina and Beunen, 2008). In girls the spurt starts at about 9-10 years, peaks at about 12 years, and stop at about 16 year (Malina and Beunen, 1996). A method for predicting time from PHV (maturity offset, years) has also been developed as a maturity indicator (Mirwald *et al.*, 2002). The method requires age, height, sitting height, leg length (height minus sitting height), weight: height ratio, weight (girls only), and interaction terms; while, the addition or subtraction of maturity offset to CA provides a predicted age at PHV (Malina and Beunen, 2008).

2.3.4 Growth and Development of Physical Performance Abilities during Childhood

Physical performance is commonly measured as an outcome of standardized motor tasks requiring speed, agility, balance, flexibility, explosive strength, local muscular endurance and static muscular strength (Beunen and Malina, 2008). Although knowledge about the influence of regular physical activity on somatic growth and maturation and on performance is expending, many gaps exist in our understanding (Bailey *et al.*, 1986; Malina, 1989; Malina, 1990; Malina and Bouchard, 1991; Shephard *et al.*, 1980). For example, experimental training studies are usually of short duration, and the programme do not necessarily reflect the activity levels of youth who participant in a variety of sport activities (Beunen *et al.*, 1992). Viru *et al.* (1999) reported that longitudinal studies confirm that the improvement of motor abilities undergoes periods of accelerated adaptation development. In the age range from 5 to 18 years the first period is from 5 to 9 years and is termed the preadolescent spurt, which may reflect the neural development process. This period is expressed by an increased rate of improvement of muscle strength, explosive power, speed and aerobic endurance. The second period, associates with sexual maturation which is reflected by an accelerated improvement in strength, explosive strength and aerobic endurance (Viru *et al.*, 1999) which are related to endocrine maturation. The acceleration of speed improvement is pronounced in boys of 12 to 14 years. Such a period was not found in girls. The accelerated improvement of muscle strength appears in boys of 13 to 16 year and girls of 10 to 15 years, and of explosive strength in the boys of 12 to 16 year and the girls of 9 to 13 year of age. With regard to increased aerobic endurance the results are conflicting as to whether the period appears at the age of 12 to 14 or 14 to 16 year (Viru *et al.*, 1999).

2.3.4.1 Upper Body Isometric / Static Strength. Isometric strength increases linearly with age during childhood and the transition into adolescence in both sexes (Beunen and Malina, 2008). In boys, isometric strength increases linearly with age from early childhood to approximately the age of 13 year, when there is a clear adolescent spurt (i.e. acceleration in strength development/adolescent strength spurt) (Figure 2.4). In girls, strength increases linearly until 15 years in several studies (Beunen and Malina, 2008; Beunen and Malina, 1996) though there is evidence of an adolescent spurt at about 16 or 17 years with no clear evidence for an adolescent spurt as in boys, which is a function of viewing the strength data cross-sectionally by age (Malina *et al.*, 2004).

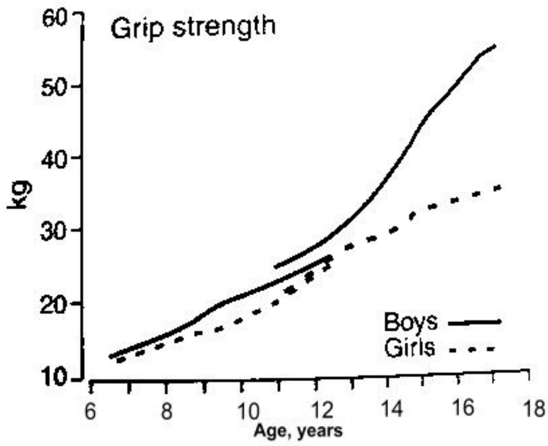


Figure 2.4: Mean grip strength between 6 and 18-year-old (Malina *et al.*, 2004, pp 219).

Sex differences in strength are consistent, throughout childhood and the transaction into adolescence (Malina *et al.*, 2004). Among Belgian youth, for example, the median arm pull strength of 17-year-old girls falls below the corresponding third percentile for boys (Beunen *et al.*, 1989). During childhood and adolescence boys tend to have greater strength in the upper body and trunk, than girls. This is particularly due to the size advantage in boys, particularly due to the increment of body size and muscle mass (Beunen and Malina, 1996). It is widely believed that testosterone causes muscle hypertrophy although there is relatively little evidence about the effects of physiologic levels. However, the association between the increase in muscle strength in boys and increasing circulating testosterone is very strong (Round *et al.*, 1999). Other factors including age, sex and growth in height and body mass influence and differentiate strength performance, maturation and neurological factors, muscle size, fibre type and contractile characteristics, endocrinological influences, genetic influence strength and physical activity are factors thought to be interrelated and thus may influence strength development through common or shared variance (Froberg and Lammert, 1996).

2.3.4.2 Lower Body Power. Jumping performance of children was reported by Malina *et al.*, (2004) in standing long jump and vertical jump, where they found on average, performance in the standing long jump increases linearly with age in both sexes until 14 years in females and 18 years in males (Figure 2.5). Moreover, average vertical jump and standing jump performance of girls improve only slightly after 14 years of age. In contrast, study by Malina *et al.* (2005) found that the difference in explosive power of lower extremities (vertical jump) was small in divers aged 13 year and under, but was magnified in the 14 to 15-year-old and 16 to 18-year-old group.

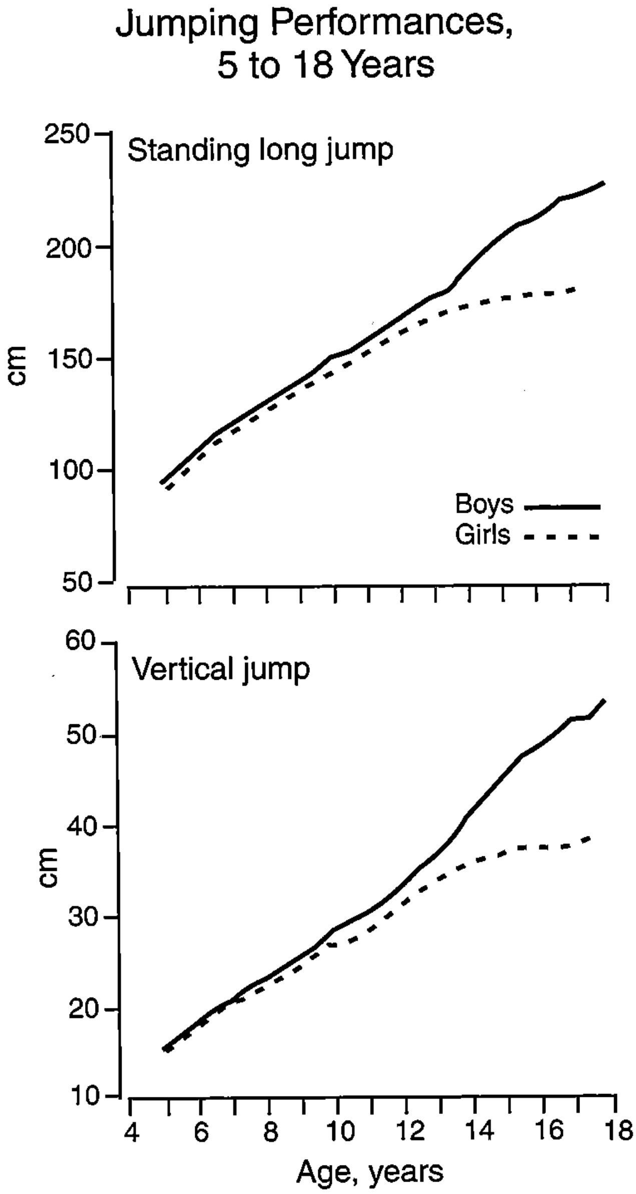


Figure 2.5: Mean performance in the standing long jump and vertical jump between 5 and 18-year-old (Malina *et al.*, 2004, pp. 221).

Sex differences are relatively small but consistent during childhood and become magnified during adolescent (Viru *et al.*, 1999; Beunen and Malina, 1988; Beunen and Malina, 1996; Beunen and Malina, 2008; Malina *et al.*, 2004; Malina and Beunen, 1996; Malina and Beunen, 2008; Malina, 2008). Age trends and sex differences in the vertical jump are similar to those for the standing long jump (Figure 2.08). The slope of the increment is somewhat steeper for the vertical jump compare to the standing long jump, suggesting an adolescent acceleration in males. A large amount of material presented by Simons *et al.* (1990) failed to demonstrate an accelerated gain of strength or explosive strength in girls at the age of 10 to 12. At that age some longitudinal studies showed a low improvement rate at sprint velocity (Shepherd and Lavallee, 1994; Branta *et al.*, 1984), and either low (Shepard and Lavallee, 1994) or considerably high (Branta *et al.*, 1984) improvement rate in jumping performance. Meanwhile, the average vertical jump performance in girls group improves to about 14 years of age, followed by smaller gain. Jones and Round (2000) reported that such activity like explosive jumps, the strength to body weight ratio would seem to be a critical factor, yet it is interesting to note that jumping performance improve steadily throughout childhood, and then dramatically in teenage boys. One reason that may explain this observation is due to increase of muscle grows at rapid rate, particularly during the pubertal growth spurt in PHV, particularly in boys (Inbar, 1996). The increase in muscle tissue typically occurs slightly after the PHV (Malina and Bouchard, 1991). Moreover, the improvements were concomitantly with maturational factor (e.g. hormone development) which leads to increased muscle mass and internal organ size (Viru *et al.*, 1999). Such hormonal responses at puberty are critical in influencing functional development and subsequent organic development (Katch, 1983).

2.3.4.3 Upper Body Muscular Endurance. Field tests of muscular endurance or dynamic strength include push-ups (Augustsson *et al.*, 2009), sit-ups (Silva *et al.*, 2008; Malina *et al.*, 2005; Philippaerts *et al.*, 2006; Beunen and Thomis, 2000), and flexed arm hang (Beunen and Thomis, 2000; Philippaerts *et al.*, 2006). In boys, flexed arm hang scores improves linearly with age from 5 to 13 to 14 years (Figure 2.6), followed by a spurt similar with isometric strength performance. (Flexed arm hang score is the duration the subject can hold the flexed arm position until the child's eye drops below the level of the horizontal bar).

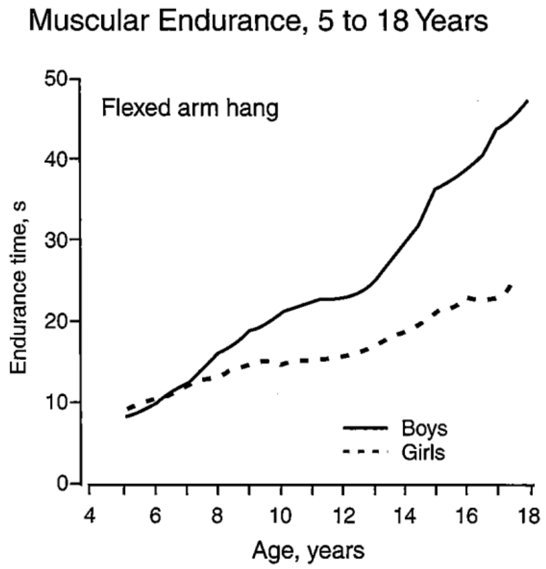


Figure 2.6: Mean muscular endurance as measured on the flexed-arm hang between 5 and 18-year-old (Malina *et al.*, 2004, pp. 220).

Muscular endurance increases with age to 16 to 17 years in girls, but there is no clear evidence of spurt as in boys (Figure 2.7). The number of sit-ups increases in boys but the increases gradually decline; in girls, scores increase until 13 year and thereafter decrease (Beunen and Thomis, 2000). Sex differences are negligible in abdominal strength and endurance during childhood and become established in adolescence (Malina *et al.*, 2004).

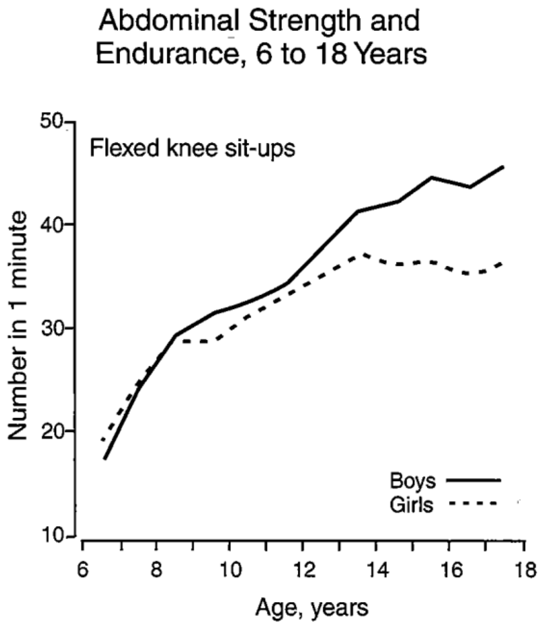


Figure 2.7: Mean abdominal strength and endurance as measured by the number of flexed knee sit-ups performed in 1 min between 6 and 18-year-old (Malina *et al.*, 2004, pp. 221).

2.3.4.4 Throwing. The overhand ball throw for distance was used for distance as a measure of coordination and muscular power of upper body performance. Data by Haubenstricker and Seefeldt (1986) measured that the mean performance of boys and girls in a softball throw for distance between 6 and 18-year-old, as shown in Figure 2.8. In boys, the throwing performance increase markedly and linear with age, with a change in the slope of improvement which suggesting an adolescent spurt, while the performance of girls improve only slightly between 6 and 14-year-old, with no subsequent improvement. Loko *et al.* (2000) reported that at 12 to 13 year of age differences of the girls groups (10 to 17-year-old) remains significant in the power arm test (pushing a stuffed ball). However, differences between the age groups from 16 to 17 years in pushing a stuffed ball stabilised. The sex difference in throwing performance during childhood is greater than for other basic skills and is magnified to a much greater extent during adolescence (Malina *et al.*, 2004).

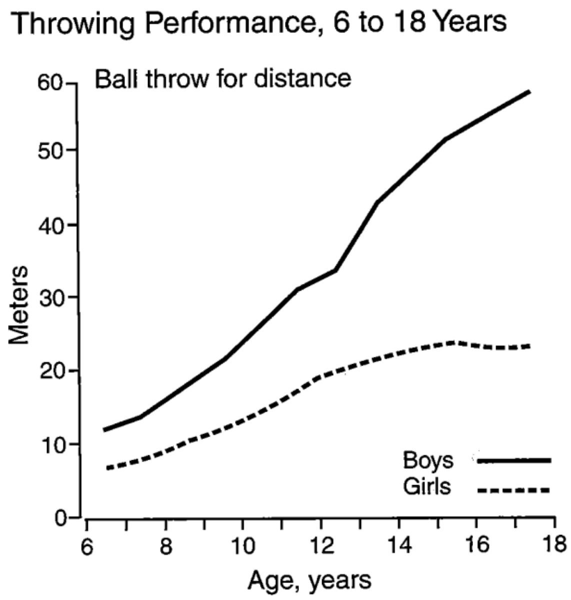
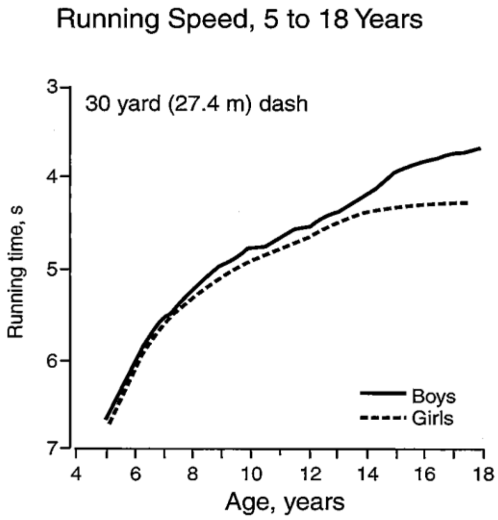


Figure 2.8: Mean performance in the softball throw for distance between 6 and 18-year-old (Malina *et al.*, 2004, pp. 221).

2.3.4.5 Running Speed, Agility Speed, Flexibility and Balance. Changes in running speed and running agility (shuttle run) during childhood and adolescence are shown in Figure 2.9 (a) and (b). The pattern of age-associated and sex-associated variation in agility shuttle run is identical with 30-yard dash. Both tests improve performance in boys and girls between 5 and 8 years of age; but then continues to improve at a somewhat lesser but more constant pace up to up to 13 to 14-year-old in girls and 18-year-old in boys for shuttle run performance (Figure 2.9a), and, the improves up to 13 to 14-year-old, with little improvement to 17-year-old in running speed (Figure 2.9b). Similarly, both data suggest an adolescent acceleration after 13-year-old (Malina *et al.*, 2004).

(a) (b)



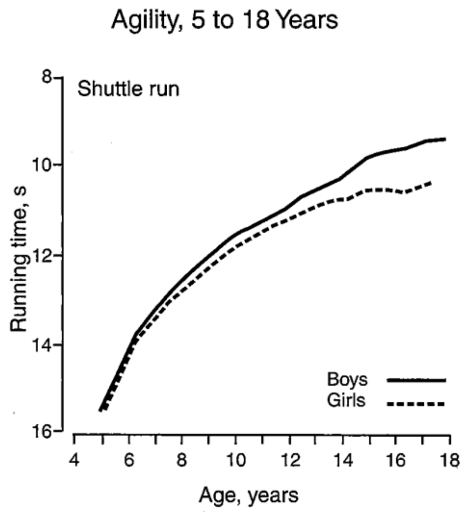


Figure 2.9 (a): Mean running speed, measured as the time elapsed in covering 27.4 metre with a running start; **(b)** mean agility as measured by performance on a shuttle run between 5 and 18-year-old. Time scale is reversed because a better time equals a lower time. (Malina *et al.*, 2004, pp. 222).

A study by Papaiakovou *et al.* (2009) in sprint performance in children age 7 to 18-year-old reported boys run faster than girls in all running phases (0-10 m phase and 0-30 m phase) and the span between genders increases after the age 15 years. They also reported that strength and power had an impact on speed ability with other factors that could interpret the gradual improvement of sprint speed during childhood and adolescence are the maturation of the neuronal system, the improved co-ordination between agonist and antagonist muscles, the increase in efficiency (running economy), and the potential transformation from slow- to fast-type motor units. Meanwhile, lower back flexibility decline linearly with age from 5 to 12-year-old in boys and then start increases through 18 years of age. Mean scores are stable from 5 to 11-year-old in girls and then increase markedly during adolescence to 15-year-old with little subsequent improvement (Malina *et al.*, 2004; Beunen *et al.*, 1989). Malina *et al.* (2004) reported that balance improved with age and on average girls perform better in balance task during childhood.

2.4.4.6 Overview of Performance

Performance in a variety of standardised tests in speed, agility and running speed, coordination and explosive strength, local muscular endurance and balance improve on average from childhood through adolescence in boys. Boys perform on average better than girls but there is considerable overlap between sexes during early and middle childhood (Malina, 2000). Average performances of girls in a variety of motor tasks (dash, standing long jump, vertical jump, shuttle run and others) improve more or less linearly from 6 to about 14-year-old, followed by a slight increase in some tasks or plateau in others (Malina *et al.*, 2004). Performance of girls fall, on average, within 1 standard deviation (SD) below average performances of boys in late childhood and early adolescence, with the exception of softball throw for distance (Beunen and Malina, 2008). Nevertheless, after 14 years average performances of girls are consistently beyond the bounds of 1 SD below the means of boys in most tasks. With the onset of adolescence, the performance of boys shows an acceleration or spurt, while those of girls improve linearly to about 13 to 14 years of age and then continue to improve, on average, at slower rate through later adolescence (Malina *et al.*, 2004).

2.4 Training Programmes in Youth Silat

The theory and methodology of training, a distinct unit of physical education and sport, has specific principles based on biological, psychological and pedagogical sciences (Bompa, 1994). The guidelines and regulations, which systematically direct training, are known as principles of training. These specific principles reflect the particularities of fulfilling important training goals, namely increasing skill and performance levels. Training principles are part of a whole concept and though we should not view them as isolated units, we describe them separately for a more understandable presentation. Correctly using principles of training will create superior organization and more functional content, means, methods, factors and training component (Bompa, 1999).

Theory and methodology of training is a vast area. Closely observing the information available from each science will make coaches more proficient in their training endeavours. The principle of training is the foundation of this complex process. Knowing the training factors will clarify the role each factor plays in training, according to characteristic of a sport or event (Bompa, 1994). The major objective of physical training is to cause biological adaptations to improve performance in specific events (Katch, 1983). By stressing the appropriate metabolic system through training, the athlete can better prepare for the specific demands of competition (Kraemer, 2000). Adenosine triphosphate (ATP) is the primary source of energy for muscle contraction and is replenished through anaerobic and aerobic metabolism (Powers and Howley, 2004). Anaerobic metabolism may be divided into 2 systems: the phosphagen system and the anaerobic glycolysis system. During maximal intensity exercise, the phosphagen system provides the majority of ATP through the initial 10 s of the effort (Powers and Howley, 2004). Beyond 10 s to approximately 120 s of maximal intensity exercise, anaerobic glycolysis predominates (Buse and Santana, 2008) with 120 s reflecting the duration of a bout in silat. As exercise intensity diminishes and duration extends 2-4 minutes or longer, reliance on energy from phosphate stores and anaerobic glycolysis decreases, with aerobic production of ATP becoming increasingly more important (Katch, 1983). As anaerobic process do not require the presence of oxygen compare to aerobic metabolism, only carbohydrates can metabolised for energy without the direct involvement of oxygen (Cramer, 2008). Aerobic metabolic occurs concomitantly with anaerobic metabolism even during short duration, or maximal-intensity exercise (Buse and Santana, 2008; Cramer, 2008). Experts agree that most activities require energy from both the aerobic and anaerobic energy metabolisms, but the percentage of ATP production from aerobic and anaerobic sources will vary according to intensity and duration (Amtmann and Berry, 2003). Table 2.09 showed energy metabolic involvement which directly dependent on the duration of the activity.

Table 2.09: Contributions of Anaerobic and Aerobic Metabolic System (Amtmann and Cotton, 2005, pp. 29).

Time (s)	Anaerobic (%)	Aerobic (%)
0-30	80	20
0-60	70	30
0-120	60	40
0-240	40	60

However, there are intermittent periods where intensity changes according to the demands of the particular match in dynamic sports such as judo (Amtmann and Cotton, 2005) or silat. Amtmann and Berry (2003) reported that at certain times the athletes may be working at 100% of their maximum intensity and at other times a sub-maximal percentage, which is true for many sports. Moreover, Bounty *et al.* (2011) reported that when 2 fighters are standing and trading strikes during a mixed martial arts match, they are usually high-intensity bursts where a fighter rapidly throws combinations of punches and kicks. Where, these bursts may be counterbalanced by numerous low-intensity periods where the fighters are circling each other, feinting movements, and ultimately actively recovering with the support of the aerobic system. The creatine phosphate (CP) is stored in relatively small amounts and phosphagen system cannot be primary supplier of energy for continuous, long duration activities (Cramer, 2008) or where there is insufficient recovery between successive bouts of high-intensity exercise (McArdle *et al.*, 1996). CP supplies the phosphate group that combines with adenosine diphosphate (ADP) to replenish ATP with creatine kinase presence during the high rate of short-term and high intensities activities (Table 2.10). Thus, phosphocreatine resynthesise is dependent on aerobic metabolism.

Table 2.10: The 3 important pathways for energy (ATP) production in human skeletal muscle and their application to the sport of mixed martial arts (Bounty *et al.*, 2011, pp. 3).

Pathway	Brief description	Duration	Application
Phosphagen system (anaerobic)	The most immediate source of energy (i.e., ATP utilization/ production)	Approximately, the first 3–6 s of intense exercise	Explosive takedown attempt; rapid combination of strikes
Glycolysis (anaerobic)	Provides ATP at a fast duration but cannot be sustained. This stage also produces lactic acid	Approximately, 6–30 s of intense exercise	Grappling for maintaining or controlling position (i.e., tie-ups, positional changes); longer duration striking
Oxidative phosphorylation (aerobic)	Provides ATP at a relatively slower rate, but it can be sustained for a much longer duration	Typically, it refers to exercise of longer duration (i.e., 2 minutes to several hours)	Used in recovery between anaerobic burst; circling an opponent; latter stages of a round

- ATP, adenosine triphosphate.
- It should be noted that all of the energy systems work in concert. However, during different exercise intensities and durations, one energy system may dominate.

Meanwhile, Beneke *et al.* (2004) reported that the metabolic demands of an average fight in karate lasting 4 mins and 27 s derived approximately 77.8, 16.0, and 6.2% of its energy demands from aerobic, anaerobic alactic, and lactic energy pathways, respectively. Whereas, most experts agree that that both aerobic and anaerobic metabolism are contributing varying percentages at various times during fight (Amtmann and Berry, 2003). However, Turner (2009) reported that Muay Thai involved pre-dominate anaerobic metabolic contribution and the speed and explosive nature of sports suggests phosphagen system dominance. It has been long known that muscle becomes acidic during intense exercise because energy demands exceed oxidative capacity-that is, when the oxygen supply is limited, muscle must rely on anaerobic metabolic sources (Melhim, 2001). Therefore, aerobic metabolic system contribution may be minimal in Muay Thai and be involved only in ring movements and recovery mechanisms. Conversely, their finding contrasted with Buse and Santana (2008) which reported that a kickboxer could derive more than 50% of ATP from aerobic metabolism. Nevertheless, these vigorous activities in combat sports impose unique stress on the body (Kraemer *et al.*, 2004). Crisafulli *et al.* (2009) reported that even though heart rate and oxygen consumption slightly decreased in the 1-minute rest between rounds, it was still above their lactate threshold and thus did not allow for full recovery. Lactate will directly affect the muscles' contractile mechanisms by inferring with the actin-myosin cross-bridge interactions (Kraemer *et al.*, 2004). Excess carbon dioxide (CO_2) production (i.e., the CO_2 produced above that of normal aerobic metabolism and has been shown to significantly correlate with increases in blood lactate (Hirakoba *et al.*, 1993 and Hirakoba *et al,* 1996). Thus, fighters need to be able to tolerate adequately buffer high acidity levels in both the blood and skeletal muscle to optimise performance (Kraemer *et al.*, 2004). Furthermore, Taekwondo practice may be an effective and specific method of anaerobic training for adolescent male practitioners, particularly, due to the high demands on short anaerobic performance ability during training (Melhim, 2001). Katch (1983) suggested concentrating on neuromuscular skill training for young children which extends to physiologic conditioning when puberty is reached. Cross-sectional comparisons among children and adolescents have demonstrated higher muscle power and muscle endurance among trained individuals than among untrained controls (Blimkie and Bar-Or, 2008).

Balyi (2001) reported that it takes eight to 12 years of training for talented athlete to reach elite levels. This is also known as 10,000 hour rule of commitment to training or 3-hour a day of training for 10 years to achieve the world class status athletes (Eriksson, *et al.,* 1993; Eriksson and Charness, 1994; Bloom, 1985; Salmela *et al.,* 1998). Balyi and Hamilton (2004) suggested that a specific and well-planned training, competition and recovery regime will ensure optimum development through an athlete's career. Success that comes from long term training is better than winning in the short term plan. This is because by undergoing a proper long term training plan athletes' will develop their physical, technical, tactical and mental abilities. Unfortunately, parents and coaches in many sports still approach training with an attitude best characterized as "peaking by Friday," where a short-term approach is taken to training and performance with an over-emphasis on immediate results (Balyi, 2001). Thus, it is suggested for coaches to identify the long-term athlete development plan to ensure the athlete is valorising the "critical" periods of accelerated adaptation, which will only take place with the proper volume, intensity and frequency of exercise implemented in training. These critical periods refers to periods of development represented by the time when children are ready and able to develop skills, fitness and function. Naughton *et al.* (2000) reported that the growth related improvements from aerobic training in well-trained male adolescent athletes (compared with well-trained pre-adolescent males) relate to changes in hormone secretions during maturation. Whereas, Baquet *et al.* (2003) suggest that there is an exponential rise in peak oxygen uptake following peak height velocity and puberty, in what Katch (1983) and Rowland (1997) describe as the ‘‘trigger hypothesis’’. Although there is inconsistency in the literature, Viru *et al.* (1999) have reviewed several longitudinal studies to show that peak development of relative aerobic capacity ($mL \cdot kg^{-1} \cdot min^{-1}$) occurs between 12 and 16 year in both boys and girls. Viru *et al.* (1999) also reported that cross-sectional research shows that the peak development period for aerobic capacity occurs at 10–16 and 7–13 year in boys and girls, respectively. Pfeiffer *et al.* (2008) concluded that both male and female, prepubescent and post-pubescent youth were trainable and that increases in $\dot{V}O_2$ max (with training) of approximately 5-10%. In addition, available literature suggests that children can show improvements in strength (Blimkie and Bar-Or, 1996; Ozmun *et al.*, 1994; Granacher *et al.*, 2011) with exercise training.

The adolescent growth spurt varies considerably in timing, tempo and duration among individuals (Philippaerts *et al.*, 2006). Allowing for this variation, peak height velocity (PHV) rather than chronological age has been used to characterize changes in size, body composition and performance relative to the adolescent spurt in height (Beunen and Malina, 1988; Beunen *et al.*, 1988; Malina *et al.*, 2004). Although the trainability of skill, speed and suppleness is based on chronological age (Viru, 1995; Viru *et al.*, 1999; Balyi and Ross, 2009a; Balyi and Ross, 2009b; Rushall, 1998), biological markers (PHV) can identify the sensitive periods of trainability to exploit the adaptation to training for stamina and strength (Balyi and Way, 2009). It is considered that the initial pre-pubertal period is related to chronological age-related enhancements in neuromuscular efficiency, whereas the second circa- or post-pubertal period is attributable to maturity-related increases in androgen levels, muscle fiber-type development, and muscle mass (Viru *et al.*, 1999). These are particularly true due to the maturation of the endocrine system to provide increased circulating anabolic hormones required to make training gains. Whereas, skill, suppleness and speed are related to chronological development, as these are primarily determined by central nervous system (CNS) development which may not be maturation dependent. Thus, it has been suggested that the timing of the training emphasis can be determined to induce optimal training effects (Balyi and Way, 2009). The onset of PHV will mark the beginning of the emphasis of aerobic training in aerobic sports, the implementation of continuous training methods (e.g. long slow distance running (LSD) and Fartlek) between the onset of PHV and PHV and interval training after PHV (after growth decelerates) (Lawrence, 1999; Kobayashi *et al.*, 1978; Rushall, 1998). These evidences had been used in the development of long-term athlete development (LTAD) model by Balyi and Hamilton (2004), which has been adopted by a number of sports governing body worldwide. Although the implementation of the model, and its derivatives, has provided a more structured approach to athlete-centered programming, there is arguably a lack of empirical evidence for the development of the components of the original model (Lloyd *et al.*, 2011). Thus more evidence is required to support the theory of critical periods of accelerated adaptation to establish whether sensitive periods represent optimal time for realising specific training tasks.

Sports can be divided into two categories under the long-term athlete development (LTAD) model, which are the early specialisation and late specialisation sports (Balyi, 2001). Table 2.11 shows the overview of the LTAD programme that can be specified into five stages; fundamental stage, learning to train, training to train training to compete, training to win and retirement/detainment stage. Each category is separated by chronological age. Looking to the current research, this LTAD model is similar with the silat curriculum that is implemented in Malaysian school which was developed by Anuar (2007). This silat curriculum separates each group of students based on their age before moving into a subsequent higher ranked group (which in martial arts is known as the belt system). The training system is divided into seven levels (belt rank). Every level is then divided into seven topics or disciplines that need to be mastered before moving to the next level (Anuar, 2002). Each level is distinguished by belt color, starting with white to blue, blue to brown, brown to yellow, yellow to green, green to red, and ending with black belt. After that the silat student can upgrade their level to junior instructor, senior instructor, guru and senior guru position. Each level consists 60-80 hours of learning depending on the silat exponents performances However, each silat exponent requires at least 60-hours of training (Anuar, 2007) before being allowed to participate in grading to another level. Table 2.12 shows the overview of silat curriculum syllabus implemented in Malaysian schools.

Table 2.11: The overview of Long Term Athletes Development (LTAD) model for late specialization sports (Balyi, 2001, pp. 6).

Key Element of The Programme	Overview Of The Long Term Athletes Development Model			
	Community Sports	**Introduction to Competition**	**Competition - Development**	**Competition – High Performance**
General Orientation	Fundamental	Training to Train	Training to Compete	Training to Win
Age Group Between ( ) and in *italics; early specialisation sports*	Chronological/biological Male: 6 – 10 years Female: 6 – 10 years	Biological Male: 10 – 14 years Female: 10 – 13 year *(10-11)*	Chronological/biological Male: 14 – 18 years Female: 13 – 17 years *(12-15)*	Biological Male: 18+ years Female: 17+ years *(16+)*
Specialisation	None; participation in different sports	Participation in complementary sports (similar movements and demands); preferred sport becomes more important	Sport-specific technical, tactical, and physical preparation; specialisation in a discipline or in a position	Sport-specific technical, tactical and physical preparation
Objectives	Fun and participation; general development; experiment with new forms of sport activities	General development of athletic abilities and some limited form of sport-specific conditioning; acquisition and consolidation of appropriate technical and tactical elements; first serious competitive experience	Consolidation and/or development of physical, tactical, technical, and mental abilities and skills in order to perform successfully in provincial and national competitions	Maintenance of physical abilities at a high level and improvement of tactical, technical and mental skills in order to reach peak performance in national and international level competitions
Ratio of Practice (Training) to Competition	Very large majority of time devoted to games and activities to develop motor skills; competition and results are not a priority	75% of the time devoted to sports participation should be spent training and 25% to competing (these percentages may vary slightly depending on the sport)	50% of the time devoted to sports participation should be spent developing physical conditioning and tactical and technical skills, and the other 50% in sport-specific preparation for competitions	75% of the time should be devoted to sport-specific preparation and to participation in competitions

Type of Periodisation	Not applicable; no periodisation, but well structured programme	Single periodisation	Double periodisation	Triple or multiple periodisation; frequent recovery breaks
Length of Programme	A few weeks (6-12)	20 – 30 weeks	35 – 45 weeks	45 – 50 weeks
Number of Practices per Week	Athlete's preferred sport: 1-2 per week; participation in other sports 2-4 times per week	Sport-specific training 3-4 times per week plus participation in other sports	6 - 9 times per week	9 - 12 times per week
Training Means and Methods	Games; fun activities; medicine ball activities; activities with Swiss balls; general resistance training exercises using body weight to improve strength and strength-endurance	Frequent use of general exercises; sport-specific physical conditioning and technical preparation	Frequent use of sport-specific exercises and competition-specific exercises	Patterning of every possible aspect of training and performance; individualisation of all aspects of training and competitive preparation
Training Priorities – Physical Preparation	Speed, power, and endurance acquired through fun and games	General physical conditioning	General development of athletic abilities; individualised sport-specific conditioning	Highly individualized sport-specific physical conditioning; slight improvements sought, if possible
Training Priorities – Motor Development	Agility, balance, coordination, and speed	Agility, balance, coordination, and speed		
Training Priorities – Technical Development	Running, jumping, and throwing techniques	Progressive acquisition and consolidation of basic sport-specific skills	Advanced technical preparation	Refinement of advanced technical skills, where necessary
Training Priorities – Tactical Development	Introduction to the basic rules and ethics of sport	Basic tactical preparation; correct decision-making in frequently encountered competitive situations	Development of national level tactical skills and decision-making abilities	Development of international level tactical skills and decision-making abilities
Training Priorities – Mental Skills	Do your best, keep trying	Basic mental skills	Advanced psychological preparation	Advanced psychological preparation; highly individualised approach

Table 2.12: Overview of silat curriculum in Malaysia (Anuar, 2007, pp. 179).

	LEVEL						
Phase	**Lower Phase (7 to 13-year-old)**		**Intermediate Phase (13 to 18-year-old)**			**High Phase (18-year-old and above)**	
Level	1	2	3	4	5	6	7
Title Topic	Beginner silat Exponent	First Rank Junior silat Exponent	Second Rank Junior silat Exponent	Young silat Exponent	Silat Exponent	Junior Warrior	Warrior
Bunga	7 Movements	15 Movements	15 Movements	15 Movements	20 Movements	20 Movements	20 Movements
Jurus	7 Movements	15 Movements	15 Movements	15 Movements	20 Movements	20 Movements	20 Movements
Belebat	Hand Blocking	Leg Blocking	Avoiding/Dodging	Blocking	Catching	Counter-attack	Combination of all levels
Tapak	Vertical	Horizontal	Square	Triangle	Round	Star	Combination of all levels
Buah	Learning type of strikes in counter attack	Application of strikes during silat fight	Single strike	Variety or continuous strikes	Receiving and exchanging strikes	Weaponry	With and without weapon
Tempur Seni	Performance Basis	Square Basis	Single strike of soft combat art action	Continuous strikes of soft combat art action	Variety continues strikes of soft combat actions	The art of soft wrestle combat using weapon	Silat Melayu or combination of all levels
Tempur Beladiri	Direct combat	Two-way sparring	Continues avoiding combat	Continues blocking combat	Alternate wrestle	Combat and silat wrestle	The art of self defense

Bunga = the basis of silat movements which consists of steps (depending on level), stances and hand positioning on how to master the defensive and striking position in silat. Jurus = the activities of defending and attacking of silat movements, which are well known as *kata* in karate. Belebat = discipline or specific-technique on how to receive attacks during a fight. Tapak = step pattern or floor plan that is used in silat to ease the step movements in silat. Buah = self defense or counter-attack technique during fight. Tempur Seni = soft combat actions. Tempur Beladiri = hard combat sparring.

The issue of youth trainability in the context of sport has been discussed primarily for muscular strength and aerobic power; and to lesser extent anaerobic power (Malina *et al.*, 2004). The issue of trainability also applies to the development of proficiency in general and sport-specific motor skills (e.g. responses of youth to instruction and practice protocols) (Malina, 2008). Thus, the development of performance into competition is achieved through a training process that is designed to induce automation of motor skills and enhance structural and metabolic functions (Smith, 2003). Therefore, the objective of training is to progressively and systematically increase the training stimulus (the intensity, volume of training loads, and frequency of training) to introduce superior adaptation and, as a result, improve performance (Bompa and Haff, 2009). The adaptation to exercise is related to the type training stimulus (Hickson, 1980). For example, heavy resistance, low-repetition strength exercise, such as weight training, results in increases in strength and muscle cell hypertrophy (Gollnick *et al.*, 1972; Thorstensson *et al.*, 1976). Whilst, with high-intensity anaerobic training, the neuromuscular, metabolic and cardiovascular systems adapt, allowing the athletes to generate more adenosine triphosphate (ATP) per unit time, thus increasing muscular endurance and speed of movement over short periods of time (Wilmore *et al.,* 2008). Thus, determining the principle of individuality, specificity, overloaded, reversibility, hard/easy in silat will help coaches to plan the details for silat training programme plan that complements with the exponents needs.

In order to develop any training programme in silat sports, it is important to determine the specificity of training due to the nature of competition. Aziz *et al.* (2002) reported that competitive silat matches are characterised by high anaerobic and anaerobic responses. Thus, the concept of trainability of readiness and critical periods (Malina,

2008) might need taken into consideration in order to accommodate with the demand of the silat sports as growth, maturation, and development occur simultaneously and interact, and show considerable inter-individual variability (Malina *et al.*, 2004). Readiness relates to the ability of the individual to handle successfully the demands of a structured learning situation (e.g. specific instruction and practice of sport skills) (Malina, 2008). These include determining athlete growth, maturation, development features at a given point in time and also the demands of instructional and practice situations which may depend on many factors (e.g. skill *per se*, the style and quality of teaching or coaching, individual or group activity and general conditioning, Malina, 2008). Moreover, the identification of athlete sensitive periods of accelerated adaptation (Lloyd *et al.*, 2011) as proposed by Balyi and co (2004; 2009) in LTAD, even though it is not completely convincing, needs to be put into a coach's perspective (Ford *et al.*, 2011). The identification of periods of accelerated adaptation is paramount to further understand the potential adaptation during childhood to adulthood to maximise the athletic potential of young performers (Lloyd *et al.*, 2011). It assumes that changes underlying growth, maturation and development occur rapidly during specific time periods and that organisational process can be modified easily at this time (Scott, 1986; Bronstein, 1989) such as via exposure to training stimuli. Nevertheless, the concept of critical periods appears to be implicit in sport talent identification and development programme (Bompa 1995). In term of youth silat training, this information might help coaches in drawing a general and specific training plan based on the aforementioned trainability concept, in order to prepare the young athlete for competition demands based on their readiness and critical periods of development.

One of the goals of a training programme is to allow silat exponents to maintain optimal performance for the entire duration of spar. Determination of work:rest ratios, activity profiles during a silat match and physiological characteristics (Aziz *et al.*, 2002) needs to be put into consideration when designing a youth training programme, as well as considering developmental patterns. This training programme should emphasize improving aerobic and anaerobic metabolic systems, other factors, strength, power based on the work/rest rate ratio whilst also incorporating sport-specific movements, so that the silat exponents can perform well during the competition. Currently it is not known if coaches are using such a training design, however, this seems unlikely given that there are no published research studies in this area and information on the demands of silat competition have not been reported prior to this thesis.

2.5 Developing Circuit Training in Silat

It has been suggested that silat match is an intermittent sport characterized by high anaerobic and aerobic metabolic responses (Aziz *et al.*, 2002) which required silat exponent to have explosive legs power and ability to perform short duration high-intensity exercise in the lower body. Thus, circuit training programme was suggested to be useful form of training in silat due to the flexibility to perform the combination of many anaerobic exercises performed consecutively (e.g. kick, punch, jump) with very short rest in between, besides to achieve a cardiovascular training effect (Taskin, 2009). Moreover, circuit training is a form of progressive resistance loading and is designed to improved general muscular and circular-respiratory condition (Adamson, 1959). However, there was no research available on circuit training in adult or youth silat. Therefore such information from other sports (Taskin, 2009; Rahami and

Behpur, 2005; Spurrs *et al.*, 2003; Baquet *et al.*, 2003) would be appropriate in order to provide relevant information (i.e. interval training, cluster training, resistance training) to support the development of new silat-specific circuit training. Debbie and Bob (2007) suggested that designing effective sport-specific training sessions is achieved by conducting an analysis based on:

- The main movement activities and skills used in the sports
- How the joints moves
- Which muscles are involved and how they contract (concentric, eccentric, isometric and plyometric)
- Predominant energy pathway used (aerobic/anaerobic)
- Common injuries associated with particular sport.

Thus, spending time on this analysis will ensure that the circuit training designed will be safe, effective and follow the principle of specificity. Scholich (1996) reported that training methods are based on two major components of training; the intensity of the training and the volume of the training. The stimulus intensity of exercise (how hard or intensity) and the stimulus density of exercise (type of training) are the subcomponents of intensity. While the stimulus volume of exercise (how often or frequency) and the stimulus duration of exercise (how long or time/duration) are the subcomponents of the volume of training. Tabata *et al.* (1996) found that 8 sets of interval training with the same work to rest ratio had a profound effect on both aerobic and anaerobic capacities. Based on the anaerobic conditioning by Buse and Santanta (2008) it was suggested that the number of training rounds and rest duration between training rounds should mirror the same number of rounds and rest duration scheduled for competition. Moreover, intensity may vary from light to high, the duration of the same sets may extend to 2 minutes to develop power endurance and/or muscular endurance, and rest periods between interval training rounds may extend to 4 minutes (Buse and Santanta, 2008). The main purpose for circuit training was to develop a toleration of high hydrogen ion and lactic acid concentration, which will subsequently enhance the acid-buffering mechanisms within the body (Kraemer *et al.*, 2004). Work to rest ratios of 2:1 and 3:1 have been found to be most effective at developing the aerobic and anaerobic systems in grappling sports (Pulkkinen, 2001).

Bounty *et al.* (2011) suggested three types (depending on the targeted intensity) of high-intensity interval training (HIT) which is characterised by alternating high-intensity (i.e., near maximal effort or near $\dot{V}O_2$ peak) exercise bouts with relatively longer active recovery periods that are less intense (Gibala and McGee, 2008). The benefits of performing HIT are that it may increase $\dot{V}O_2$ peak and increase oxidative capacity in skeletal muscle (assessed by mitochondrial enzymes) faster than more traditional high-volume endurance training such as continuous cycling (Gibala and McGee, 2008). The first suggestion was an athlete running on a treadmill for 30 s at an 8–12% incline, then practicing striking combinations on a heavy bag for 1 minute and then resting for a certain length of time. The ultimate goal would be to have the rest period reflect those used during a real fight (Bounty *et al.*, 2011). However, the total exercise time of 1.5 minute does not mirror the fight time of 2-minute per round in silat. Moreover, the running actions on a treadmill are not specific to the activity actions in silat.

The second suggestion was interval training workout could include resistance exercises in which a trainer could choose 8–10 (mainly multijoint) exercises that his or her athlete could perform back-to-back without rest between the exercises. For example, one could perform a predetermined number of repetitions (reps) of free squats, lunges, step-ups, overhead presses, push-ups, pull-ups, kettle bell swings, and dips performing all exercises back to back and then resting after all exercises have been completed. This hypothetical interval could last 2 minutes and then the athlete could rest or perform an active recovery for approximately 1–4 minutes between exercise intervals, depending on the condition of the athlete (Bounty *et al.*, 2011). As the requirements of circuit training are the volume, intensity, stimulus duration and density of exercise (Scholish, 1996), the second suggestion does make sense of volume of exercises could mirror the work duration during a silat match, with the density of work and rest phases in training that similar with silat with 2-mins work and 1-minute rest per round in competition (Anuar, 1987; 1992; 1993; Aziz *et al.*, 2002). However, the 2 mins of continuos exercises without rest between exercises would not mirror the demands of silat (Aziz *et al.*, 2002). This is because as intermittent type of sports, there should be a short rest period between bursts of high-intensity activity.

The third suggestion was the athlete punch a heavy bag for 30 s (15 s moderate speed and 15 s full speed), followed by 5 sprawls (a defensive move to avoid a takedown), and then perform a takedown using a grappling dummy and finish with 10 s of punches from the mount position. Finally, concluding by having the athlete perform some type of active rest such as lateral side stepping with tubing for extra resistance (Bounty *et al.*, 2011). This suggestion did emphasise specific exercises that mimic the mixed martial art fight. However, it was reported that repeatedly working on the same metabolic system at high intensity will lead to fatigue and possible over use injuries and cold lead to burn out (Harrison *et al.*, 2008). Thus, it was suggested the combination of sport-specific with general exercises may be appropriate to avoid such issues.

The information gathered above was based on the strength and conditioning in mixed martial arts (MMA) (Bounty *et al.*, 2011) and may need to be adapted in relation to silat and paediatric populations. Moreover, Kraemer *et al.* (2004) reported that interval training appeared to effectively prepare MMA athletes for the metabolic demands of an actual competition. The physical effort required in each competitive bout produces very high levels of lactate, with heart rate reaching 80-90% maximum heart rate (Aziz *et al.*, 2002). It is important to note that lactate accumulation can inhibit actin and myosin cross-bridge cycling (i.e. muscle contraction) (Kraemer *et al.*, 2004). Thus, fighters need to be able to adequately buffer high acidity levels in both the blood and skeletal muscle to optimize performance (Kraemer *et al.*, 2004). As the body has two mechanisms that 'buffer' this inhibition; bicarbonate (in the cell) and phosphate (between cells), a proper training programme can improve both of them. This is because the better adapted silat exponents, the better they will be able to tolerate high levels of lactate and recover more rapidly between rounds (especially if there are multiple fights within the same day of competition). So, it is necessary to get the silat exponents to work at high-intensities to overload these tolerance and buffering systems to cause a positive adaptation

In developing a circuit training programme in silat, a wide variety of exercises and equipment can be used such as a silat exponent's body weight, hand target, body target, medicine balls, silat mat (mat used in silat competition) and any martial arts accessories related to training. Silat requires the exponents to excel in attacking and defending situations. It is necessary for young silat exponents to develop their motor fitness or physical and skill-related components of fitness (agility, balance, speed, coordination, reaction time and power) in silat to improve their effectiveness and efficiency of silat movements. Table 2.08 (pp. 60) shows the physical/physiological characteristics some research have used to profile combat sports. Performance tests which distinguish across ability levels, indicates which fitness characteristics are important to the demands of the sport. It was reported that the grappling sports such as judo and wrestling require speed, power and also a great deal of isometric strength with specific attention being paid to neck strength and grip strength (Amtmann and Cotton, 2005; Kraemer *et al.*, 2004). Wrestling success requires high levels of both strength and power; however each wrestler has a distinct style and various strategies, which will affect the design of an individual's training regimen (e.g. some wrestler may perform many offensive actions in a short burst of time, whereas others may be more defensive and slow the action of the match) (Kraemer *et al.*, 2004). Meanwhile, most combat sports (Turner, 2009; Bounty *et al.*, 2011; Melhim, 2001; Kraemer *et al.*, 2004; Amtmann and Cotton, 2005; Buse and Santana, 2008; Amtmann and Berry, 2003; Amtmann *et al.*, 2008) agreed that most activities require energy from aerobic and anerobic system, but vary according to intensity and durations. In addition Muay Thai involves predominantly anaerobic energy contribution and the speed and explosive nature of the sport further suggest phospogen system dominance (Turner, 2009). Aerobic metabolism occurs concomitantly with anaerobic metabolism even during short-duration, maximal-intensity exercise in kickboxing (Buse and Santana, 2008). Mixed martial arts (MMA) is a physiologically demanding sport and potentially challenge all of the energy system (Bounty *et al.*, 2011).

Circuit training may also be used to maintain the interest and assist motivation for participants, particularly children who naturally engage in intermittent type exercise (Bailey *et al.*, 1995). Circuit training that involves a variety of drills and brief bouts of high-intensity exercise which will help replicate the natural play type activities of children and keep them motivated to engage and adhere to this type of training programme. In addition, due to the demands of the silat sports, this format can be used for muscular strength and endurance-biased (speed-power) sessions. Thus, preliminary information such as presented before is needed to establish the demands of silat sport.

CHAPTER THREE

Study One (a): Distribution of Fight and Break Time in International Silat Matches

3.1 Introduction

Performance analysis has been used as a research tool to investigate various aspects of different combat sports such as boxing (Hughes and Franks, 2004), taekwondo (Wojtas *et al.*, 2007), Muay Thai (Harris, 2005) and mixed-martial arts (William and O'Donoghue, 2006). There are several references of notational analysis of combat sports that describe the pattern of attacking and defensive techniques in sports including boxing (Hughes and Franks, 2004), Muay Thai (Harris, 2005) and mixed-martial arts (William and O'Donoghue, 2006). However, these studies do not report the work to rest ratio, which is important in determining the duration of the average work and recovery period between action periods.

Time motion analysis has been used widely to develop an understanding of the physical demands of many field games including Gaelic football (O'Donoghue and King, 2005), football (O'Donoghue *et al.*, 2005b), netball (O'Donoghue, 2004b) and rugby (Hughes and Blunt, 1998), with all of these studies reporting the work to rest ratio for the players studied. One of the initial steps in prescribing training programmes for sports is through analysis of the major physical requirements of match-play (Withers *et al.*, 1982). However, little attention has been focused on the performance analysis of silat exponents. The knowledge of the range of durations for work and rest periods is important to the understanding of the intermittent nature of silat.

As junior athletes (and their coaches) aspire to senior success it is important for youth athletes to have an appreciation of and be conditioned towards the demands of elite senior sport. Therefore, it is useful to characterise the demands of International silat match in order to promote the sport towards the young participations. The primary purpose of the current investigation is to use time motion analysis to describe and identify the intermittent nature of a silat match in term of the duration of fight time and break time within rounds of international silat contests

3.2 Methodology

3.2.1 Research Design

Publicly available video recordings of 7 male silat matches from an international silat competition (National Sports Council, Malaysia) were used for analysis. These matches included fighters from a range of weight categories. The POWER (Periods of Work Efforts and Recoveries) system (O'Donoghue *et al.*, 2005a) was used to enter timed work and rest periods performed by the 14 silat exponents during seven International silat competition matches. An intra-reliability of 7 fights was undertaken to establish the objectivity of the method. Intra-observer reliability was measured by the same observer repeating measurements on 7 fights in two separate occasions, with at least 7 duration sub-ranges work between the analyses of same bouts.

3.2.2 Computerised Work-Rate Analysis

The POWER system was used while observing the DVD of an exponent movement on a separate computer. All the match activity was classified as either "work" or "recovery" instead of a larger classification of movement because:

- "Work" was defined as any attacking or defensive activities or movements that happened within the start instruction given by referee in a match. "Rest" was defined as any activity or movements that happened within the *stop* instruction given during a fight.

- Many time-motion analysis studies classify movement as high or low intensity activities and the key results reported are the proportion of the time spent performing high intensity activity and the work to rest ratio.

"Work" would typically include punching, avoiding, kicking, parrying, catching, jumping, toppling-down and any silat movements by both fighters unless stop by the referee. All actions and movements with or without contact with the other exponent's while in action time (as long as the referee did not stop the fight) was classified as "work". The assumption was based on the rules of silat olahraga competition, which require the exponent to develop a competing pattern which consists of '*sikap pasang*' (silat posture), '*pola langkah*' (step pattern), measuring the distance against the opponent, coordination in performing an attack/defence, and finally return to '*sikap pasang*' (Anuar, 1993). "Rest" would typically be all the actions that happen in the round when the referee gives the command "*henti*" or "stop". This two-movement classification enables the researcher to enter the sequence of activity performed by the exponents into the POWER system during observation of the video-recorded performances.

The computerised system used the F2 function key to record the beginning of each work period and F1 key to record the beginning of each rest period. The F10 key was used to indicate that the POWER system had finished observing the current match period. The system summarised the sequence of timed work and rest periods entered for each exponent using the following variables:

- The number of work period performed.

- The average duration of work as well as the average duration of rest periods.
- The number of work of under 2 s, 2 s to under 4 s, 4 s to under 6 s, 6 s to under 8 s, 8 s to under 10 s, 10 s to under 12 s and 12 s or greater.
- The number of rest periods of under 2 s, 2 s to under 4 s, 4 s to under 8 s, 8 s to under 12 s, 12 s to under 20 s, 20 s to under 45 s, 45 s to under 90 s and 90 s or greater.
- The percentage of observation time spent performing work and rest activity.

The durations of work exercise and rest periods were chosen by author after considering the nature of the competition that showed that the referee was actively involved in influencing the match tempo. This is due to the requirement of the competition that a series of attacks should be delivered in row, a combination of various techniques towards the target, with no more than 4 kinds of attack. An exponent who performs than 4 kinds of attack/defence in a row will be stopped by the referee (Anuar, 1993). Therefore, both silat exponents will be doing the same work periods and rest periods together. This is because the referee is the main factor for every activity that happens in a fight. Three possibilities will take place that are either both silat exponents are in attacking movements or defensive movement or either one is in an attacking movement and the other is in a defensive movement.

3.2.3 Reliability of Observation

The data in the current research was examined by the researcher. To investigate the reliability of the observation process, each of the contests was entered twice. The second observation was done a day after the first observation took place. The researcher analysed all the 7 matches using the POWER system. The work period was being classified according to the instruction given by the referee. Therefore, it is important to other researchers that using the same software POWER system to understand the instruction given by the silat referee. It was therefore essential to establish the strength of agreement associated with the instruction given by the referee of work and rest activities when applied to silat.

Table 3.1: Kappa values for each round of 7 international silat matches.

Matches	**Observation**		
	Round 1	Round 2	Round 3
Match 1	0.9101	0.6125	0.8497
Match 2	0.9273	0.8869	0.9411
Match 3	0.9302	0.8236	0.7037
Match 4	0.9137	0.8374	0.8553
Match 5	0.8050	0.9082	0.8646
Match 6	1.0000	0.9800	0.9823
Match 7	0.9137	0.9643	0.9311

Kappa was used to measure the strength of agreement between independent observations. The POWER system implements an algorithm to apply the kappa statistic to the movement sequence recorded (O'Donoghue, 2005). This algorithm determines the proportion of observation time where 2 independent observations agree on the activity being performed, addressing the proportion of time where the observations would be expected to agree by guessing (O'Donoghue *et al.*, 2005b). Table 3.1 shows the kappa values achieved for round 1, round 2 and round 3 for the 7 matches observed by the researcher. Kappa has been described by Altman (1991) for the comparison of nominal variables when recorded by independent raters. It adjusts the proportion of cases where the two raters agree to address the proportion they could be expected to agree on by guessing. A study by O'Donoghue *et al.* (2005a) has suggested that kappa values are interpreted as a very good strength of agreement if over 0.8, good if between 0.6 and 0.8, moderate if between 0.4 and 0.6, fair if between

0.2 and 0.4 and poor strength of agreement if between 0.0 and 0.2. It is mathematically possible for kappa values to be below 0.0 where the level of agreement is lower than would be expected if the two observers guessed the activity being performed for entire duration of the observation. Values of kappa below 0.0 are classified as very poor.

The data for current research were entered for two of the rounds had a good strength of agreement between independent observations ($0.61 < \kappa < 0.80$) while the remaining 19 rounds had a very good strength of agreement between independent observations ($\kappa > 0.81$). The kappa values represented predominantly very good reliability across the two observations performed by researcher for all 7 matches.

3.2.4 Data Analysis

The POWER system (O'Donoghue *et al.*, 2005a) was used to enter the start of all periods of action and breaks that occurred within 7 international silat matches that went the full distance of 3 rounds. A DVD of the contest under investigation was viewed on a television or microcomputer while a separate computer was used to execute the data entry component of the POWER system. Each round was entered as a separate match period, with all 21 rounds of recorded data being summarized within a single Microsoft Excel spreadsheet for further processing and subsequent statistical analysis when loaded into SPSS (SPSS Inc., Chicago, Il, USA). A series of Friedman tests were used to compare several frequency, duration and percentage time variables of interest between the 3 rounds of a contest. The POWER system determined the number of action periods of 7 different durations (0-2s, 2-4s, 4-6s, 6-8s, 8-10s, 10-12s and 12s+) and break periods of 8 different durations (0-2s, 2-4s, 4-8s, 8-12s, 12-20s, 20-45s, 45-90s and 90s+) as well as combinations of action periods and the break periods that followed them (O'Donoghue, 2005). A chi square test of independence was used to determine if there was an association between the duration of a period of action and the duration of the recovery period that followed it. It was necessary to merge some classes of break and some classes of action period to ensure that there was an expected frequency of at least 5.0 in at least 80% of the cells of the cross-tabulation of action and break period entered into the chi square test. An alpha level of (p <0.05) was taken to show statistical significant.

3.3 Results

The mean for the two observations for each contest were determined and are presented in Table 3.2. There was no significant difference between the 3 rounds for the frequency of fight periods (p = 0.084), the duration of break periods (p = 0.867) or the percentage of round time spent in fight action (p = 0.368), whilst, the duration of fight periods tending to be significant (p = 0.050). Table 3.3 shows the frequency of fight periods of different duration time and Table 3.4 shows frequency of break periods of different duration time.

Table 3.2: Work and rest periods performed in each round.

Performance Indicator	Round 1	Round 2	Round 3	All Rounds
Frequency of fight periods	9.3±4.2	10.0±5.6	10.7±5.0	30.0±14.4
Mean duration of fight periods (s)	16.0±6.2	17.0±11.1	13.0±4.4	15.3±6.7
Mean duration of break periods (s)	8.6±0.5	8.5±2.5	8.1±1.8	8.4±1.3
%Time spent in fight mode	63.8±10.5	63.2±16.6	60.8±13.3	62.6±12.8

Table 3.3: Frequency of action period of different durations (mean ± SD).

Duration of fight periods	Action in one silat round
Under 2 s	0.8 ± 0.6
2 s to under 4 s	1.1 ± 0.8
4 s to under 6 s	5.1 ± 9.2
6 s to under 8 s	4.3 ± 5.8
8 s to under 10 s	3.9 ± 3.2
10 s to under 12 s	3.0 ± 1.8
12 s to greater	11.9 ± 5.5

Table 3.4: Frequency of break periods of different durations (mean ± SD).

Duration of recovery periods	Recoveries in one silat round
Under 2 s	1.8 ± 1.2
2 s to under 4 s	1.9 ± 0.4
4 s to under 8 s	9.4 ± 5.6
8 s to under 12 s	10.9 ± 8.6
12 s to under 20 s	4.4 ± 3.4
20 s to under 45 s	0.9 ± 1.2
45 s or greater	0.0 ± 0.0

Table 3.5 shows the total number of action periods and following break periods of different durations recorded for all of the contests. The values used were the means of the 2 observations for each contest. There was no significant association between the duration of a period of action and the duration of the break which followed it (χ^2_8 = 13.0, p = 0.113).

Table 3.5: Duration of activity periods and the break periods that followed them (based on the mean of two observations)

Duration of action period	**Duration of following recovery**					
	0-4s	4-8s	8-12s	12-20s	20s or longer	All frequency
0-6s	11.5	9.0	18.0	6.0	3.0	47.5
6-12s	6.5	28.0	29.5	12.5	1.5	78.0
12s or longer	7.5	29.0	27.5	12.0	1.5	78.5
All Actions	25.5	66.0	76.0	30.5	6.0	204.0

3.4 Discussion

The lack of comparative research considering the demands of elite silat competition makes it difficult to make direct comparisons with previous research – in fact there is a lot of value because this is the first study of its kind. To the authors knowledge no previous research has used a similar approach when designing tests specific to silat or any other martial art. However, the results provide the evidence those exponents involved in an international silat match will have more time in a fighting mode compared to break mode. Table 3.2 also shows the similarity of the frequency of fight periods (9 -10 actions) during a silat round. This information is important in order to condition silat athlete to familiarise with the work periods involved in a silat match. Results of this research express average work to rest ratio during the silat matches approximately of 2:1. Table 3.2 shows that the average work was 15 s and average of break period was 8 s. The former is the average work duration in a match; the latter is the average break duration. Silat exponents will continue to fight to score as many points as possible which contribute to frequent fight-contacts which are often interspersed with very short recovery bouts. A study by Aziz *et al.* (2002) showed that male and female exponents were operating between 89-97% and 84-92% of Hr_{max} (heart rate maximum) throughout a national silat match. The overall intensity of a silat match indicated an exertion intensity close to the individual's maximal cardiovascular responses that was sustained throughout most of the match. This suggests that silat exponents are accustomed to numerous bouts of high force intensity actions alternating with lower intensity movements throughout a match. Furthermore, Aziz *et al.* (2002) reported that all the post-round lactate samples taken during the silat matches of 60 exponents indicated high vales, ranging from 6.7 to 18.7 $mMol.L^{-1}$ while mean heart rate of 13 male silat exponents increased from 174 $bmin^{-1}$ (round 1), 186 $bmin^{-1}$ (round 2) to 190 $bmin^{-1}$ (round 3).

Table 3.3 shows that there are full ranges of fight periods from under 6 s to over 12 s in a silat match. It shows that more than 50% of the fight times were greater than 10s or 40% of duration of fight time was above 12 s. While, almost 70% of the recovery breaks were between 4-12 s in duration (Table 3.4). The results suggest that there are a full range of fight periods from under 6 s to over 12 s. Furthermore, the current study has shown that almost all break period are less than 20 s in a round of a silat match. Previous laboratory based research has shown that blood lactate accumulation and performance decrements over five 6 s maximal sprint bouts performed on cycle-ergometer equipment were greater when a recovery of 30 s was taken between sprint bouts than when the recovery was 60 s (Wootton and Williams, 1983). Muscle creatine phosphate may not be sufficiently replenished after recovery periods of less than 45 s (Balsom *et al.*, 1992; Bogdanis *et al.*, 1995). Therefore, the number of recoveries of different durations discovered in the current study may have implications for the sources of energy utilised in elite silat competition. Hughes *et al.* (2005) undertook a laboratory study that showed that the power output of a series of ten 6 s bursts was influenced by the duration of the recovery period in between. Moreover, the action periods that occur in silat cannot be considered as isolated bursts from which contestants will get full recovery. It is most likely that the energy required for the action periods within silat matches at this level is derived from a combination of anaerobic and aerobic sources. This is because there are action periods of over 12s and because there are very short recoveries between some of the shorter action periods (Table 3.5).

A mean fight time of 15 s and short (8 s) recovery will likely lead to a depletion of phosphor creatine and greater reliance on anaerobic glycolysis and aerobic metabolism, which is supported by the high blood lactates and heart rate reported by Aziz *et al.* (2002). The fight period here is the moment of instruction as given by the referee to start the fight between both of the silat exponents until the stop instruction is given to stop the fight action. Thus, silat exponents should be conditioned to the demand of the sport in order to compete in silat competition. Moreover, during the observational analysis process, it was apparent that the activity periods do not involve a consistent work-rate. Thirteen of fourteen possible actions during fight periods are considered high-intensity (see Study 1, pp. 116-119). There was usually a period of low intensity positioning prior to engaging the opponent followed by higher intensity action until a break was necessitated. This has implications for the training of the metabolic systems required in international silat competition with aspiring international competitors and their coaches needing to be aware of the requirements of the sport.

It is recommended that future studies to characterise in detail the nature of action periods within silat matches. This should involve the analysis of footstep movements, agility requirements and specific silat attack and defence skills that are performed during the match. Such details analysis will require the use of a commercial video analysis system such as those used to analyse speed, agility and quickness requirements of a sport (Bloomfield *et al.*, 2004). Furthermore, there is a need for an improved version of the POWER system that can allow some discrimination between different bursts in work periods. Ideally this will permit the user to identify the exact duration of either high or low intensity periods of action and the periods of recovery of interest that are performed by exponents in a silat match. Then the system will analyse the observer activity according to the classification itself.

3.5 Conclusions

The current study has provided new information for the silat coach by examining the range of fight (work) bursts and break (recovery) periods that occur during competition. The average work to rest ratio during a silat match was 2:1. There was usually a period of low intensity positioning prior to engaging the opponent followed by higher intensity action until a break was necessitated. With 62.6% of silat matches involves silat action with action periods ranging from under 6 s to over 12 s with 69% of break time between 4 – 12 s, the results demonstrate the demands of a match, highlighting the period of fight and recovery durations. There is no association between the duration of fighting and the subsequent duration of the break period. Therefore, exponents must be required for a random amount of recovery following a burst of fighting, suggesting the possibility for periods of high metabolic stress. Silat exponents must be prepared for short recoveries after burst irrespective of the duration of the burst of action. It is therefore recommended an improved version would permit the user to identify the durations of periods of action and periods of recovery of interest and then the system would analyse the observed activity according to this classification.

CHAPTER FOUR

Study One (b): Activity Profile during Action Time in National silat Competition

4.1 Introduction

The requirement and prescription of training programmes for sport requires an understanding of the physiological requirements of the match. Various forms of time motion analyses have been used widely to estimate the nature of specific intermittent high intensity and low intensity activities as they relate to the energy requirements of team sports (Davidson and Trewartha, 2008; King and O'Donoghue, 2003; O'Donoghue *et al.*, 2005b). Previous research notated the technique used in defensive and offensive movements such as in mixed-martial arts (William and O'Donoghue, 2006), boxing (Hughes and Franks, 1997) and Muay Thai (Harris, 2005). However, there is no research that specifically describes the activity involved in silat that specifically describes the activity that contributes to the physiological demands of this combat sport.

The nature of work periods within any combat sports depends on the frequency, volume and type of the activity being performed. The distribution of fight time and break time has been determined in international silat competition in the previous study (Study 1 [a]), which indicated that 62.6% of the match is spent in fight time. In addition, a single match contains 30.0 mean action periods with on average 15.3 s being performed with break periods averaging 8.4 s. The work to rest ratio of 2:1 in silat might be misinterpreted if people count the action periods performed in silat in the same way as work periods in field games and racket sports are interpreted. The nature of "purposeful movement" in team games (Bloomfield *et al.*, 2004), rallies in racket sports (Richers, 1995) and action periods in martial arts are very different. Therefore, the objectives of this study are to describe the detail activity that occurs during the fight time of a silat match, especially the profile of technical events.

4.2 Methodology

4.2.1 Match Analysis

A publicly available video recording of one female silat match from the national silat competition in Malaysia (National Sports Council, Malaysia) was used for the analysis. This was a female final match of class E of the 65-70 kg weight category. Subsequent player motion analysis was carried out using a commercial sports performance analysis software package called Focus X2 (Elite Sport Analysis, Delgaty Bay, Scotland). The system was used to identify 14 different types of event performed by the two female contestants as well as the start and end of action periods.

Video sequences were repeated where necessary and the playback rate was reduced to 50% to allow accurate measurement of each offensive and defensive movement category. The video could be paused and played back frame-by-frame for ease of use. Silat exponent motion was subjectively categorised by an experienced observational analyst for silat competition. Information could be entered into the computer system using a 'Mouse', via representation on the screen of the silat match, and specially designed screen functions for each exponent (red or blue), action and outcome for each activity. The timed list recorded in Focus X2 was exported for processing in excel (Microsoft Excel 2002, Microsoft Corporation, USA). The commencement and completion of each individual action period was recorded and the duration was calculated by spreadsheet programming allowing durations (differences between action period end and start times) to be computed. The frequency, mean duration and percentage of total time were subsequently calculated. An intra-operator reliability study of fights was undertaken to establish the reliability of the method.

4.2.2 Motion categories

Silat exponent's motions were coded into 14 different types of categories and were defined as follows:

1. **Punch**:

   The punch '*tumbuk*' attack is done by a hand with a closed fist hitting the target. In silat punching is often used to fight the opponent. It can be a straight punch '*tumbuk lurus'* or uppercut '*sauk*' to the exponent body's (Anuar, 1993).

2. **Kick**:

   The kick 'tendang / *terajang*' is an attacking movement which is performed with one leg or two legs simultaneously. A kick can be aimed at any target. It can be front kick ' *tendang depan*', side-kick '*depak*' or semi-circular side kick '*tendang lengkar*' (Anuar, 1993).

3. **Block**:

   The blocking movements begin with the posture position '*sikap pasang*': the exponent stands straight with his hands around his body or close to his chest. Blocking or parrying '*tangkisan*' can be done using arms, elbows and legs with the purpose to block off or striking back at any attack (Anuar, 1993).

4. **Catch**:

   The catch '*tangkapan*' is done by using the hand to obstruct the opponent from carrying out an attack. The silat exponent is able to prevent himself from being attacked by pointing the attack which he has caught to another direction. A catch which twists or drags the opponent is forbidden. Also, a catch which could break the part which is being held such as the leg and waist is also forbidden. These regulations exist to protect the silat exponent's (Anuar, 1993).

5. **Topple**:

   There are various ways of toppling down one's opponent. For example, a silat exponent '*pesilat*' can either push, shove the opponent's back leg from the bag or from the side, shove, hit, kick, strike or punch to make the opponent lose his balance. Every fall is considered valid as long as the silat exponent topples his opponent down without wrestling or he is able to overpower the opponent whom he has brought down (Anuar, 1993).

6. **Sweep**:

   Swiping 'sapuan' involves attacking an opponent's leg which are on the ground to unstabilise him and bring down to the ground. A silat exponent can perform this attacking movement either with his right or left leg, Hence, front sweep '*sapuan depan*' is done by swinging the leg to the front to push an opponent's front leg, while back sweep '*sapuan belakang*' is carried out by swinging the leg backward to hit the back leg (Anuar, 1993).

7. **Evade/Dodge**:

   The evade '*elakan*' technique is carried out by silat exponent when he tries to evade an attack. This technique does not require the silat exponent to touch the opponent in fending off the attack. They are many ways of carrying out his defensive movement such as dodging '*gelek*', retreat '*mundur*', evasion to the side '*elak sisi*', bending '*elak serung*', jumping 'lonjak', ducking '*susup*' and etc. (Anuar, 1993).

8. **Self-Release**:

Self-release '*lepas tangkapan*' technique is a technique to unlock any clinch or catch from an opponent (Anuar, 1992).

9. **Block and Punch**:

The blocking technique is used to block any hand or leg attack from the opponent and followed by counter attack using the hand to punch the opponent.

10. **Block and Kick**:

The blocking technique is used to block any hand or leg attack from the opponent and followed by counter attack using the leg to kick the opponent.

11. **Block and Sweep**:

The blocking technique is used to block any hand or leg attack from the opponent and followed by counter attack using sweeping technique to the opponent.

12. **Fake Punch**:

An action which a silat exponent intends to confuse the opponent using a fake punch to break his opponent's defensive posture.

13. **Fake Kick**:

An action which a silat exponent intends to confuse the opponent using a fake kick to break his opponent defensive posture.

14. ***Others***:

Both silat exponents are either in posture position '*sikap pasang*' or coming close to each other using silat step pattern '*pola langkah*'.

All the activities are considered high intensity except for *others* which at that time both silat exponents are in low intensity periods.

4.2.3 Reliability of Observation

The author analysed all the activities and simultaneously classified each change of motion in a single match. Two observations were done separated by 48 hours. It requires experienced silat practitioners to analyse the data as the movement of both exponents is fast, needing close inspection. The classification of movement was subjective with work being classified according to the instruction given by the referee.

4.2.4 Statistical Analysis

The observation generated data will be frequency counted, a method of recording in observational research in which the researcher records each occurrence clearly defined behaviour within a certain time frame (Thomas and Nelson, 2001). All the raw data generated by the FOCUS System was exported into Microsoft Excel Spreadsheet and then transferred into SPSS for more detailed analysis. Statistical analysis was conducted using Statistical Package for Social Scientists, version 14.0 (SPSS, Chicago, IL). A chi square test of independence was used to determine if there was a similar profile of actions performed by the red and blue contestant in the match. An alpha level of (p <0.05) was taken to show statistical significant.

4.3 Results

Table 4.1 shows the summary of the intra-operator reliability study revealed that the strength of agreement for the actions was moderate (*k*=0.44), the exponent performing the action was moderate (*k*=0.47) and the outcome of an action was fair (*k*=0.25). The action factors used were description of the action, the exponent performing the action and outcome of actions. Each of these reliability results was recorded in Table 4.2, Table 4.3 and Table 4.4. Table 4.2 shows the actions performed during the contest and their outcomes in the match. Table 4.3 shows the frequency profile of actions for the 2 contestants. A chi square test of independence revealed that the two contest acts performed a different profile of actions during the bout ($\chi^2_2 = 74.0$, $p < 0.001$) with the red contestant performing more kicks and less blocks proportionately than the blue contestant. A chi square test of independence also revealed no significant association between an action performed by a contestant and the previous action that was performed ($\chi^2_2 = 7.6$, $p = 0.108$). The red contestant performed 0.34 events per s of fight time while the blue contestant performed 0.33.

Table 4.1: Reliability of silat data (kappa).

Variable	**Intra-observer reliability**
Action	0.449
Exponent performing the action	0.469
Outcome of actions	0.253

Table 4.2: Frequency of actions and outcomes recorded during a silat match.

Action	Outcome				
	Hit elsewhere	**Hit Target**	**Miss Opponent**	**Not Available***	**Total**
Block		14			14
Block and Kick	8		1		9
Block and Punch		1	1		2
Block and Sweep	1				1
Kick	76	13	12		101
Fake Kick				6	6
Punch	4	28	2		34
Fake Punch				3	3
Self-Release		3			3
Topple		1	3	1	5
Sweep	1		4		5
Catch		3	2		5
Dodge				1	1
Others				48	48
Total	**90**	**63**	**25**	**127**	**237**

**Note*: Not available - means action that did not count as outcome by observer. *Others* – means low intesity activities.

Table 4.3: Frequency profile of the 2 contestants.

Exponent	Block	Kick	Other*	Total
Blue	5	76	35	116
Red	21	31	69	121
Total	26	107	104	237

Note: **'Other'** here refers to other activities than block and kick.*

4.4 Discussion

Table 4.2 shows that the 57% of the fight was comprised of kick and punch actions. However, the percentage of punches (82.6%) that hit the target was greater than percentage of kicks (12.9%). The data indicated that national silat exponent needs to be good both at punching and kicking. Even though the frequency of punching is lower than kicking, the high percentage of hitting the target showed that punching is the most successful action for a silat exponent to get a point in competition. Therefore, training should aim to develop punching ability and accuracy. However, it is important to know that any local muscular fatigue experienced during a match maybe more likely to occur in the lower limbs due to the large number of kicks performed in a short period of time. Aziz *et al.* (2002) also suggested that silat exponents possess high levels of anaerobic power capability of the lower body, which is supported by the high frequency of kicks reported in this study.

There were 20.3% of the 237 actions performed by the exponents were classified as *others* actions and would be classified as low-intensity activity. The remaining attacking and defensive actions were classified as high intensity activity. Study 1 (a) indicated that average work to rest ratio during a silat match is approximately 2:1. In the present study 79.7% of the actions or activities recorded were considered high intensity but in the real time the duration of low intensity periods maybe greater than high intensity periods that involved in the silat match. It can be assumed that anaerobic sources contribute to the metabolic demands during the work spent performing high intensity activity such as punching, kicking, blocking, dodging, catching, swiping and toppling. During the low intensity activity both of the silat exponents were deemed to be performing low activity actions such as "*sikap pasang"* posture or coming close to each other using silat step pattern "*pola langkah*". Anaerobic sources contribute a major amount of the total energy required during high-intensity burst, thus aerobic metabolic is vital during the low-intensity activity to allow recovery. The aerobic sources contribute to the metabolic demand during the *others* action (low-intensity action) in a round of silat (Table 4.2). Even though the break periods are the best time for recovery, the low intensity periods contribute to aid both exponents to recover from high intensity actions. Therefore, the aerobic system needs to be specifically developed to help aid recovery during the intermittent activity (e.g. replenish creatine phosphate).

Current study shows that there were significantly different fighting styles between the two exponents. The blue exponent was taller than then red exponent; and she used more kicks and was responsible for 76.0% of the kicks made during the fight (match won by the blue exponent). The red exponent produced more blocks and less kicks proportionally than blue contestant. The red exponent produced 80.8% for the blocks performed by the two exponents suggests the blue exponent was superior on this technique. The action profiling of both exponents showed that block is a common action in silat for defensive actions and kicking was the common action for striking. It was observed that during the match both of the exponents were good at the catching technique but failed to topple down the opponent. This is because both of the exponents were good in the self-release technique. Furthermore, the blue exponent was using the blocking technique more while receiving an attack from the red exponent which in this study was categorised as a kick technique. Thus, beside from silat techniques the results suggested successful silat exponents tended to demonstrate high upper body isometric strength (catch) and power (punch and block) and superior lower body strength and power (kicks), endurance (repetition of kicks) and speed (kick velocity). Aziz *et al*. (2002) reported that in comparison to judo and taekwondo athletes, the silat exponents have better explosive leg power and comparable ability to perform short duration high-intensity exercise in the lower body, which is similar with the current finding. Moreover, it is advised that exponents should be well trained in understanding the concept of distance in silat while receiving an attack. This is because failure to understand the concept may result in injuries (e.g. using blocking when the exponent should use dodge / evading technique) during the silat match. Thus, the need for limb speed (Schepens *et al*., 1998) for kicking and punching, better co-ordination to evade strikes and also other factors as aforementioned that influences movement patterns common to silat competition need to be taken into consideration. Therefore, it is important to develop skills that contribute to scoring points besides developing the metabolic systems that involved in silat competition.

4.5 Conclusions

Post-event analysis of hand notation indicates that the prototype system developed for this study can be used to record and evaluate a silat match. This study complemented with those of the broad work and rest study undertaken in the Study 1 (a). The current study has provided a great understanding of information for the silat by looking at the activity involved in competition. Both of the exponents performed more high intensity actions than low intensity actions (i.e. the frequency count). However it is important to understand that high intensity actions will contribute more in the score points (i.e. outcome that count) rather than low intensity actions. There is also a range of frequency in attacking and defensive activities used by both of the exponents. The winner (blue exponent) used more kicks than the loser which may reflect greater skill or fitness or both. However, it is still doubtful that these are the only factors that influence the match. It is recommended that future studies determine the full range of activities performed with movement classifications and the variation of strikes that contribute to losing and winning the match.

It is recommended that those developing conditioning elements of training programmes for silat athletes are aware of the frequency and spread of durations of action and rest periods within action periods. The implication from a coaching perspective of the types and frequencies of strikes used would suggest that in training, a large proportion of time needs to be utilised in development of kicking and blocking as well as the conditioning of lower limbs in order to absorbs strikes and resist fatigue during a match to being able to defend and counter attack effectively.

There is a limitation of this case study as the findings here only represent one silat match, so the findings cannot be generalised to all silat competition. However, the purpose of this study was to develop a system for monitoring actions during a silat match (and not establishing normative data). Furthermore, the system developed is used later in the thesis (Study 4). This was the first study to provide descriptive detailed information of a silat match, increasing the knowledge base and providing a methodology that can be used in future research and by coaches. Furthermore, the other sports where the frequency and duration of high intensity activity periods fail to provide sufficient information to fully characterise the demands of the sport.

CHAPTER FIVE

Study Two: The Physiological and Performance Characteristics of Youth Silat Performers

5.1 Introduction

A comparative study on youth sport in 20 countries around the world has indicated that in most countries martial arts are among the most popular extracurricular sports that are practised by youths aged between 10 and 15 years (De Knop *et al.*, 1996). There are an estimated 75-120 million children and adults worldwide participating in martial arts with an estimated annual growth of 20-25% (Birrer, 1996). Many studies indicate the physiological benefits of participating in martial arts, which will help in increasing strength, anaerobic capacity, balance and flexibility (Hain *et al.*, 1999 and Zehr *et al.*, 1997). With five combat sports (taekwondo, judo, boxing, freestyle wrestling and Greco-Roman wrestling) already included in Olympic Games, the importance of determining the physiological parameters of combat sports which relates to competitive performance are critical to provide coaches with the knowledge to develop elite athletes. For instance in taekwondo, Heller *et al.* (1998) demonstrated that experienced taekwondo performers had lower percentage (%) body fat as well as higher aerobic endurance and better flexibility than less successful performers. Others have also confirmed that elite taekwondo athletes may be characterized by low body fat and well-developed aerobic endurance (Bouhlel *et al.*, 2006). While, Markovic *et al.* (2005) found higher explosive leg power, aerobic endurance and flexibility in successful female Croatian elite taekwondo exponents. Table 2.08 (pp. 60) shows details of physiological and performance tests used to profile the fitness of athletes involved in martial arts.

Despite numerous studies investigating the physiological demands and characteristics of martial arts, there is little known about the demands of silat. Although the number of participating countries that are involved in the world championship is increasing, it is surprising there is a lack of research that has examined the physiological characteristics of silat. In a review of applied research of many combat sports all over the world such as taekwondo (Thompson and Vinueza, 1991; Pieter, 1991 and Heller *et al*, 1998), wrestling (Yoon, 2002), judo (Callister *et al.*, 1991 and Thomas *et al.*, 1989) and boxing (Khanna and Manna, 2006; Guidetti *et al.*, 2002) there was only one paper that specifically focussed on profiling silat exponent's fitness (Aziz *et al.,* 2002). The authors characterised silat competition as placing high demands on aerobic and anaerobic responses but the conclusions concerning the contribution of various metabolic pathways requires more detailed explanations. A comparison with judo and taekwondo athletes showed that silat exponents achieved better explosive power and ability to perform short duration high-intensity movement in the lower body but possessed a lower grip strength, aerobic fitness, and anaerobic upper body capability (Aziz *et al*,. 2002). The distribution of fight time and break time of international silat competition has been examined in Study 1 (pp. 99-112). Study 1 also indicated that 62.6% of a single match was spent in fight time with 30 action periods, the mean duration of fight period was 15.3 s with mean duration of break periods of 8.4 s. This suggests that silat exponents are accustomed to numerous periods of high intensity action alternating with briefer, lower intensity movements. This information supports the research of Aziz *et al.* (2002) and the nature of silat competition; which requires silat exponents to develop both their aerobic and anaerobic systems to compete at an international level. Study 1 (pp.112-126) describes in detail the activity that occurs during a silat fight. Study 1 found that 57% of the actions were accounted for by kick and punch actions in a silat match. This indicated that a good ability of kicking and punching are important for contestants involved in silat competition, revising well developed local muscle endurance. Moreover, the ability to recover from high-burst intensity actions, particularly during the off-fight periods will aid recovery for the next high intensity action. The results of Study 1 showed 37.8% of the match consists of *off-fight contact actions*. This also supports the work by Aziz *et al.* (2002), highlighting the importance of high aerobic fitness for rapid recovery from bursts of high-intensity anaerobic efforts. The above factors need to be considered when designing appropriate test batteries to monitor the fitness of silat exponents; this would include the need to test the upper and lower body, explosive ability, local muscular endurance and the ability to recover during brief recovery.

As the previous study on silat focuses on adult population there is currently no information available on the youth silat. There are no previous studies on the fitness characteristics of youth silat performers although several other studies have produced information on youth physical demands and characteristics in other combat sports (Khanna and Manna, 2006; Heller *et al.*, 1998; Noorul *et al.*, 2008). For instance, Suzana and Pieteer (2006) reported that there was an improvement in sit up and 90° push-ups in young Malaysian taekwondo athletes following a period of training. An appropriate fitness test battery would be needed for benchmarking fitness, evaluating training and monitoring sport-specific developmental changes during growth and maturation. Erie *et al.* (2007) found boys to have greater aerobic endurance (49.03 $mL \cdot kg^{-1} \cdot min^{-1}$) than girls (39.54 $mL \cdot kg^{-1} \cdot min^{-1}$) even after controlling for height (48.40 $mL \cdot kg^{-1} \cdot min^{-1}$ versus 40.17 $mL \cdot kg^{-1} \cdot min^{-1}$) in recreational adolescent taekwondo. It has also been noted that senior boxers have greater back and grip strength compared to junior athletes; this has been attributed to a higher body mass and strength training history (Khanna and Manna, 2006). Nonetheless, the research in youth martial arts is sparse and it appears to be non-existent in silat.

Understanding the demands of silat is important to allow the identification and development of suitable physiological tests, which can then be used to track the fitness development and trainability of youth silat performers. Understanding the physiological demands in silat tournament is an important part of identifying possible factors that influence the athlete's performance in competition. Moreover, Study 1 identified the work and rest rates and movement patterns during silat match, helping to characterise the demands of the sport. Performance and physiological responses can be monitored during actual fight or with field and laboratory protocols. The problems of collecting the physiological data during a fight, together with the unpredictable nature of martial arts match, have led to investigations being mostly based on standardised protocols (Table 2.08) that characterise fitness (rather than physiological responses during competition).

Reliability is the ability of a test to produce consistent and repeatable results (Hopkins, 2000). Tests with proven reliability can reflect even slight changes in performance when evaluating a condition programme. If a test is unreliable, differences in its results may reflect only the variation of the test and not the effectiveness of the training programme (Hoffman, 2006), or improvement due to growth or maturation. The validity of having field testing is high and field based protocols can allow the testing of many participations simultaneously (MacDougall and Wenger, 1991). While, the advantage of laboratory testing is that it provides a controlled environment in which to measure performance variables such as force, speed, power, and isokinetic strength (Winter *et al.*, 2007). The complexity of trying to recreate the demands of a silat match in the laboratory presents a number of problems and as a result such research in this sport is very limited. In order to enhance the sensitivity of the test, the results should be obtained from a situation which is as similar to competition as is practical. This may be especially important for a sport like silat where the pattern of movement adopted during the match is highly specific and cannot be simulated on any ergometer.

The information in Table 2.08 (pp. 60) provides useful information regarding the types of tests that are typically used to assess fitness characteristics in various martial arts. This includes several important aspects of fitness that may contribute to performance, such as endurance, upper and lower body strength, speed on striking and defensive actions and also the agility of evading strikes from the opponent. Several standard protocol have previously been used when profiling martial arts; $\dot{V}O_2$ max test, handgrip test, push-up test, jump test, modified seated arm crank Wingate and cycle Wingate test (Table 2.08). These fitness protocols have been widely used in taekwondo, judo, boxing and others (Thomas *et al.*, 1989; Khanna and Manna, 2006; Guidetti *et al.*, 2002; Heller *et al.*, 1998). However, the relevance of some of these tests may be questioned. Adequate aerobic power is indispensible because it enables relatively fast recovery between rounds and fights in taekwondo competition (Markovic *et al.*, 2005). High aerobic power also facilitates faster recovery during and after a training session (Aziz *et al.*, 2002; Markovic *et al.*, 2005). However, the scores of $\dot{V}O_2$ max are unremarkable in martial arts and do not distinguish between competitive standards. Krustrup *et al.* (2003) reported that the Yo-yo intermittent test performance was a more sensitive measure for variations in soccer performance than $\dot{V}O_2$ max. This is supported by the finding that the top-class soccer referees improved their Yo-yo test performance by 31% and the amount of high-intensity running during competitive matches by 23% after 8-week of intense intermittent exercise training, with negligible change in $\dot{V}O_2$ max (3% increase) (Krustrup and Bangsbo, 2001). This suggests the intermittent nature of the yo-yo test reflects the intermittent nature of soccer or martial arts (as mentioned in Study 1) and the need to use oxygen to recover between high intensity bouts. Jacob (1986) reported that several authors have found that $\dot{V}O_2$ max, as determined in laboratory conditions, is less sensitive to changes in endurance fitness than the assessment of blood lactate concentrations at sub-maximal intensities. Also, the difficulties of finding the required facilities and expertise might limit the coaches' ability to directly determine their athlete's $\dot{V}O_2$ max. Thus, the Yo-yo intermittent test appears a better choice to determine an athlete's endurance performance given the intermittent nature of a silat fight and the requirement to use the aerobic system to recover between bouts of intense exercise. The test has a high reproducibility and sensitivity, allowing for detailed analysis of the capacity of athletes in intermittent sports with a test-retest *CV* for the yo-yo intermittent recovery test of 4.9% (Krustrup *et al.*, 2003). Similar findings were reported in competitive basketball, which is also an intermittent high-intensity sport (Stone and Steingard, 1993 and Stone and Kroll, 1991). A study by Castagna *et al.* (2008) showed the of yo-yo intermittent test as a valid field-test to assess aerobic-fitness and game preparedness of basketball players. Therefore, the evidence supports the fact that yo-yo test as a reliable and valid measure of aerobic power in intermittent sports.

The medicine ball throw test has been used to measure upper body explosive muscle power (Malina *et al.*, 2005; Solania *et al.*, 2004; Szymanski *et al.*, 2007; Faigenbaum *et al.*, 2006; Stockbrugger and Haennel, 2001). The medicine ball throw is expected to have high ecological validity due to the involvement of punching in silat (Study 1) and that is reliable (Stockbrugger and Haennel, 2001; Davis *et al.*, 2008). The reliability of other field-based fitness tests that have been reported elsewhere; handgrip test (Clerke *et al*., 2005) in teenagers aged 13 to 17 years, vertical jump (Aragon-Vargas, 2000; Hespanhol *et al*., 2006) in university students (N = 52, mean age = 20.2 ± 2.1) and adults (N = 18, mean age = 25.74 ± 4.71 years), and push-ups test (Baumgartner *et al.*, 2002; McManis *et al.*, 2000; Wood and Baumgartner, 2004) in college-aged students. The results from the Study 1 showed that more kicks are used in a silat match compared to punching, while it is also clear that the movement patterns in silat are unique (compared to other martial arts). Thus, it is necessary to test not only generic athletic abilities but also physical abilities and movement patterns that are specific to the sport of silat. As no silat-specific tests exist it is necessary to develop tests to measure the typical movement patterns and the kicking ability specific to the sport of silat.

Not much is known about the physical and physiological characteristics that distinguish younger and older silat competitors, or how these develop with age and maturation. The available literature on adult silat competition suggests that the sport is characterised by brief, high-intensity bouts of activity, short recovery periods and the need for competitors to repeatedly punch, kick and grapple with their opponent (Aziz *et al.*, 2002; Study 1). This suggests that a variety of attributes, such as upper and lower body strength, speed and power, co-ordination, resistance to fatigue and the ability to recover would all be desirable traits. Identifying sport-specific fitness trends across youth silat performers will enable identification of those traits which are most important to performance, helping to inform training. Moreover, a reliable and valid battery of tests is required in order to be able to test silat athletes. More importantly (in the context of silat research), the above is needed to measure how fitness develops in youth silat athletes. Compared to other age ranges in childhood development, the author is focusing on aged of 13 to 16-year-old athletes in current study. This is an intermediate age range for silat which represents the adolescents years when large performance changes are expected to occur. Moreover, the theory of accelerated adaptation and trainability, as promoted in the long-term athlete development model of Balyi and co-workers (2000, 2003, 2004), also suggests that when there is a naturally occurring rapid increase in fitness, a child will be most responsive to training that particular component of fitness. This increament will be useful in identifying what are the most distinguishing fitness components of silat and whether there are any particularly important periods during development (such as accelerated adaptation to help identify periods when children might be more sensitive to training). With a detailed battery of fitness tests it would be possible to profile the fitness of youth silat exponents, providing information that does not currently exist. Therefore, exploratory research is needed to further understand the components of fitness important for silat and how these develop throughout childhood.

5.1.1 Aims of The Study

The aim of the study was to profile the fitness characteristics of both male and female youth silat athletes aged between 13 and 16-year-old.

Specific aims of the study were:

- To establish the reliability of newly developed silat-specific fitness tests.
- To profile the development of male and female youth silat performers with the respect to age, maturation, and physical fitness.

5.2 Methodology

5.2.1 Participants

Participants actively participating in silat activities as co-curriculum activities in school under the management of Pusat Cemerlang Silat, Malaysia were approached to participate in the study. All information letters and assent forms outlining the study details and scope of the child's involvement were handed out to the children. Written informed assent was obtained from child as well as the consent of the the parent/guardian. None of the participants reported injury at the time of testing, and all were involved in regular silat training. One hundred and seventy eight participants (96 boys and 82 girls), aged from 13 to 16 years volunteered and submitted assent forms and parental consent to participate in the study. Participants attended two test sessions in which they completed various tests of general and silat-specific fitness. Participants were asked to wear their silat uniform with footwear and to avoid drinking, eating and participating in any exercise activities up to two hours before testing. All the testing methods and procedures were granted ethical approval by the University Research Ethics Committee. Participants were divided into age groups based on their chronological age and school year.

5.2.2 Procedures

All participants participated in 1 introductory training session a week before the testing procedures. During this time, they were taught the proper technique (i.e. controlled movements and body positions) on each testing exercise, and any of their questions answered. All participants were required to attend 2 sessions of fitness testing with a minimum of 48-hours between each session (Figure 5.1).

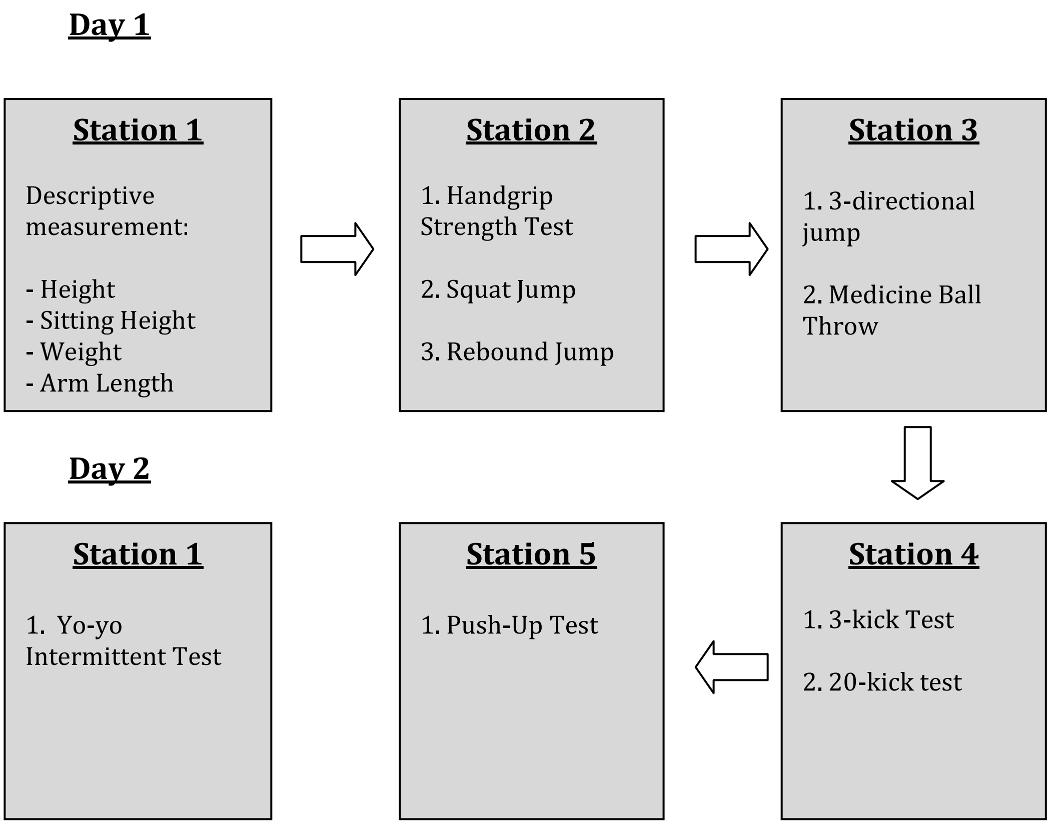


Figure 5.1: Schematic diagram representing fitness protocols in day one and two.

On the first session all the participants were required to undergo measures of body size and completed upper body strength test using a grip strength test, lower body concentric strength (squat jump) and power (rebound jump), agility co-ordination (3-directional jump) and upper body power (seated medicine ball throw) type tests. Then the sport-specific speed kicks test (3- and 20-kick test), and muscular endurance test (push-ups) were measured. On the second session all the participants were required to complete yo-yo intermittent endurance test level one. A warm-up session consisting of 10 minutes of low to moderate intensity aerobic exercise and calisthenics was performed prior to testing. At the end of the testing session, participants performed 5-10 minutes of static stretching exercises.

5.2.2.1 Height, Sitting Height, Weight, Arm Length and Peak Height Velocity

Height and sitting height (sitting mode) were measured to the nearest mm using a mobile stadiometer (SECA Leicester Height Measure Vogel & Halke, Hamburg, Germany). For standing height, participants removed their shoes. Stature was measured with the participant instructed to stand straight up looking straight ahead while holding a deep breath. The sitting height measurement was taken from the highest point on the head to the base sitting surface. The participant sat on the table with both feet hanging freely and positioned his or her back and buttocks to the backboard of the stadiometer. The lower back and shoulders should against the stadiometer, looking straight ahead. The measurement of the length of leg can be measured by subtracting the sitting height from the standing height (Simmons, 2000). To measure body mass the participant stood with minimal movement with hands by their side. Body mass was measured using a digital scale (SECA- Model 770, Vogel & Halke, Hamburg, Germany). While, for arm length measurement the participant stood straight with the arms hang freely by the sides of the trunk with palm facing the thighs. A tape measurement (Body Tape Measure, Power System, USA) was used to measure the arm length from the point of the shoulder (acromium) to the tip of the little finger.

As age of PHV is the most commonly used indicator of maturity in longitudinal studies of adolescence (Malina and Bouchard, 1991), it provides an accurate benchmark of the maximum growth during adolescence and provides a common landmark to reflect the occurrence of other body dimension velocities within and between individuals. By using the age of PHV as the maturational benchmark, each measurement occasion was described as years from PHV by subtracting the predicted age of PHV from the chronological age at each measurement occasion. The difference in years was defined as a value of maturity offset (Mirwald *et al.*, 2002). The biological maturity was assessed noninvasively by incorporating measures of age, body mass, standing height, and sitting height into a regression equation to calculate the age from peak height velocity (PHV). This method was chosen owing to its measurement accuracy (standard error of estimate $\pm$ 0.592 years), and the non-invasive nature of the technique, deemed beneficial when assessing maturational status in children (Roche *et al.*, 1988). In male, maturity offset = - 9.236 + 0.0002708 * Leg length and sitting height interaction - 0.001663 * age and leg length interaction + 0.007216 * age and sitting height interaction + 0.02292 * weight by height ratio. In female, maturity offset = - 9.376 + 0.0001882 * Leg Length and Sitting Height interaction + 0.0022 * Age and Leg Length interaction + 0.005841 * Age and Sitting Height interaction – 0.002658 * Age and Weight interaction + 0.07693 * Weight by Height ratio (Mirwald *et al.*, 2002).

5.2.2.2 Upper Body Strength Test

The handgrip strength test was carried out to assess isometric strength of the upper body using an electronic dynamometer (T.K.K. 5401 Takei, Tokyo, Japan) with standardised protocols (American Collage of Sport Medicine, 2010). The participant adjusted the grip bar to fit comfortably within the hand so that the second joint of the fingers was bent to grip the handle of the dynamometer. Before the test begins, the handgrip dynamometer was set back to zero. The subject was asked to hold the dynamometer parallel to the side of the body. The elbow should be flexed 90°. Then the participant squeezed the handgrip dynamometer as hard as possible with care not to hold their breath (Valsalva maneuver). It was optional if the subject wished to extend the elbow however any movement of other body part was not permitted. The measurement of grip strength was recorded and repeated using the opposite hand. The subject was given three trials for each hand, with the highest measurement taken as the grip strength for that hand (N).

For the seated medicine ball throw the participants were given 3 trials in which they attempted to throw a medicine ball as far as possible using the procedures previously described by Faigenbaum *et al.* (2006) with a population of 6-12 year old children. The children were given 2 trials to practice the throw, before being given 3 trials to throw with 1 to 2 minutes rest between each throw (Davis *et al.*, 2008). The subject sat with their back to a wall facing the area to which the ball is to be thrown with the feet extended and slightly apart. They were instructed to throw the ball as far as they could with both hands (similar to a chest past) without any trunk movement. The back should remain in contact with the wall at all times. Before each toss, the ball was coated with magnesium carbonate (e.g., weightlifting chalk) so that when the ball landed on the floor, it left a distinctive mark allowing for a precise measurement. Each throw was measured for distance (cm) from the wall to the marked sign of the throw. The seated medicine ball throws were performed using 2-kg rubber medicine ball (HeavyMed, Gr 2000 Gymnic, Italy) for females and 3-kg rubber medicine ball (Jordan, 3 kg Jordan Fitness, United Kingdom) for males (Loko *et al*, 2000; Roetert *et al.*, 1996).

The push-up test was administrated with the participant positioned with the lower body weight on the toes and the hands shoulder width apart. The participant worked in pairs; whilst one performed the test their partner counts the 90° push-ups and observes the technique of the participant being tested to ensure the elbow is flexed to 90° and the upper arm parallel to the floor at the lower point of push-up (Marilu and Gregory, 2007). The participant pushes up with the arms extended, keeping the legs and back straight. The arms must be completely extended and the body kept in alignment to be counted as a complete press-up (Roetert *et al.*, 1996). The back should be kept in a straight line from head to toes throughout the test. The participant then lowered the body using the arms until the elbows are flexed to a 90° angle and the upper arms are parallel to the floor. The movement is repeated as many times as possible. While for female participants the modified “knee push-up” position was used (legs together, lower leg in contact with mat with ankles plantar-flexed, back straight, hand shoulder width apart, head up, using the knees as the pivotal point) (Hoffman, 2006). The test ended when the participant stopped or rested, did not maintain correct body position, did not extend the arms fully, or did not achieve a 90° bend at the elbow on at least two push-ups. The number of push-ups performed in 60 s or to failure if within 60 s was recorded.

5.2.2.3 Lower Body Strength and Power Tests

Squat jump and rebound jumps were assessed to determine the lower body concentric strength and power for silat participants. A mobile contact mat (Smartjump, Fusion Sport, Australia), and data instantaneously collected via a hand-held PDA (iPAQ, Hewlett Packard, USA) were used to measure the flight time (FT), contact time (CT), reactive strength index (RSI) and jumping performance during rebound jumping on a contact mat. Timing was accurate to 1 ms. For both jumps, participants were instructed to keep hands on the hips at all times thus avoiding upper body interference (Lees *et. al*, 2004); jump and land on the same spot; land with legs fully extended; and to look forward at a fixed position to aid balance. Both jumps were carefully monitored by the tester during each testing session.

The squat and rebound tests were administered following procedures previously described by Lloyd *et al.* (2009) for use in paediatric population. The authors found the modest reliability of the squat jumps height (7.47% $\leq$ *CV* $\leq$ 8.64%) and reactive strength index of rebound jumps (13.98% $\leq$ *CV* $\leq$ 14.24%). The squat jump was performed from an initial semi-squat (90 knee flexion), determined from visual inspection and once achieved, participants held the position for two seconds before jumping vertically for maximum height on the command of tester. In the rebound jumps, participants were required to lower themselves from an initial standing position to a self-selected squat position, followed immediately by a vertical jump on the command of tester (countermovement jump) followed by another four maximal rebound jumps. The rebound jump test involved participants performing four repeated maximal vertical jumps on the contact mat. Participants were encouraged to perform the eccentric phase of the jump as quickly as possible with the depth of the rebound phase being self-selected by the participant to maximise jump performance (Cormark *et al.*, 2008). Participants were instructed to maximise jump performance and minimise ground contact (Dalleau *et al.*, 2004). Within each testing session, participants were given three trials of the squat jump and rebound jump. The best trial of each test was subsequently used for further analysis. All jumps were performed on a mobile contact mat (Smartjump, Fusion Sport, Australia), and data instantaneously collected via a hand-held PDA (iPAQ, Hawlett Packard, USA). Data obtained from the contact mat enable calculation of the following variables:

- *Flight time (FT)*: The amount of time (s) between leaving and returning to the mat.

- *Jump height*: Calculated from the flight-time method as described by Flanagan and Comyns (2008):

  Jump height = (gravity*(flight time)^2) / 8.

  where gravity = 9.81 ms^{-2} and flight time is in seconds

- *Contact time (CT)*: The amount of time (s) the participant was in contact with the ground (Llyold *et al.*, 2009).
- *Reactive strength index (RSI)*: The ratio between jump performance and contact time (mm/ms) (McClymont and Hore, 2004), calculated during the maximal hopping test.

5.2.2.4 Endurance Test

The methodology of the Yo-yo intermittent endurance test level one (IE1) was similar to the Yo-yo intermittent recovery test utilised by Krustrup *et al.* 2003; Aziz *et al.*, 2005. The test consist of repeated 20-m shuttle runs back and forth between the starting, turning and finishing line at a progressively increased speed controlled by audio bleeps from a cd recorder (Jens Bangsbo, www.bangsbosport.dk). Between each running bout, the participants have a 5-s active rest period, consisting of 2 x 5 m of jogging. When the participants fail to reach the finishing line in time, the total distance covered is recorded. The Yo-yo IE1 starting speed is 8.0 km·h^{-1}. The test consisted of 6 running bouts of (2 x 20 m) at 8-10 km·h^{-1} (0-240 m) and another 30 running bouts at 10.5-11.5 km·h^{-1} (240-1440 m), where after the test continues with stepwise 0.5 km·h^{-1} speed increments after every 6 running bouts (i.e., after 1680, 1920, 2160 m, etc.) until exhaustion. The test was performed indoor on running lanes, marked with cones, having a width of 2 m and a length of 20 m. Another cone placed 5 m behind the finishing line marked the running distance during the active recovery period. Before the test begins, all the participants carried out a warm-up period consisting of the first four running bouts in the test. The total duration of the test was 6-20 min. All the participants were familiarized to the test by at least one pre-test. Participant's performance in the Yo-yo IE1 was defined as the maximum distance covered (Bangsbo, 1996).

5.2.2.5 Silat-Specific Kicking Speed and Agility Test

The methodology of these sports-specific tests was based on the nature of silat movements and ability to attack and defend in the competition. There were two fitness tests developed that mimics the kicking action and duration (as described in Study 1). Thus, as most of the silat points were scored with kicks, it is important to be able to monitor silat-specific kicking performance. One further test was also developed to test movement proficiency in a silat-specific context using a 3-directional jump test, reflecting the need for a silat exponent to evade their opponent.

3-Kick Test. A computer electronic timing system was used to measure kicking speed (via time) during a 3-kick test with a contact mat (Smartjump, Fusion sport, Australia). The 3 kicks were used to reflect the need to explosively repeat kick efforts in competition, where the number of repeated strikes allowed is limited. The subjects performed three rapid kicks against a kicking pad (target) held by the tester at chest height (of the participant, reflecting the target area of silat competition). The emphasis was on speed and the contact with the pad should be minimal. The contact mat was placed on the floor and timed periods when the kicking foot was and was not in contact with the mat, with the time taken from the initiation of the first kick to returning the foot to the floor after the final kick reflecting the total kicking time (via a hand-held

PDA, iPAQ, Hewlett Packard, USA). The dominant leg was used for kicking. A tester held the kicking pad approximately 1 m in front of the subject (based on the distance of attacking in silat match). The subjects were given several practice trials before undergoing the protocol, particularly to self-select the horizontal distance between themselves and the kicking pad to allow as quick a kicking action as possible. Before beginning kicking, the subjects were instructed that the foot of their stance leg should be in between the kicking pad and contact mat (Figure 5.2). The foot of the kicking leg should be touching the contact mat before and intermittently during the test. To commence the test participant stood in '*pasang*' position as per the beginning of a silat match and was given a command of '3-2-1-Go!. Simultaneously to the 'Go!' command the subject performed 3 kicks as rapidly as possible (front kick). The subject was given a total of three trials. The best trial for total time was used for the analysis. To prevent the contact mat from slipping during the kicks the mat was secured to the floor.

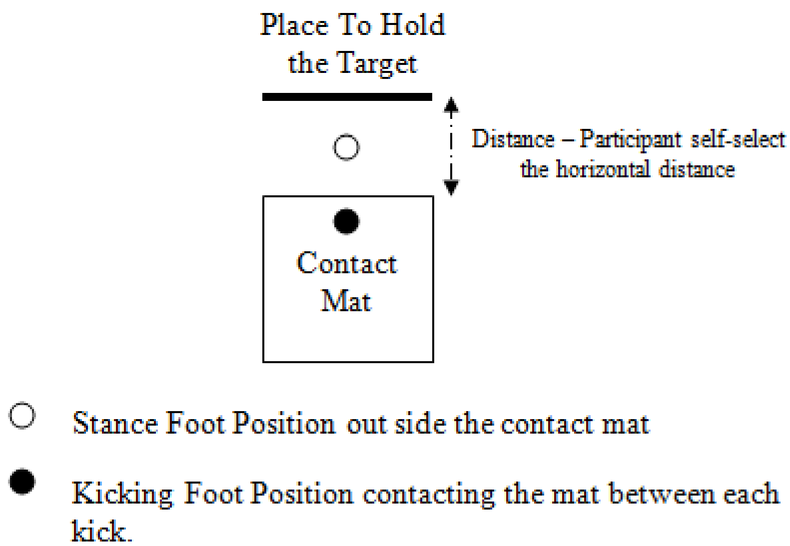


Figure 5.2: Schematic representation of the 3-kick test and 20-kick test.

20-Kick Test. The speed endurance 20-kick test procedure was similar to the 3-kick test, except 20 repetitive kicks were completed as quickly as possible. The 20 kicks were used based on the pilot testing which revealed the time taken to complete 20 kicks was similar to the average duration of work during silat competition (pp. 150). Verbal encouragement was given during the kicks to make sure the participants maintained their kicking rhythm. Participants completed three trials with a full recovery between trials (1-3 minutes). The best trial for total time was used for further analysis.

3-Directional Jump. The agility 3-directional jump (Figure 5.3) measures body awareness during jumping and the ability to move in different patterns of silat movements, which mimics evasive movements during a silat match. This test was designed to reflect the evading and attacking movement patterns observed in martial arts. This test covered the agility, balance and co-ordination of the athletes even though the primary objective was to determine the speed of the silat athletes to change direction. The test was performed on a flat non-slippery floor surface with approximately one metre distance between the centre of the contact mat (marked ‘a’ in Figure 5.3) with 3 other markers.

The participants start in the middle of a contact mat and performed lateral jumps to the left and right and a jump forwards and backwards whilst facing forward. The best trial for total time was subsequently used for further analysis. To commence the test participant stood in the middle of contact mat in the ready position and were given the command ‘3-2-1-Go!’. Simultaneously to the ‘Go!’ command the subject started to perform the 3-directional jump with both feet jumping (at least one feet over the marker) to marker 'A' and back to 'a' first, followed to marker B and back to 'a', and lastly to marker 'C' and back to 'a' for one complete trial (Figure 5.3). The subject needed to complete three trials for this test. Verbal encouragement and hand signals were given to help subjects to jump correctly to each marker during the jumps. Similar to the kick test, the contact mat was secured to the floor.

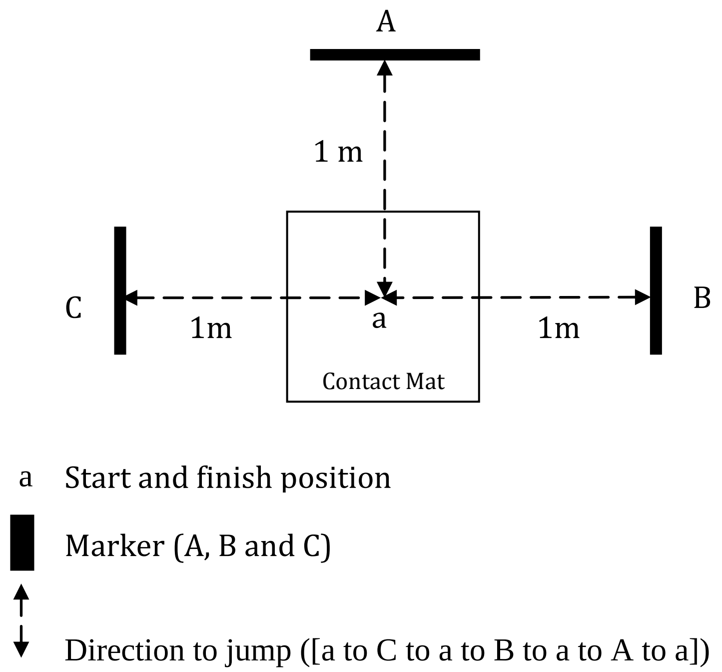


Figure 5.3: Schematic representation of the 3-directional jump test.

Most of the above tests represent standard functional tests routinely used within the literature. The 3-directional jump is a modification of other horizontal jump (National Sports Council, 1998) protocols. Tests of kicking speed are more unique and represent development of more specific measurement tools that can be used in a field testing. To examine the reliability of these test measures (3-directional jump, 3-kick and 20-kick test), forty participants were asked to attend one additional session and repeat these brief tests. The sample of participants involved in the reliability study consisted of 20 male and 20 female silat performers with a chronological age between 13 to 16-year-old. Within each testing session, participants were given three trials of the 3-kick, 20-kick and 3-directional jump test. The details of descriptive data for reliability study are presented in Table 5.1.

Table 5.1: Physical and characteristics of male (*N=20*) and female (*N=20*) youth silat that participated in the reliability study.

	Variable	Male (*N*=27)		Female (*N*=13)		Overall (*N*=40)	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Descriptive Data	Age (years)	13.6	1.1	14.23*	1.3	13.8	1.2
	Body Mass (kg)	46.8	12.6	46.9	6.3	46.8	10.9
	Arm Length (cm)	72.2	5.1	73.9	6.5	72.7	5.6
	Height (cm)	152.5	8.3	154.5	4.8	153.2	7.4
	Sit Height (cm)	75.8	4.7	76.3	3.4	76.0	4.3

*Significant difference between males and females ($p < 0.05$)

5.3 Statistical Analysis

Paired-Samples t-test and coefficient of variation (*CV*) were used to determine the reliability of the three silat-specific fitness tests (3-kick test, 20-kick test and 3-directional jump test) during the test-retest protocol. The paired samples t-test was used to assess any systematic bias. A mean *CV* was calculated to determine the amount of random variation for each performance variables across both trials. Data were reported as means and standard deviations. In the main study, a two way ANOVA using a 2 x 4 model (gender * age group) with Bonferroni post-hoc adjustment was used to determine the significant main (gender and age group) and interaction effects for all descriptive, physical and sport-specific fitness tests. Maulchy's test of sphericity was examined and were violated the Greenhouse-Geisser adjustment employed. All tests were significant at the 5% ($p \leq 0.05$) level. All statistical analysis of the data was carried out in SPSS © (Version 17.0); SPSS Inc, Chicago, IL).

5.4 Results

5.4.1 Reliability

Means ± SD and *CV* for total times are displayed in Table 5.2. Significant within trials differences were reported in the 3-kick test (decrease in trials 1-2, [all, $p < 0.05$]), whilst no significant differences in total time of 20-kick test and 3-directional jump test ($p < 0.05$). Moderate *CV* values were reported in total time of 20-kick test (*CV* = 6.83%) and 3-directional jump (*CV* = 9.00%). While, 3-kick test showed high *CV* value (> 20%).

Table 5.2: Means and *CV*s for flight times (FT), contact times (CT) and total times across all three fitness test variables.

Performance Variables	Mean Results		Statistical Analysis
	Trial 1	Trial 2	*CV* (%)
3-Kick Test			
- Total Time (ms)	2304 ± 992	1722 ± 330*	23.10
20-Kick Test			
- Total Time (ms)	14962 ± 1670	14729 ± 2262	6.83
3-Directional Jump Test			
- Total Time (ms)	3179 ± 550	3141 ± 349	9.00

*Significant difference ($p < 0.05$) between trials.

5.4.2 Physical and Performance Data

Descriptive statistics and fitness variables for the full sample spilt by gender are presented in Table 5.3. The statistical analysis showed that on average the female group were more mature and older than the male groups ($p < 0.05$). However, the descriptive data showed that male group was significantly taller in standing height than the female group ($p < 0.05$). The male groups were heavier than the female groups but this difference was not significant ($p < 0.05$).

Table 5.3: Physical and performance characteristics of male (*N=96*) and female (*N=82*) youth silat athletes.

Variable		**Male**	**Female**
		Mean ± SD	**Mean ± SD**
Descriptive Data	Body Mass (kg)	49.6 ± 12.7	48.1 ± 8.6
	Arm Length (cm)	72.8 ± 5.8*	71.1 ± 4.7
	Height (cm)	155.3 ± 9.3*	152.0 ± 5.4
	Sitting Height (cm)	77.0 ± 5.4*	75.9 ± 3.5
	Estimated age at PHV (years)	14.9 ± 0.7*	13.3 ± 0.6
	Years from PHV	-0.9 ± 1.1*	1.1 ± 0.7
General Physical Abilities	Handgrip Strength (N)	316 ± 77*	243 ± 39
	MedBall (cm)	259.98 ± 65.42*	238.20 ± 43.47
	Yoyo (m)	1134.71 ± 608.75*	684.39 ± 278.12
	Push- ups	29 ± 13*	26 ± 9
	Squat Jump (cm)	32.7 ± 7.50*	23.35 ± 4.73
	Rebound Jump		
	- best jump height (cm)	26.31 + 7.61*	20.72 + 5.01
	- best jump CT (ms)	343 ± 104*	286 ± 79
	- best jump RSI	0.73 ± 0.17	0.71 ± 0.16
Sport-specific Abilities	3-directional Jump (ms)	3101 ± 486	3126 ± 542
	3-kick Test (ms)	1999 ± 571	2191 ± 460
	20-kick Test (ms)	14881 ± 2298*	16311 ± 2291

*Significant difference between males and females ($p < 0.05$) **Handgrip Strength is the highest mean value of the left and right hand; MedBall=Medicine Ball throw distance; Yoyo = Yoyo Intermittent Endurance Test Leve1 1; CT=Contact Time; RSI=Reactive Strength Index (jump height/CT); PHV = Peak Height Velocity

For the combined sample, the means showed that males were superior to females in many of the fitness characteristics. Males were superior to females in grip strength, medicine ball throw, push-ups, squat jump, yo-yo endurance, rebound jump height and 20-kick performance (all, $p < 0.05$). However, the female group showed a shorter contact time in the rebound jump compared to the male group ($p < 0.05$). Consequently, there was no significant difference ($p > 0.05$) in RSI between the two groups. The medicine ball throw and push-ups test used gender specific protocols, which in this study showed that the magnitude of the difference was smaller than if both groups completed the same protocols. However, both medicine ball throw and push-up test were significantly different ($p < 0.05$) between male and female groups.

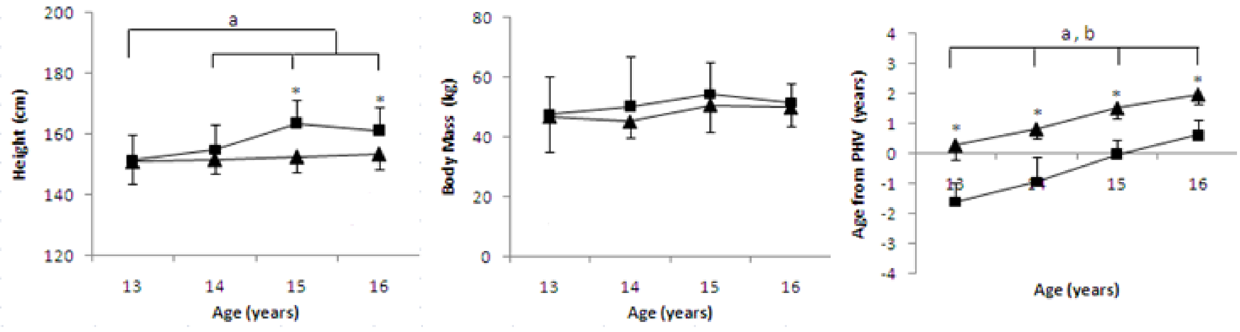
The major difference was in yo-yo endurance performance, where the males covered (on average) almost twice as much distance as the females.

Meanwhile, data from sport-specific abilities in silat showed that male groups have better agility and co-ordination in 3-directional jump performance compare to the female groups. The male group kicked faster than the female groups in 20-kick ($p < 0.05$) and 3-kick test. However, the differences in 3-directional jump and 3-kick test were not significant between the two groups ($p > 0.05$).

5.4.3 Age and Gender Effect on Size and Physical Performance

5.4.3.1 Height, body mass and age from Peak Height Velocity (*PHV)*

The results for standing height are shown in Figure 5.4 (A). The two-way analysis of variance revealed that there was a significant main effect of age on the standing height ($F_{3,\ 170} = 9.26$, $p < 0.001$). There was also a significant interaction effect between gender and age on standing height ($F_{3,\ 170} = 4.74$, $p < 0.05$). Post hoc testing showed that the standing height between males and females was significantly difference at 15 years ($p < 0.001$) and 16-year-old ($p < 0.05$), but was not significantly different at 13 and 14-year-old ($p > 0.05$). Post hoc tests also showed that the standing height for females increased by a small amount with increasing age, but any changes were non-significant ($p > 0.05$). Whereas, post-hoc tests showed there were significant differences in standing height between 13 and 14-year-old with 15 and 16-year-old groups in male silat exponents (all, $p < 0.05$).



A) Height B) Body mass C) Age from PHV

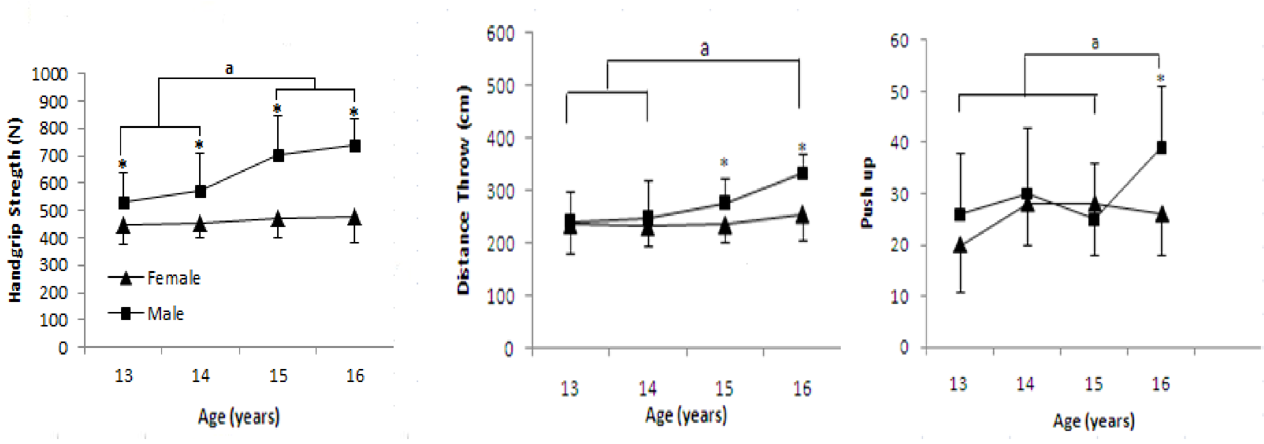
Figure 5.4: Results for (males ■ and females ▲) in (A) standing height; (B) body mass; (C) mean of years from PHV in silat athletes of different ages. *Significant difference between males and females ($p < 0.05$). [a]Significant difference across male age groups ($p < 0.05$). [b]Significant difference across female age groups ($p < 0.05$).

The results for body mass are shown in Figure 5.4 (B). There was a non-significant main effect of age on body mass ($F_{3, 170} = 2.14$, $p = 0.097$). The results also showed there was no significant interaction effect between gender and the four age groups on body mass ($F_{3, 170} = 0.365$, $p = 0.779$). The body mass did not increase with age in the females participants (Figure 5.5). Similarly with females any change in body mass with age in the male groups was not significant ($p > 0.05$).

Results for estimated age from peak height velocity (PHV) (Figure 5.4C) showed that there was a significant main effect of age ($F_{3, 170} = 105.997$, $p < 0.001$). Results showed there was no significant interaction effect between gender and age on years from PHV ($F_{3, 170} = 2.009$, $p = 0.115$). However, the post-hoc test showed that females were significantly more mature than males at each age group (all, $p < 0.05$). Post hoc testing also suggests there were significant differences between each age groups for both genders (all, $p < 0.05$).

5.4.3.2 Handgrip Strength Test, Medicine Balls Throws Test and Push-Up Test

Results for handgrip strength are shown in Figure 5.5 (A). There was a significant main effect of age on grip strength ($F_{3, 161} = 12.92$, $p < 0.001$). While, there was a significant interaction effect between age groups and gender ($F_{3, 161} = 6.73$, $p < 0.001$). The post-hoc testing showed that at each age there was a significant difference between the genders (all, $p < 0.05$). The post-hoc test also suggests that the grip strength of females did not improve with increasing age, with no significant differences between any of the age categories (Figure 5.5A). Conversely, the grip strength of males aged 15 and 16 year was significantly greater than that of those aged 14 years and below. There was an approximate 40% increase in grip strength from the youngest to oldest boys.



A) Handgrip B) Medicine ball throw C) Push-up

Figure 5.5: Results for (males ■ and females ▲) in (A) mean of best left and right handgrip strength; (B) best results for the medicine ball throw test distance; (C) number of push-ups completed by silat athletes of different ages. *Significant difference between males and females ($p < 0.05$). [a]Significant difference across male age groups ($p < 0.05$).

The results for the medicine ball throw test are shown in Figure 5.5 (B). Similar to handgrip strength, the two-way analysis of variance revealed that there was a significant main effect of age on the distance throw ($F_{3, 154} = 7.74$, $p < 0.001$). There was also a significant interaction effect between gender and age ($F_{3, 154} = 3.191$, $p < 0.05$). The post-hoc testing showed that the distance thrown by male and females was not significantly difference at 13 year ($p = 0.712$) and 14-year-old ($p = 0.328$), this is due to the gender-specific nature of the protocols, with the females throwing a lighter ball compared to the males but was significantly different at 15 and 16-year-old ($p < 0.05$). The post-hoc test showed the distance thrown by females did not increase with age, but any increases were non-significant. Males aged 16 threw the medicine ball significantly further than those aged 14 and below (all, $p < 0.05$), with an approximate increase in the distance thrown of 28% from the youngest to oldest groups.

Results of the push-up test are shown in Figure 5.5 (C), which show a large amount of variability about the mean scores. There was a significant main effect of age on the number of push-up in this muscular strength-endurance test ($F_{3, 162} = 5.593$, $p < 0.05$). There was a significant interaction effect between gender and age on the number of repetitions of successful push-ups in one minute ($F_{3, 162} = 2.751$, $p < 0.05$). Post hoc testing showed that the number of push-ups completed by males and females was significantly different ($p < 0.05$) at 16 year of age, but was not significantly different in all other age groups (all, $p > 0.05$). Similar with the results of medicine ball throw test, this finding is influenced by the gender-specific nature of this test (with females completing push-ups with their knees on the floor). Meanwhile, the post-hoc test suggests that the number of push-ups completed by females did not improve with increasing age, with no significant differences between any of the age categories

(Figure 5.9). Conversely, the number of push-ups completed by the males 16 year was significantly greater than 15 years and below.

5.4.3.3 Squat Jump and Rebound Jump

Results for the squat jump test are shown in Figure 5.6 (A). There was a significant main effect of age on the jump performance ($F_{3, 157} = 3.063$, $p < 0.05$). The result also showed there was a significant interaction effect between age and gender ($F_{3, 157} = 2.683$, $p < 0.05$). The post-hoc testing showed that the jump performance of males and females was significantly different ($p < 0.05$) at all ages. Moreover, the post-hoc test suggests that the jump performance of females did not improve with increasing age between any of the age categories (Figure 5.6A). Conversely, the jump performance of males aged 16-year-old was significantly greater than those aged 15-year-old and below. There was an approximate 20% increase in jump performance from the youngest boys to 16-year-old boys.

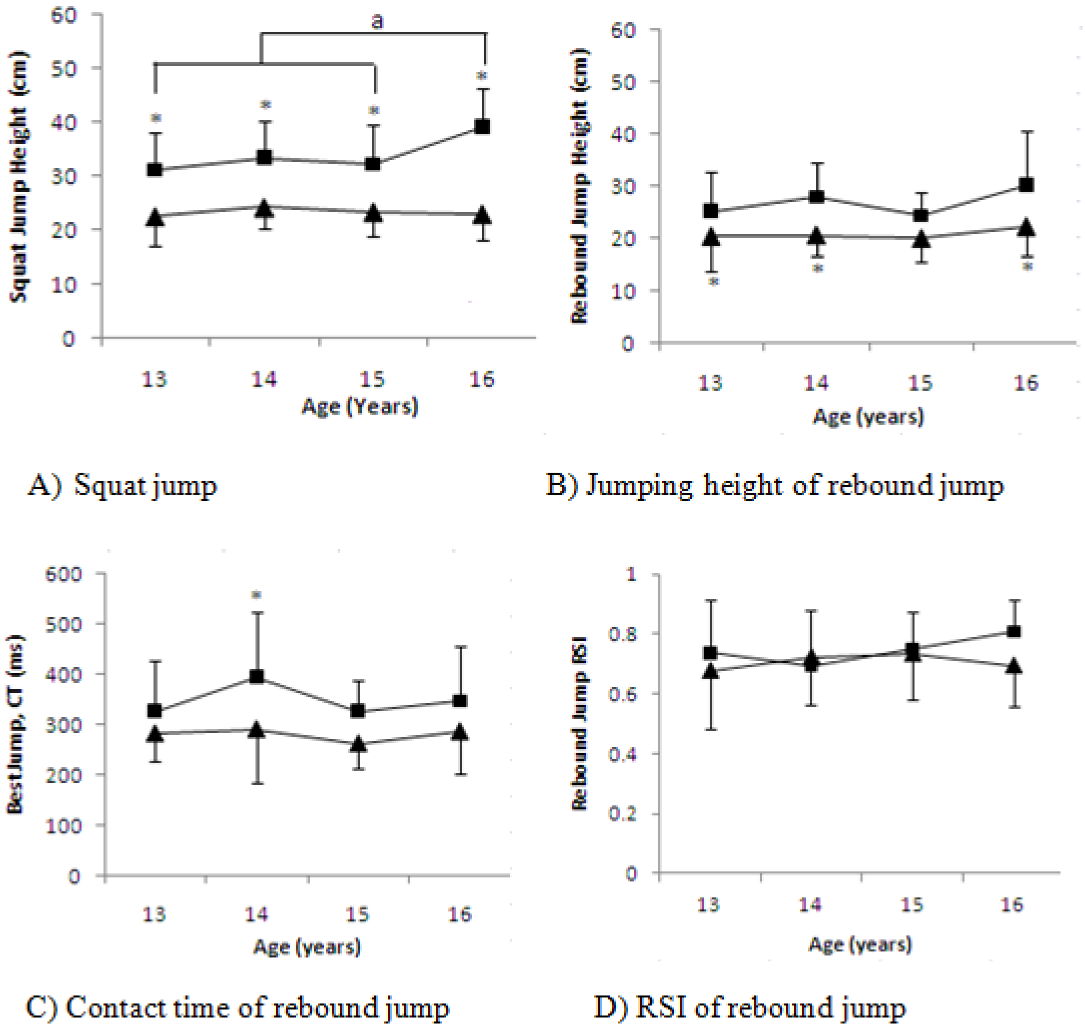


Figure 5.6: Results for (males ■and females ▲) in (A) squat jump performance; (B) best jump performance for the rebound jump test; (C) contact time during the rebound jump; (D) best reactive strength index (RSI) score for the rebound jump in silat athletes of different ages.*Significant difference between males and females ($p < 0.05$). [a]Significant difference across male age groups ($p < 0.05$)

The results for best jump performance during the rebound jump test are shown in Figure 5.6 (B). There was a non-significant main effect of age on the jumping performance (cm) ($F_{3, 149} = 2.378$, $p = 0.072$). There was also a non-significant interaction effect between gender and age ($F_{3, 149} = 0.634$, $p = 0.594$). However, the jumping performance for boys and girls was significantly difference at all age groups (all, $p < 0.05$) except at 15-year-old ($p = 0.068$). The jump performance of both male and female groups did not improve with increasing age, with no significant differences between any ages categories ($p > 0.05$) for both genders.

Results for contact time (CT) for the rebound jump are shown in Figure 5.6 (C). There was a non-significant main effect of age on the CT performance in rebound jump test ($F_{3, 149} = 2.062$, $p = 0.108$). There was also a non-significant main effect for the gender age group interaction ($F_{3, 149} = 1.005$, $p = 0.392$). The contact time of males and females was significantly different ($p < 0.05$) at 14-year-old, with no significant differences between any other age groups (all, $p > 0.05$). The CTs of females did not improve (lower CT = better) with increasing age, with no significant differences ($p > 0.05$) between any of the age categories. Similar to females any change in contact time in males group was not-significant ($p > 0.05$). Large variability in CT is evident for most age groups.

Results for best RSI during the rebound jump test are shown in Figure 5.6 (D). There was a non-significant main effect of age on the RSI of rebound jump test ($F_{3, 148} = 0.700$, $p = 0.553$). While, there was also a non-significant interaction effect between genders and the four age groups on the RSI score in this test ($F_{3, 148} = 1.065$, $p = 0.366$). The RSI scores of the female groups did not improve with increasing age, with no significant differences between any of age categories ($p > 0.05$) (Figure 5.6C). Male groups showed improvement in RSI score after the age of 14 years, but any increment was non-significant ($p > 0.05$). Analyses also showed that females tended to have shorter ground contact times (Figure 5.6B) and lower jump performances (Figure 5.6A) than the males, which explain the similar RSI values in both groups.

5.4.3.4 Yo-Yo Endurance Test Level One

Results for the yo-yo endurance test level one are shown in Figure 5.7. There was a significant main effect of age on the distance covered ($F_{3, 161} = 3.11$, $p < 0.05$). Also, there was a significant interaction effect between gender and age on performance ($F_{3, 161} = 3.68$, $p < 0.05$). The post-hoc testing showed that the distance covered by males and females was not significantly difference at 14-year-old ($p = 0.159$), but was significantly different between genders at all other age groups (all, $p < 0.05$). Moreover, the post-hoc tests suggest the distance covered by females did not increase with age, with no significant difference between any of the age categories (Figure 5.14). Conversely, the male group aged 16-year-old ran significantly further than those aged 13, 14 and 15-year-old (all, $p < 0.05$), with an increase in the distance run of 35% from the 13 to 16-year-old age groups.

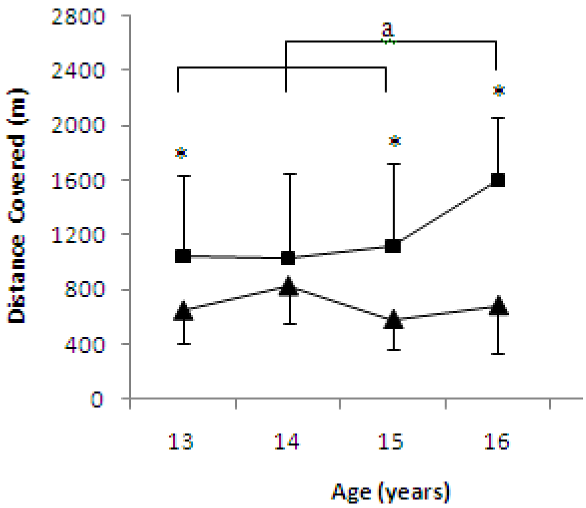
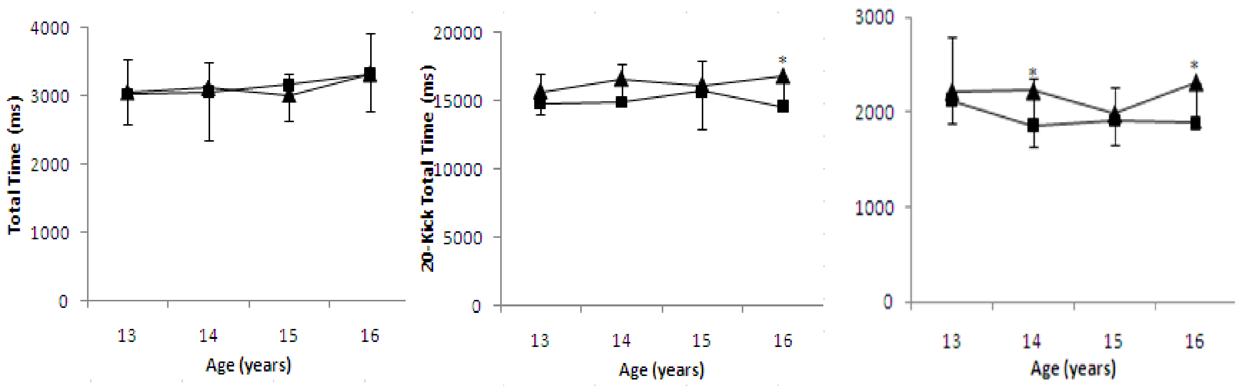


Figure 5.7: Results for (males ■ and females ▲) in distance covered for the yo-yo endurance level one test in silat athletes of different ages. *Significant difference between males and females ($p < 0.05$). [a]Significant difference across male age groups ($p < 0.05$).

5.4.3.5 Three-Directional Jump Test, Twenty-Kick and 3-Kick Test

Results for total time of the 3-directional jump test are shown in Figure 5.8 (A). There was a non-significant effect of age on total time ($F_{3, 137} = 1.906$, $p = 0.131$). There was also a non-significant interaction effect between gender and age ($F_{3, 149} = 0.193$, $p = 0.901$). The total time of females did not improve with age, with no significant differences between any of the age categories (Figure 5.8). Similarly, there was no improvement in jumping performance in males.



A) Three-directional jump B) Twenty-kick test C) Three-kick test

Figure 5.8: Results for (males■ and females▲) in (A) total time for 3-directional jump; (B) total time for the 3-kick test; (C) total time for 20-kick test in silat athletes of different ages. *Significant difference between males and females ($p < 0.05$).

Results of total time of the 20-kick test are shown in Figure 5.8 (B). Two way analysis of variance revealed that there was no-significant main effect of age on total time ($F_{3, 138} = 0.614$, $p = 0.607$). Also, there was a non-significant interaction effect between gender and age ($F_{3, 138} = 0.758$, $p = 0.520$). Result also showed that the total kick time of males was significantly better than females for the 16-year-old age group only ($p < 0.05$). The total time taken by both the females and the males did not improve with increasing age, with no significant difference between any of the age categories (Figure 5.8B).

Results for the total time of 3-kick test are shown in Figure 5.8 (C). Similar with 20-kick test, there was a non-significant main effect of age on the total time of 3-kick test performance ($F_{3, 135} = 1.021$, $p = 0.385$). There was also a non-significant interaction effect between age and gender on total time ($F_{3, 138} = 1.001$, $p = 0.395$). However, the total time of males and female was significantly different ($p < 0.05$) at 14 and 16-year-old, but was not significantly different at any other age group (all, $p > 0.05$). The total time taken by the males and females did not improve with increasing age.

5.5 Discussion

The present study found that some of the new proposed silat-specific variables were reliable. The overall results showed males tended to outperform females despite being less mature. Females did not show any change in performance for any variables. Measures of isometric strength (grip strength), upper body power (medicine ball throw) and endurance (push-ups), lower body power (squat-jumps), and endurance (yo-yo test) showed significant (all, $p < 0.05$) gains after 15-year-old in males.

5.5.1 Pilot Study of Reliability Data

The results of the pilot study demonstrate that a range of total times from the 3 different fitness test protocols exhibit different reliability results. The 20-kick test and 3-directional jump showed a modest reliability ($6.83\% \leq CV \leq 9.00\%$), whilst poor reliability was found in the 3-kick test total time ($CV > 20\%$). Mean total-kick-times in the 20-kick test and 3-directional jump test were the only variables possessing *CVs* below the 10% cut off used as a determination of test reliability (Cormark *et al.*, 2008;

Cronin *et al.*, 2004 and Hunter *et al.*, 2004). Due to the lack of previous research on the measurement error associated with kicking speed in martial arts, the moderate reliability values reported for both tests and the existence of some measurement variability are deemed important findings from the current research. Conversely, results for the 3-kick test suggest that poor reliability due to the high *CVs* and systematic bias reported for total time. This is likely to be partly due to a learning effect in this test, as observed from the signing decreases in kick time in the second trial. Therefore, it may be with more familiarisation reliability would improve in the 3-kick test.

The *CV's* for the 3-directional jump and 20-kick tests were similar to those reported in the previous jumping studies (Flanagan and Comyns, 2008; Lloyd *et al.*, 2009). Owing to differences in the mean age between the sample of the current study and that in Flanagan and Comyns (2008) suggests there may have existed age-related differences in motor control strategies during the jumping protocols. Lloyd *et al.* (2009) stated that both maximal and sub-maximal jumping tasks are whole-body; multi-joint activities that require high levels of motor co-ordination and that an immature neurophysiological status may lead to greater variability in test scores. This is supported by Gerodimos *et al.* (2008) and Harrison and Gaffney (2001), who supported that the variability in the performance of stretch-shortening cycle tasks is greater in younger participants and reduces as participants move towards adulthood. So, it is reasonable to expect that results tend to be more variable in younger populations as children continue to develop co-ordination (Lafayye *et al.*, 2005). Furthermore, the differences in the protocol involved in this research may also contribute to the lower reliability of the data, with the 3-directional jump protocol requiring repeated multi-directional jumps. Due to the tests being of a short nature, performing multiple trials will reduce the noise of tests, thus improving reliability (Pyne, 2004), without impinging on the time required to collect the data.

Test-retest results suggest that the 3-kick test is not reliable to measure kicking speed in youth silat population partly due to the existance of systematic bias. This situation reflects a learning effect between trials. Unfamiliarity with certain movement patterns or skills has a large effect on reliability. Hopkins (2000) reported that to avoid this bias, it is important to perform enough trials to make learning effects or other systematic change negligible before applying the intervention. Once the skill is learned, the reliability improves. Often in athletes with little to no experience in a specific-test, improvements in performance are rapid. These rapid improvements relate more to a learning effect than to any physiological adaptation (Hoffman, 2006). Unfortunately, as only test-retest data were collected it is not known if the learning effect was completed by the second trail, or if this effect would continue in further repeated trials. Thus, based on the statistical reliability results, it is concluded that the use of total time (ms) as the standard variable for this protocol was not reliable to measure kick-speed in a youth silat population. Using multiple trials would also be expected to improve the *CV's* and this approach should be considered in future.

5.5.2 Physical and Performance Characteristics Data

Data describing the physiological capabilities of young silat performers reflects the demands of the sport. The differences between male and female youth silat athletes in descriptive data (height, sitting height, and arm length) were significantly small. The normative data for North America and European youth showed that the expected mean age at PHV for girls was 11.6 – 12.1 years and 13.8 – 14.1 years for boys (Malina *et al.*, 2004). As there was no data published on the average age of PHV in Malaysian children, this study provides useful information regarding youth involved in silat. Compared to the normative data, the girls achieved PHV around 13-year-old and 15-year-old for boys in silat. Malaysian children maturing late may be due to nutritional status, sporting training history, activity level, hormonal secretions and genotype-environment interactions contributed to the current issue. However, the age from PHV is estimated from an equation that was constructed on a different population (silat population), so there might be some error when applying this to Malaysian children. However, the offset of 2 years between boys and girls for PHV is as expected. Additionally, the boys aged 15 shows increament in height suggesting they are likely to be around PHV as suggested by the PHV calculations. Maturation has been reported to explain a better percentage of the variability in muscle (maximal and static) strength than that in other motor performance tests that reflect neuromuscular maturation in children and adolescents (Beunen *et al.*, 1981 and Katzmarzyk *et al.*, 1997). However, Vaeyens *et al.* (2006) found that maturation had a marked effect on performance on almost the same physical tests when comparing Belgian elite, sub-elite, and non-elite youth soccer players aged 12–16 year, but the observed differences in height, body mass, and adiposity were much smaller. Since chronological age, maturation, height, and body mass are interrelated during puberty and adolescence; it is difficult to show their specific effects on performance on strength, speed, and other physical tests (Malina *et al.*, 2004).

5.5.3 Field Measures

The results obtained from the general physical abilities appear to show that the silat performers mean grip strength test from 13 to 16 years was similar with the descriptive data reported by Hoffman (2006) in youth baseball athletes. It was also reported that previous studies have shown no significant strength difference between genders at 7 to 12-year-old group (Blimkie, 1989; Faigenbaum *et al.*, 2003). However, based on this study there were significantly difference between the 13 to 16-year-old male and female silat athletes in grip strength. This is supported by Malina and Roche (1983) who explained the sex different in strength is consistent but small through childhood. With increasing age during adolescence, the percentage of girls whose performance on strength test equals or exceeds that of boy's declines considerably. After 16 year of age, few girls perform as high as the average strength of boys, and, conversely, few boys perform as low as the average strength of girls (Malina *et al.*, 2004). A study on an adult population showed that silat athletes' (Aziz *et al.*, 2002) mean absolute grip strength was 435 $\pm$ 79 N in males and 271 $\pm$ 58 N in females, which is substantially lower than scores for both genders in other martial arts (Heller *et al.*, 1998; Pieter, 1991; Little, 1991; Kim *et al.*, 1996 and Borkowski *et al.*, 2001). However, the result for the older students (16-year-old) in boys in this study was 391 $\pm$ 55 N and in girls 252 $\pm$ 51 N. This shows that at 16 year of age the grip strength of silat athletes is reasonably close to that previously reported in adult silat athletes and if results were expressed relative to some measure of size it is likely results across studies would be similar. Due to nature of silat competition, which is based on accumulating points to the winner rather than relying on a technical knockout, it may be argued that in silat, the need to tightly grip the opponent may not be as critical as in other martial arts (e.g. judo). This was particularly true as result from Study 1 showed only 5 from 237 actions were grappling. As the physiological and neuromuscular basis of changes in muscular strength during childhood and adolescence has not received much attention in martial arts, this study will help to describe the changes in physical performance with age during adolescence.

The push-up test was used in an attempt to describe muscular endurance performance in silat. Results showed that the boys outperformed the girls in push-up performance in the present study, when compared to normative data (Hoffman, 2006) the females were in the 80th-90th percentile (push-up bent-knees protocol) compare to the boys who were in the 50th-70th percentile (push-up protocol) except in 15 year old (in 25th percentile). Moreover, the push-up test showed high variability across groups of different ages. Even though there were gender-specific protocols, the results still show significant differences between male and female groups at 16-year-old. This is because the maximal gains in upper body power become significant only in the oldest age groups (16-year-old). This occurred on average after PHV in both sexes with estimated gain in boys was approximately twice as great as in girls (Malina *et al.*, 2005; Froberg and Lammert, 1996). The older group (16-year-old) outperformed the younger age (15-year-old and below groups) in push-up tests. It was speculated that less mature boys and girls were perhaps not able to tolerate acidosis on local anaerobic performance/fatigues resistance, particularly as the anaerobic pathway (e.g. anaerobic enzymes) development were not fully mature compared with older or more mature boys and girls. However, Inbar and Chia (2008) suggested that maturational changes in metabolic pathway that involved in maximal anaerobic exercise are more pronounced in male subjects than in female subjects.

In the medicine ball throw, male and female silat performers did not differ significantly in upper body test in 13-14 age groups, but did significantly differ at 15 and 16-year-old; males performed significantly better than female. However, due to the different protocols used in this study (boys threw 3 kg ball and girls threw 2 kg ball), results across gender are not directly comparable. It was suggested that the changes in upper body power occurred after the adolescent spurt in muscle mass increasing the performance in the male 16-year-old group. Malina *et al.* (2004) reported that the adolescent weight spurt in males includes principally gains in stature, skeletal tissue, and muscle mass. Thus, at 16-year-old, males were post-PHV, which is equivalent to peak weight velocity (PWV) reflecting the increased of muscle mass.

The pattern of the upper body performance in the handgrip strength and medicine ball throw tests showed that males performed significantly better than females in isometric and muscular strength, especially, when examined at an age of 16-year-old. This is likely to reflect the maturation process (Viru *et al.*, 1999); it is only by 16-year-old that the boys are post-PHV and likely to be getting peak strength development by benefiting from greater levels of circulation of testosterone (Viru *et al.*, 1999), which helps to improve upper body strength and power. The hormonal changes that accompany puberty lead to marked increases in strength in pubescent males because of the increase muscle mass particularly when testosterone production increases dramatically (Malina *et al.*, 2004, Viru *et al.*, 1999; Wilmore *et al.*, 2008). Qualitative factor (fibre type) may also be able to produce greater performance in adolescent. Inbar and Chia (2008) reported that greater superiority of type 2 muscle fibres in adolescence than in childhood may explain the increase of maximal anaerobic capability from childhood through adolescence.

The male silat athletes performed significantly better than female in explosive power of the lower extremities (squat jump) in each of different age groups and significantly better in the rebound jump performance (best jump during the rebound jump test) in 13, 14 and 16-year-old age group. Sex differences were only significant at 14-year-old in CT but not significant in lower body power in all age categories in rebound jump (best jump, CT and RSI). The results showed that the females tend to show no improvement or plateau in performance with advancing age. This is particularly because of changes with accumulation of fat mass during adolescence. Meanwhile, the boys tend to show an improvement when comparing the older groups to the younger group. Froberg and Lammert (1996) reported that less mature boys and girls were perhaps not able to maximally activate their muscles because the degree of the motor unit activation, which is dependent upon both the level of voluntary neural drive and the level of activation of recruited motor units, is diminished in comparison to older or more mature boys and girls, which may be seen in current squat jump performance of male silat athletes. It was also likely to be associated with maturational factors such as hormone development that leads to increased muscle mass and internal organ size (Viru *et al*., 1999) providing lower body strength benefits in more matured male silat exponents groups, respectively.

Sex differences in muscular endurance (Yo-yo IE1) were significant in 13, 15 and 16-year-old groups with male exponents covering more distance than female. The Yo-yo IE1 performance observed in this sample of male silat exponents 1119.6 $\pm$ 598.2 m (n = 101, mean age = 14.1 $\pm$ 1.3 years) was lower than those observed in junior handball players 1206.7 $\pm$ 365.2 m (n = 7, mean age = 15.3 $\pm$ 1.5 years) (Ho, 2007) and young trained soccer players 1676.0 $\pm$ 214.0 m (n = 21, mean age = 17.7 $\pm$ 0.4 years) (Aziz *et* *al*., 2005). However, due to the differences of the distance of active- rest period (players walked or jogged slowly around the 2.5/5.0 m marker back to the start point) at the end of 40 m run of yo-yo intermittent test in handball players and soccer players (2.5 m compare to 5.0 m to silat exponents), small size sample in handball players which results between groups unlikely to be significant and participants; a year (handball players) and three years (soccer players) older than present study it can be concluded that the results using Yo-yo IE1 and Yo-yo IE2 were actually quite similar. With the onset of puberty and the growth spurt, there will be a large increase in internal organ size (e.g. heart size and lung) and blood volume improving maximal oxygen uptake (aerobic power) and lung volumes. However, simultaneously girls will be impeded by the addition of a greater amount of fat mass. This gives a clear picture of the influence of maturation as one of the factors that influence endurance performance between female and male group in youth silat. In addition, it has been suggested that the improvement in older males is related to increased plasma volume, improved myocardial contractility, and more powerful skeletal muscle pump to augment ventricular filling (Rowland, 1997). Given the importance of high aerobic fitness for rapid recovery from bursts of high-intensity anaerobic efforts (Tesch and Wright, 1983), the present silat exponents may need to further enhance their aerobic fitness.

Speed in silat is based on the ability to rapidly kick, punch and evade an opponent. Thus, rather than using any other standard protocols that have been established the researcher established speed kick tests due to the high frequency of this activity (45%) during a silat match (Study 1). In the silat-specific kicking test (20-kick test) males were able to kick quicker than the females, but there was no age effect for either gender. Both tests did not distinguish any significant interaction across the gender or groups. Similar to the speed tests, the 3-directional jump was established to measure agility, co-ordination and balance motor skills in this study. This was based on movement patterns common to silat competition; when evading any attacks during the silat match. The study showed that 3-directional jump did not distinguish participants' speed, agility and co-ordination performance across gender or age groups. These may reflect similar findings of other; limb speed (i.e. step frequency) does not increase in sprinting in children (Schepens *et al.*, 1998). Moreover, RSI did not distinguish performance differences between age groups or gender. This could reflect the fact that this test is not specific to the demands of silat sports or may reflect developmental trends. Lloyd *et al.* (2011) showed that RSI significantly improved in boys up to the age of 13, but there were no significant improvements between 13 and 16-year-old. Reactive strength may be more related to neural development and chronological age than maturation (Balyi and Hamilton, 2000), with the majority of neural development (RSI) completed by 13 year of age in current study.

Some aspects of the present study need to put into perspective, particularly in youth martial arts fitness performance. Subjects in this study regularly participated in at least 4 - 6 hours of silat training a week. The present study showed that the physical abilities of boys was closely affected by the peak height velocity during maturation phase (Malina *et al.*, 2005; Papaiakovou *et al.*, 2009; Naughton *et al.*, 2000) while this was not the case for girls. The females achieved PHV at age of 13 which is 2 years earlier compared to the male silat exponents. The period between 15 and 16-year-old of age appears to be a critical moment for male silat performers in Malaysia to develop their potential to be elite exponents in future. Females did not show any improvement with age for any variable. Average performance of females in variety of motor task (handgrip strength, push-ups, medicine ball throws, squat jumps and others) did not improve after 13 year of age. By the youngest age group females were already at the time of PHV and had advanced maturation compare to the males. In early adolescence, the average performance in females has been reported to fall within one standard deviation of the averages boys (Malina *et al.*, 2004). In the present study there were significant differences between genders in a number of fitness tests (handgrip, medicine ball throw, yo-yo, push-ups, squat-jumps, jumping height and contact time of rebound jump, 3-kick and 20-kick test) but not all (reactive strength index of rebound jump and 3-directional jump). It was likely showed that the female silat exponents were impeded by the accumulation of fat during adolescence, even though this was not measured in this study. The flatness of performance curves during adolescences probably reflects an interaction of biological and cultural factors (Malina *et al.*, 2004) such as changing social interests and expectations, pressure from peers, and lack of motivation. Although being involved in silat did not enable female exponents to improve their fitness with increasing age or maturation, it did allow females to maintain their levels of fitness (with no significant decreases in performance). This may itself reflect a positive response, with some previous authors reporting a decline in the fitness levels of adolescent girls (Malina *et al.*, 2004; Viru *et al.*, 1999; Naughton *et al.*, 2000).

Meanwhile, the male silat exponents outperformed girls in a number of the performance tests, even at the younger age when boys were still awaiting their growth spurt. This may reflect the greater habitual activity of boys (Beunen *et al.*, 1992) and the negative consequences associated with the earlier maturation of the girls. The boys were around PHV in the 15 year old group and beyond PHV in 16-year-old group. The older two groups had greater grip strength score than the other two groups and the 16-year-old had better medicine ball throw, push-up performance, squat jumps heigh, and yo-yo test distance. The adolescent spurt in boys includes gains in stature; skeletal tissue and muscle mass compared to girls, who experience smaller increases in skeletal and muscle mass and a larger increase in fat mass. Staggering of these fitness improvements in boys post-PHV may better reflect the timing of peak weight velocity. Thus, improvements are likely to be associated with maturational factors such as hormone development that leads to increased muscle mass and internal organ size (Malina *et. al*, 2004) providing strength and endurance benefits, respectively. This supports the trigger hypothesis (Rowland, 1997), which suggests the hormonal responses at puberty are critical in improving performance. The trigger phenomenon is the result of the modulating effects of hormones that initiate puberty and influence functional development and subsequent organic adaptations (Katch, 1983). Katch argued that children will make limited training induced gains prior to the "trigger" seems to be supported by the correct research; although all the boys were involved in regular silat training, fitness only improved at or post-PHV. Alternatively, it may be that silat training does not provide an adequate stimulus to promote training gains across 13 to 16-year-old boys and girls and more frequent or intense physical conditioning is required. The technical coaching involved in silat training may only expose children to a low physiological workload. Thus, it is important to understand that with proper guidance and exercise training boys can show improvement in strength, aerobic fitness and anaerobic fitness. Based on the theory of sensitive periods of development (Viru *et al.*, 1999) and trainability/windows of opportunity suggested in the long-term athlete development mode (Balyi and co, 2000; 2003; 2004), the largest improvements were observed for the 16-year-old male age group, therefore it could be speculated that this group could be at the optimum stage of development to obtain physical conditioning (Balyi and Hamilton, 2004). The 15-16-year-old or PHV to PWV period in boys appears to reflect a period of accelerated adaptation and may consequently represent a ‘window of opportunity’ where boys would be more trainable at this stage of development. However, future research is needed to confirm this.

5.6 Conclusions

This was the first study to report fitness characteristics and performance of youth silat performers. For speed, agility and co-ordination motor tests, the reliability data did show there was a systematic error with learning process that occurs in a 3-kick test protocol. However, moderate levels of random variation were found in a 20-kick test and 3-directional jump test. Multiple trials of the tests (Pyne, 2004) and for the familiarisation (Hopkins, 2000) are options that should be taken into consideration in future studies to improve reliability. Results demonstrated that males outperformed female youth silat exponents in all fitness test even though at 13 and 14 year old the boys were pre-PHV. The female athletes were advanced, on average, by about 2 years compared to the male at onset of secondary sex characteristics of the growth spurt and at age at PHV. Girls were already at PHV in the youngest group and all females were likely to be experiencing the effects of increased fat mass with maturation. Although females actively participating in silat did not improve their fitness with increasing age/ maturation, silat training did allow the female athletes to maintain their fitness. Developing and mastering a variety of silat techniques such as kicking, punching, and sweeping consumes a lot of training time and this may be at the expense of more demanding physical conditioning. Whereas, performance in most of the fitness protocols in the male groups increased during and/or after age at PHV. The boys were at PHV in the 15-year-old group and post-PHV in the 16-year-old group. Measures of isometric strength (grip strength), uper body power (medicine ball throw, push-ups), lower body power (squat-jumps), and endurance (yo-yo test) showed peak gains after 15 years olds. These improvements were likely due to changes in body dimensions and tissues growth (increased muscle mass and organ size) during the maturation stage.

The usefulness of the newly developed silat-specific tests is not clear. This is because even though the newly developed sport-specific tests (20-kick test and 3-directional jump) were found to be adequately reliable, the results of those tests did not distinguish differences between any age groups in either males or females. Therefore, measures of general physical abilities may be better at distinguishing silat athletes of differing ability; although it seems likely that improving (and being able to measure) / improved kicking and movement speed would be desirable for silat performance and this requires further examination.

However, as the first such study in this field (youth silat) the data provides valuable information on the current fitness standards of youth silat athletes. Previously there has been no standard fitness testing battery used to profile a silat athlete's general and sport-specific fitness and movement skills. As youth development is very important for long-term athlete development (Balyi, 2001), this study has implications for the training system for youth silat competitors and their coaches. In boys the period 15 – 16-year-old may reflect a period of maturity related accelerated adaptation that could be exploited to maximise training gains. However, research is needed to confirm this. For girls and younger boys traditional silat training alone may not provide enough of stimulus to promote fitness development although involvement in silat will allow fitness to at least be maintained. The development of speed kicking and agility tests will help coaches to consider the establishment of sport specific needs in silat. These findings may help improve training prescription, although further research is needed to examine training responses at different stages of maturation.

CHAPTER SIX

Study Three: Effect of Circuit Training On Fitness Development in Youth Silat

6.1 Introduction

The development of performance in competition is achieved through a training process that is designed to induce automation of motor skills and enhance structural and metabolic functions (Smith, 2003). Some literature suggests that specific adaptations take place in adolescents when a task is repeated frequently, particularly in sports training (Violan *et al.*, 1997; Baundry and Roux, 2009). Powers and Howley (2001) reported that an understanding of exercise metabolism is important to the sports coach, since the design of a training programme to optimise athletic performance requires knowledge of the principle metabolic systems utilised by the sport. However, there are only a few published studies that have evaluated the effectiveness of training programme in martial arts (Melhim, 2001; Violan *et al.*, 1997). Moreover to date, there is no research examining the effect of specific training methodology on fitness development either in young or adult silat performers.

Matos and Windsley (2007) suggested that children can show improvement on their strength, aerobic fitness and anaerobic fitness from exercise training. Children may have higher initial levels of fitness than adults; they made need a higher training intensity and they may be more habitually physically active (Rowland, 1997). The trigger hypothesis suggests that there are certain periods in a child's lifetime where training adaptations follow predictable patterns after puberty (Katch, 1983). It is theorised that a child will be most sensitive to additional stimuli (such as training) during these naturally occurring periods of accelerated adaptation, which have become termed 'windows of opportunity' (Balyi and Hamilton, 2004). Therefore, the ability to identify periods of acceleration is paramount to further understand potential physical adaptation during childhood and into adulthood to maximize the athletic potential of young performers (Lloyd *et al.*, 2011). If this is true then the findings from Study 2 would suggest that boys who are post-PHV (peak height velocity) will be more responsive to silat training than those in pre-PHV period. However, this is a theory driven perspective and there is limited empirical evidence to support this (Ford *et al.*, 2011).

Circuit training is a training programme that embraces a number of carefully selected exercises designed simultaneously to exercise in one session the four major groups: legs, abdomen, arms and shoulders and back and trunk (Scholich, 1996). Circuit training is a form of progressive resistance loading designed to improve general muscular (muscular strength, muscular endurance, general endurance and muscular power) and circular-respiratory conditions (Adamson, 1959). It is an evolving training programme structured to combine low impact aerobic and anaerobic activities between sets of sport-specific exercises. The effect is to create a highly effective and time-efficient programme that mimics the action performed during competition. There is lot of literature that shows the benefits of planned circuit training to enhance physiological improvements either in adolescents (Baquet *et al.*, 2003 and Jacobs *et al.*, 2000), college-students (Mosher *et al.*, 1994), older adults (Takeshima *et al.*, 2004) or chronic disease populations (Mosher *et al.*, 1998). Nevertheless, there are limited numbers of studies on circuit training in youth martial art (Baudry and Roux, 2009), particularly silat. Most studies show large benefits of circuit training using a variety of special equipment such as resistance training equipment (i.e. dumbbells, weight, bars and etc.) and also laboratory equipmenter (Teng *et al.*, 2008; Obert *et al.*, 2001; David *et al.*, 1996 and Takeshima *et al.*, 2004) which is not accessible to most practitioners.

Well-designed training programmes have given a positive indication on how to enhance the capacity of both aerobic (Obert *et al.*, 2001 and Keren and Epstein, 1981) and anaerobic (David *et al.*, 1996) metabolism. The provided information could lead to a positive benefit (of training) on silat performance by allowing silat exponents to maintain a high exercise intensity for the entire duration of fight. During high-intensity exercise lasting more than a few seconds, adenosine troposphere (ATP) is resynthesized by both aerobic and anaerobic processes (Medbø and Tabata, 1989). Both the aerobic and anaerobic metabolism systems are taxed during silat competition (Aziz *et al.*, 2002). The ability to resynthesized ATP may limit performance of the athletes. Thus, if possible, the training of athletes for sports involving high-intensity exercise should improve the athletes' ability to release energy both aerobically and anaerobically (Tabata *et al.*, 1996) and to resist metabolic fatigue. Obert *et al.* (2001) reported that maximal power output (maximal anaerobic power) on the lower limb muscle mass can be improved in prepubertal children after 13-weeks of an aerobic training programme. While, Sargeant *et al.* (2001) reported that in 13-year-old boys after an 8 week mixed aerobic/anaerobic training programme, a 8.5% increase in peak power developed during a supra-maximal isokinetic cycle ergometer test, which was associated with similar 9.7% increase in upper leg muscle volume. The anaerobic system provides the short all-out bursts of maximal power and strength that characterise combat sports such as silat, whereas the aerobic system contributes more to recovery from the explosive bursts, reflecting the high-intensity intermittent profile of silat competition. Therefore, in order to offset fatigue and to maintain silat skills, high levels of physical fitness are necessary. Bounty *et al.* (2010) reported that the purpose of interval training in mixed martial arts was not to primarily develop strength but to condition one's body metabolically (i.e., reduce and/or clear lactate/acidosis more efficiently and enhance oxidative capacity in skeletal muscle by specifically increasing the activity of the mitochondrial enzymes such as citrate synthase and cytochrome oxidase) to prepare for the high-intensity bouts that will be experienced through the rigors of fighting. However, from a neuromuscular standpoint, speed and power cannot be maximized if anaerobic training is conducted in a fatigued state or with subpar effort (Buse, 2009 and Kraemer, 2000). As such, a high degree of mental concentration should be devoted to each repetition in power training, the repetition should be performed with maximal force in the least amount of time, and inter-set rest periods should be sufficiently long to allow the fighter to recover for the next set (Buse, 2009). Although the overall intensity of a power training session may be relatively light as compared with interval training sessions, each movement during power training should be executed with utmost explosiveness (Buse *et al.*, 2008). In addition, because power production is largely a consequence of efficient neuromuscular processes, quality should be stressed at all times (Turner, 2009). However, during competition an exponent will be required to repeatedly produce powerful efforts, which will require an exponent to be able to produce power under potentially fatiguing conditions. Therefore, training for power maintenance in silat may be more specific than simply training for maximal power.

Study 2 characterised that silat is a sport that required an exponent to have a well-developed endurance, upper and lower body strength and power and possibly good speed of kicking. Therefore, training should aim to develop these aspects of fitness and circuit training provides an ideal opportunity to develop these multiple components of fitness. While, Study 1 characterised the demands of silat competition as short-duration, high-intensity, intermittent exercise incorporating constant silat moves;

punching, kicking, blocking, catching and dodging movements in preparation for the next explosive effort. Therefore, training should attempt to reflect the specific demands of competition (sport-specific and overloaded) by improving the system (physiology or neuromuscular) that contributes to performance. With typically 62.6% of the match spent in fight time with 30.0 action periods of 15.3 s being performed with break periods averaging 8.4 s, respectively. This underscores the important contribution of anaerobic metabolism during the fight and aerobic metabolisms to allow silat exponent to recover from the high bursts activity for the entire duration of combat.

Edwards *et al.* (1973) reported that a method to stress the adaptive mechanisms of aerobic and anaerobic metabolisms during training session is to design alternating periods of work and rest. Circuit training has been used by Baudry and Roux (2009) in young judo athletes with activity and recovery durations ranging between 40 - 200 s, which would not be specific to the demands of silat. While, Buse and Santana (2008) reported that to emulate the demand of competition in kickboxing, the training interval should consists of maximal intensity sets, each set lasting approximately 10 to 30 s with minimal rest allowed between the sets. They suggested that an exponent may perform the sequence of four maximal intensity sets: 15 s of band punching, rest less than 5 s (a quick transition to the next set), 15 s of a medicine ball-resisted bob and weave technique, rest less than 5 s, 15 s of dumbbell uppercuts, rest less than 5 s, and 15 s of a hexagon fast-foot agility drill, followed by a rest of no more than 60 s before the next sequence of four sets begins. This sequence of 4 sets could then be repeated 2 to 4 times, depending on the scheduled duration of rounds planned in actual competition. The information by Buse and Santana (2008) were based on a literature review and gives an insight on the importance of sport-specific training that mirrors the demands of actual competition in kickboxing. Santana and and Fergusan (2005) suggested that the number of training rounds and rest duration between training rounds should mirror the same number of rounds and rest duration scheduled for competition although this may not allow for overload. A study by Amtmann *et al.* (2008) proved that an interval training regime appeared to effectively prepare mixed-martial art (MMA) exponents for the metabolic demands of competition. The authors found that the level of lactate during mixed-martial arts specific interval training (13.0 to 19.7 $mmol.L^{-1}$) was similar with the level of lactate found during the fight (13.3 to 18.0 $mmol.L^{-1}$), which, suggests the effectiveness of replicating the metabolic environment created in the sport of MMA. However, the above studies (except by Baudry and Roux, 2009) are in adults and there is little data available for children populations, given the ability of children to recover faster than adults more demanding intervals may be required in children. Martial artists need to be able to adequately buffer high acidity levels in both the blood and skeletal muscle to optimize performance (Kraemer *et al.*, 2004). This is because H^+ accumulation can inhibit actin and myosin cross-bridge cycling (i.e., muscle contraction). Even though circuit training will not increase muscle power; it will provide enhanced buffering capacity to resist fatigue (Kraemer *et al.*, 2004), which would be desirable for silat exponents given the high BLa observed in competition (Aziz *et al.*, 2002). Absolute strength and power should not be neglected during the training programme as these are also important components of silat. Therefore there is a need to condition silat athletes to produce rapid and powerful silat-specific exercises while resisting local muscle and whole-body fatigue during the training programme. Moreover, specific circuit training could be a means to simultaneously improve technical and physical silat skills, especially in young athletes who may have limited time for training. Consequently, exploratory research is needed to better understand how circuit training and traditional silat training can aid fitness development in children differing in maturity.

6.1.1 Aims of The study

The aims of the study are to implement a silat-specific training programme in boys aged 13 and 16-year-old, with the specific aims:

- To determine whether a 6-week circuit-training intervention can improve physiological development in youth silat athletes, reflected in improved fitness test scores.
- To determine the influence of age/maturation and whether training responses are different between 13 and 16-year-old silat performers.

6.2 Methodology

6.2.1 Participants

Eighty-seven male silat participants aged 13 (*N*=52) and 16-year-old (*N*=35) served as participants for this study. All participants were actively involved in silat as co-curriculum activities in school under the management of Pusat Cemerlang Silat, Malaysia. Participants were subsequently randomly divided into two groups; control (C) and experimental (E). Biological maturity was assessed via the non-invasive technique proposed by Mirwald *et al.* (2002) using measures of standing height, sitting height, age and body mass. Means (standard deviations) for group characteristics are presented in Table 6.1. Independent-samples t-tests showed there were no significant differences reported between the pool control and experimental group descriptive data except for sitting height. None of the participants reported injury at the time of testing, and all were involved in regular silat training. All participants submitted assent forms and parental consent to participate in the study. Participants were asked to wear their silat uniform with footwear and to avoid drinking, eating and participating in any exercise activities up to two hours before testing or training. All the testing methods and procedures were granted ethical approval by the University Research Ethics Committee.

Table 6.1: Mean (s) values for descriptive details for both experimental (E) and control (C) groups in each age group.

Group	N	Height (cm)	Arm Length (cm)	Sitting Height (cm)	Body Mass (kg)	Estimated age at PHV (years)	Years from PHV
C13	26	150.2 ± 11.4	71.8 ± 7.1	74.8 ± 10.1	45.8 ± 15.4	14.6 ± 1.3	-1.6 ± 1.3
E13	26	152.3 ± 8.2	73.2 ± 5.8	77.9 ± 4.8	49.2 ± 14.3	14.2 ± 0.7	-1.2 ± 0.7
C16	14	164.7 ± 7.3	78.5 ± 4.3	84.2 ± 4.1	59.2 ± 15.5	15.0 ± 0.7	1.0 ± 0.7
E16	21	168.4 ± 6.3	80.3 ± 3.4	87.1 ± 3.9	57.1 ± 13.8	14.7 ± 0.6	1.3 ± 0.6

C13 = age 13 control group; E13 = age 13 experimental group; C16 = age 16 control group; E16 = age 16 experimental group

6.2.2 Procedures

Forty-seven participants aged 13-year-old (*N*=26) and 16-year-old (*N*=21) were assigned to the 6-week silat-specific circuit training experimental group (E) while the remaining forty 13-year-old (*N*=26) and 16-year-old (*N*=14) participants served as a non-training control group (C). The intervention lasted a total of 8 weeks, including a week each for pre- and post-training fitness testing and six weeks of training twice per week. All participants participated in 1 introductory fitness training session before the pre-fitness testing procedures. During this time, they were taught the proper technique (i.e. controlled movements and body positions) on each testing exercise, and any of their questions answered. The fitness testing protocol and procedures used in this study replicate those previously described in study two (Chapter 5) in Figure 5.1 (pp. 138). Participants in both groups attended two fitness testing sessions with a minimum of 48-hours between each session in week 1 (pre-training) and week 8 (post-training) in which they completed various tests of general and silat-specific fitness; endurance (yo-yo intermittent test), upper body power (medicine ball throw), upper body endurance (push-up test), isometric strength (handgrip test), lower body power (rebound jump), concentric strength (squat jump), agility and co-ordination (3-directional jump), kicking speed (3-kick test) and kicking speed endurance (20-kick test). The control group continued with their normal silat training for 2 hours per session (twice per week) while the experimental group underwent 30-45 minutes circuit training plus 75-90 minutes of normal silat training. Participants in the intervention group were prescribed with an intervention programme which involved circuit training activities that consisted with 8 silat-specific activities (2 times per week for 6 weeks). Following the completion of the training programme, all participants from the study were re-tested in the same manner to baseline testing.

6.2.3 Silat-Specific Circuit Training Programme

Experimental groups from both age groups followed a twice-weekly silat-specific circuit training programme for 6 weeks on a silat indoor mat surface. The training frequency and intervention duration were similar to those used in previous training studies (Kraemer *et al.*, 2004; Gibala and McGee, 2008; Turner, 2009). Participants had at least 48 hours recovery between any two training session. The specific circuit training comprised eight stations (1 set) that included three technical silat exercises (punching, kicking and grappling); each exercise had a duration of 16 s with a 8 s break. Therefore, each exercise was completed with a work:rest ratio of 16 s work with

8 s rest, mimicking the demands of silat competition as reported in Study 1. Participants completed 3 sets in weeks 1 and 2, 4 sets in weeks 3 and 4 and 5 sets in weeks 5 and 6 of the circuit with 1-minute of rest between sets to mirror the rest duration scheduled in competition (Buse and Santana, 2008). All exercises were known and practised by the participants before the start of the training programme. At the beginning of each training session, participants completed a 10-minute warm-up composed of running, specific silat exercises and stretching. The design of the circuit is shown in Figure 6.1.

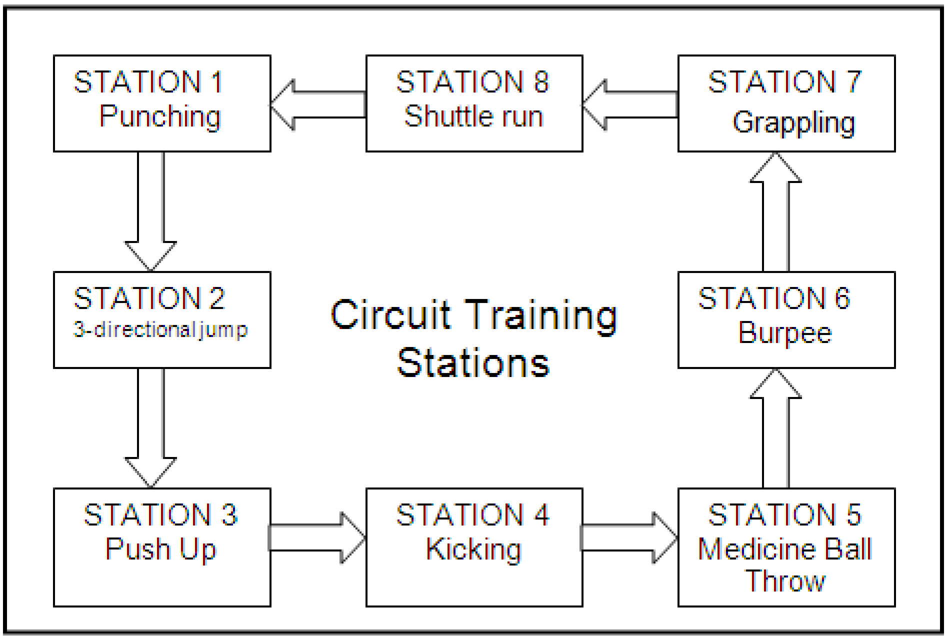


Figure 6.1: Silat circuit training.

As seen in Figure 6.1 participants were required to complete 8 exercises during the circuit, the exercises are described below;

- Punching - participants punched a pad held by the coach.
- 3-directional jump - participants jumped in 3 different directions; centre to front to centre to left to centre to right to centre continuously.

- Push up - the participant lowers the body using the arms until the elbows bend at 90^{o} angle and the upper arms were parallel to the floor.
- Kicking - participants kicked a pad held by the coach.
- Medicine Ball Throw - participants threw the 3-kg ball towards his partner (assistant coach) in *kuda-kuda* position.
- Burpee - participant began in a standing position, then drops into a squat position with hands on the floor, immediately kicks their his feet back to a push-up position, and returns their feet to the squat position and leaps up as high as possible with his hand overhead in the air.
- Grappling - participant and his partner grip one another's silat uniform (around chest area) and pull hardly towards themselves continually until instructed to stop.
- Shuttle run – shuttle run was completed over a 7-metre distance

Table 6.2: A suggested silat-specific circuit.

Station	Activity
Station 1	**Punching/Hit the target (silat-specific)** Emphasis : Muscle endurance (triceps, pectorals, deltoid, latissimus dorsi), skill, anaerobic conditioning Keeping light footed in “pasang” position, the silat exponent will punch straight to the target hold by the partner. Equipment : Hand target or body target
Station 2	**Agility 3-directional jump** Emphasis : Agility, balance and co-ordination The silat exponent should stand on the middle square of the silat contact mat. The 4 contact mat was arranged in the “reverse T” position so that the athlete can jump to the front back, left and right. The athlete jump to the front mat and back to the middle square; then jump to the left and back to the middle square; and jump to the right and back to the middle square. Equipment : 4 pieces of silat mats
Station 3	**Push-up** Emphasis: muscular strength and endurance; core stability; triceps; pectorals The push up performed in full position. Equipment: silat mats
Station 4	**Kicking (silat-specific)** Emphasis : Muscle endurance (hip flexor, quadriceps, gluteus, hamstrings), skill, anaerobic conditioning Keeping light footed in “pasang” position, the silat exponent will kick straight to the target hold by the partner. Equipment: Hand target or body target
Station 5	**Medicine ball throw/Catching skills** Emphasis : explosive power (abdominal region; anterior deltoids; triceps; quadriceps; hip flexors); skill Two silat exponents stand about 3 m from each other in position of “pasang”. The athlete begins by holding the ball against the chest and pointed straight out from each side of the body. The athlete executes the throw by pushing the ball from the chest. The partner that receives the ball and will repeat the same sequence

	over the given time period. Equipment: Medicine ball
Station 6	**Burpee** Emphasis: muscular strength and endurance: core stability; gluteus; hip flexors Bend over and squat down. Place hands on floor, slightly wider than shoulder width. While holding upper body in place, kick legs back. Land on forefeet with body in straight, plank position. Keeping upper body in place, pull legs forward under body returning feet in original position. Rise up and jump vertically on the air and back to original standing posture.
Station 7	**Grappling** Emphasis: isometric strength; skill Two silat exponents face each other in "pasang" position. Both hands grasp the other exponent cloth and the other exponent will do the same. Alternating, each exponent pulling each other while the other exponent will follow the force.
Station 8	**Shuttle/sprint** Emphasis: aerobic conditioning; changing direction; speed Run between two marks, where possible 7 m apart. The player run towards the line and touch the line with their fingers. Then, they change direction and run back to the starting line and touch it. Again repeat the sequence or laps over the given time period. Equipment : Marker cones and masking tape

The punching, kicking, 3-directional jump and grappling are the exercises that are specific to the silat skills (Table 6.2). The punching and kicking are the common attacking actions used in silat spar. The grappling and 3-directional jump are the defensive actions in silat. The grappling is an effort to topple down the opponent while the 3-directional jump is an action that similar with avoiding, jumping or dodging away from the other opponent strikes. The ability to avoid and counter strike the other opponent's will contribute to the point. Both the attacking and defensive sports-specific exercises in this circuit are intended to develop and enhance young athlete's sport-specific skills and fitness in silat.

Four forms of general exercises are introduced in this circuit. Two exercises for each upper and lower body. The push-up (Taskin, 2009) training should help to develop the muscles at the front of the chest and shoulders (pectorals and anterior deltoid) and the muscles at the back of the upper arm (triceps). It also can be used to improve youth muscular endurance specifically at the arms and shoulder girdle. While, the medicine ball throws (Buse and Santana, 2008; Turner, 2009) exercise is used to develop power and strength for all types of throwing, catching, and rotating techniques. This exercise is a total-body strength drill that develops the shoulders, arms, legs and core. The burpee exercise emphasis on core stability, gluteus and hip flexors. Because it is a full body exercise and very high intensity, burpee training could help for developing the conditioning and muscular endurance particularly to improve the cardiovascular fitness. The final exercise is shuttle or sprint (Kotzamanidis, 2006) between two markers that are separated by seven metres. This activity develops silat exponent cardiovascular fitness and also to improve on how quickly the exponent can change direction. In order to be specific the drill should be completed at a maximum/high–intensity action at each circuit training station.

There are many ways of organising circuit training workouts. The format in Figure 6.1 shows the layout of selected the circuit training format. The eight-station circuit format was chosen because it can enable a large number of participants and variety of exercise stations to be used simultaneously. Furthermore, the circuit alternates lower and upper body exercise, which are both known to contribute to a silat fight (Study 1). It may also be used to maintain the interest and assist motivation for the participants to become fitter because children naturally engage in intermittent type exercise (Bailey *et al.*, 1995 and Welk *et al.*, 2000). The experimental participants were divided into small groups that consist of around (can not be exact unless the group was a multiple of 8) 8 participants per group. An assistant coach (black belt in silat) was located at each station and acted as the partner to ensure that every participant performed all out in every exercise during circuit training. Participants were asked to perform the exercise at a near maximum intensity for 16 s at each station. Each exercise was performed using the work:rest ratio of 16:8 s. Once the researcher instructed participants to stop the exercise (single whistle blow) each participant moved to the next station during the 8-s rest period and waited for another instruction (single whistle) to start the next exercise. These procedures were followed until the participants had completed all eight stations and the researcher signalled the end of the circuit (double whistle blow). A 1-minute rest period was given before the start of the next set of circuit training.

6.2.4 Statistical Analyses

Descriptive statistics for each group pre- and post-training intervention are provided as means (± standard deviations). Separate mixed-model ANOVAs were used to test for significant differences in performance variables pre- and post-training. For all models, age (two levels: 13 and 16-year-old) and intervention (two levels: control- and experimental) groups served as the independent variables. Differences in all performance variables were analysed using a 2 x 2 x 2 model ANOVA (age x group x time), where age refers to the 13 or 16 year age groups; group refers to C (control) or E (experimental) group and time refers to pre-to-post training fitness test data. Sphericity of data was tested by Maulchy's statistic. Homogeneity of variance between groups was examined using Levene's test of equality of variance and where variances were found to be unequal Welch's adjusted F statistic was used to determine the origin of any between-group differences respectively. Statistical significance for all tests was set at alpha level $p \leq 0.05$. Descriptive statistics were calculated through Microsoft Excel®, whilst all ANOVAs were computed via SPSS® V.17 for Windows.

6.3 Results

6.3.1 Upper Body Test

Main Effects. The two-way analysis of variance (Table 6.3) revealed that there were significance main effects of age (13 and 16-year-old group) on all the upper body fitness variables (all, $p < 0.05$). The analyses demonstrated the 16-year-old outperformed 13-year-old in all fitness components. Similarly, there were significant main effects of time (pre-test and post-test variables) on handgrip strength, medicine ball throw distance and push-up performance (all, $p < 0.05$), where the post-training were better than pre-training performance. The result also showed there were no significance main effects of intervention on all upper body fitness variables (all, $p > 0.05$) which indicated that there were no differences in the abilities of the control group and experimental groups.

Interaction Effects. Table 6.3 shows that there were no significance interaction effects between age (13 and 16-year-old group) with time (pre-test and post-test variables) in all upper body variables (all, $p > 0.05$). Meanwhile, ignoring the effects of age, results showed that the were significance interaction effects between intervention (control and experimental group) with time (pre-test and post-test variables) in the push-up test ($p < 0.05$). The experimental group ($M = 35$, $SD = 12$) performance reflected in the number of push-ups was significantly better than control group results during the post-training testing.

Table 6.3: Main and interaction effects of age, interaction group and time on upper body variables.

Variable	Age	Intervention	Time	Age*Time	Time* Intervention	Age*Time* Intervention
Handgrip Strength	0.0005**	0.882	0.002**	0.089	0.517	0.119
MedBall	0.0005**	0.626	0.0005**	0.769	0.074	0.754
Push- ups	0.023**	0.587	0.0005**	0.332	0.0005**	0.735

** denoting a significant change ($p < 0.05$); Age=13 year and 16-year-old groups; Intervention=control and experimental groups; Time=pre-test and post-test; MedBall=Medicine Ball throw distance.

Group Effects on Pre- and Post-Test Performance. The overall interactions between age, time and intervention effects (age*time*intervention) was not statistically significant (Table 6.3) for all upper body fitness variables (all, $p > 0.05$). However, the individual changes for each group in upper body tests showed a significant improvement in both 13 and 16-year-old experimental groups in the push-up test (Figure 6.2A) following the training intervention (all, $p < 0.05$), whereas, the control group showed no improvement over the intervention period ($p > 0.05$). Meanwhile, there were no significance differences either in 13 or 16-year-old experimental groups for distance thrown in the medicine ball throw and handgrip tests performance (all, $p > 0.05$) following the 6-week intervention. Figure 6.2 (B) shows small but significant (both, $p < 0.05$) improvement in 13 and 16-year-old control groups medicine ball throw following the 6 weeks of silat-only training. While, the 16-year-old control group showed a significant improvement ($p < 0.05$) in handgrip strength over the intervention period (Figure 6.2 C). However, the grip strength performance remained unchanged in the 13-year-old control group.

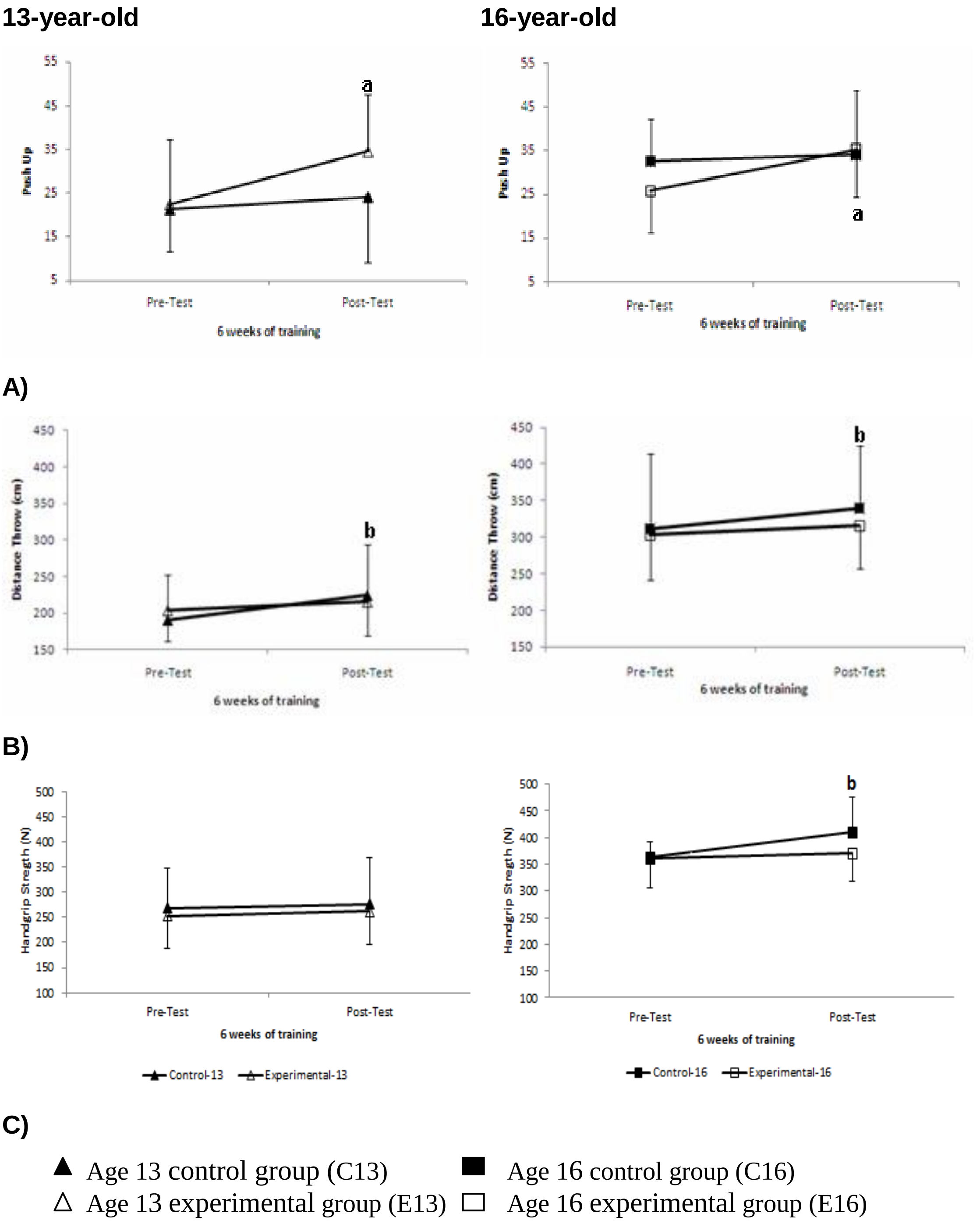


Figure 6.2: Results for pre- and post-training of upper body test performance of 13-year-old (left) and 16-year-old (right) silat performers. (A) push-ups performance; B) medicine ball throw performance; C) handgrip performance; "a" denoting a significant change ($p < 0.05$) in the experimental group and "b" denoting a significant change ($p < 0.05$) in the control group.

6.3.2 Endurance Test

Main Effects. The two-way analysis of variance revealed that there were significance main effects of age on yo-yo endurance test performance ($p = 0.0005$). The analyses demonstrated the 16-year-old outperformed 13-year-old ($p < 0.05$). The result also showed there were no significance main effects of intervention on endurance test ($p = 0.224$) which indicated that there were no differences in the aerobic endurance performance of the control group and experimental group. While, the results showed that the was statistically significant main effect of time (pre-test and post-test) on yo-yo endurance test performance ($p = 0.035$).

Interaction Effects. Result showed that there were significance interaction effects between age with time ($p < 0.05$). The significant interaction showed the endurance fitness variable had a training effect over time with respect of age but ignoring the intervention effect (control and experimental groups) ($p < 0.05$). Meanwhile, ignoring the effects of age, results showed that there were no significant interaction effects between intervention with time ($p = 0.072$) in endurance test. However, due to the p value approaching significance, the result suggests that the post-training values were higher than pre-training group in experimental group.

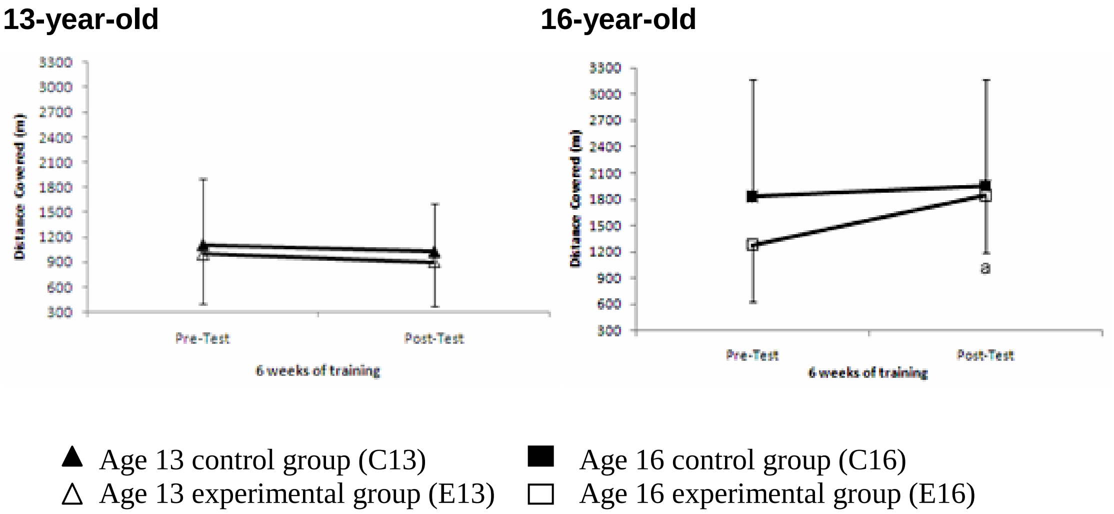


Figure 6.3: Results for pre- and post-training yo-yo intermittent endurance test level one performance in 13-year-old (left) and 16-year-old (right) silat performers; "a" denoting a significant change ($p < 0.05$) in the experimental group.

Group Effects on Pre- and Post-Test Performance. The overall interaction between age, time and intervention effects (age*time*intervention) approached significance ($p = 0.058$). Individual group results showed that the 16-year-old in the experimental group significantly improved ($p < 0.001$) the distance covered in the yo-yo test (Figure 6.3), whereas all other groups showed no change in performance over the intervention period (all, $p > 0.05$).

6.3.3 Lower Body Performance

Main Effects. The two-way analysis of variance (Table 6.4) revealed that there were significance main effects of age on all the lower body fitness variables (all, $p < 0.05$) except for reactive strength index (RSI) ($p > 0.05$). The analyses demonstrated the 16-year-old outperformed 13-year-old in almost all instances ($p > 0.05$). However, the analyses showed that the 13-year-old group to have significantly shorter ground contact times than the 16-year-old group, which explains the similar RSI values in both groups (Table 6.4 and Figure 6.4). The result also showed there were no significance main effects of intervention on all fitness variables (all, $p > 0.05$) which indicated that there were no overall differences in the abilities of the control group and experimental groups. Meanwhile, the results showed that there were statistically significant main effects of time (pre-test and post-test) on best jump height and contact time in the rebound jump (all, $p < 0.05$).

Interaction Effects. Table 6.4 showed that there were significance interaction effects between age with time in jumping height and RSI (both, $p < 0.05$). The significant interaction showed both fitness variables had a training effect over time with respect of 13 and 16-year-old but ignoring the intervention effect. Meanwhile, ignoring the effects of age, results showed that there were significant interaction effects between intervention (control and experimental group) with time (pre-test and post-test variables) in contact time and RSI of rebound jump test (all, $p < 0.05$). The result showed that there were significant improvements in the experimental group for both fitness variables compare to the control group.

Table 6.4: Main and interaction effects of age, interaction group and time on lower body variables.

Variable	Age	Intervention	Time	Age*Time	Time* Intervention	Age*Time* Intervention
Squat Jump	0.0005**	0.418	0.733	0.078	0.391	0.138
Rebound Jump						
- jump height	0.0005**	0.565	0.0005**	0.031**	0.107	0.108
- CT	0.0005**	0.124	0.040**	0.069	0.0005**	0.244
- RSI	0.204	0.195	0.125	0.006**	0.008**	0.974

** denoting a significant change ($p < 0.05$); Age=13 year and 16-year-old groups; Intervention=control and experimental groups and Time=pre-test and post-test.

Group Effects on Pre- and Post-Test Performance. The overall interactions between age, time and intervention effects (age*time*intervention) showed there were no statistically significant interactions (Table 6.4) in any lower body variables (all, $p > 0.05$). However, only the 16-year-old experimental group demonstrated a significant improvement in squat jump height following the intervention (Figure 6.4A). As shown in Figure 6.4 both experimental groups demonstrated a significant reduction in rebound jump height (Figure 6.4B), reductions in ground contact time during rebounding were significant for the 16-year-old experimental group (Figure 6.4C), and the change in RSI was non-significant for 16-year-old in the experimental group but significantly ($p < 0.05$) improved for 13-year-old in the experimental group (Figure 6.4D). While there were some instances of significant changes in rebound height and contact times in the control groups the RSI remained unchanged in both 13 and 16-year-old control groups.

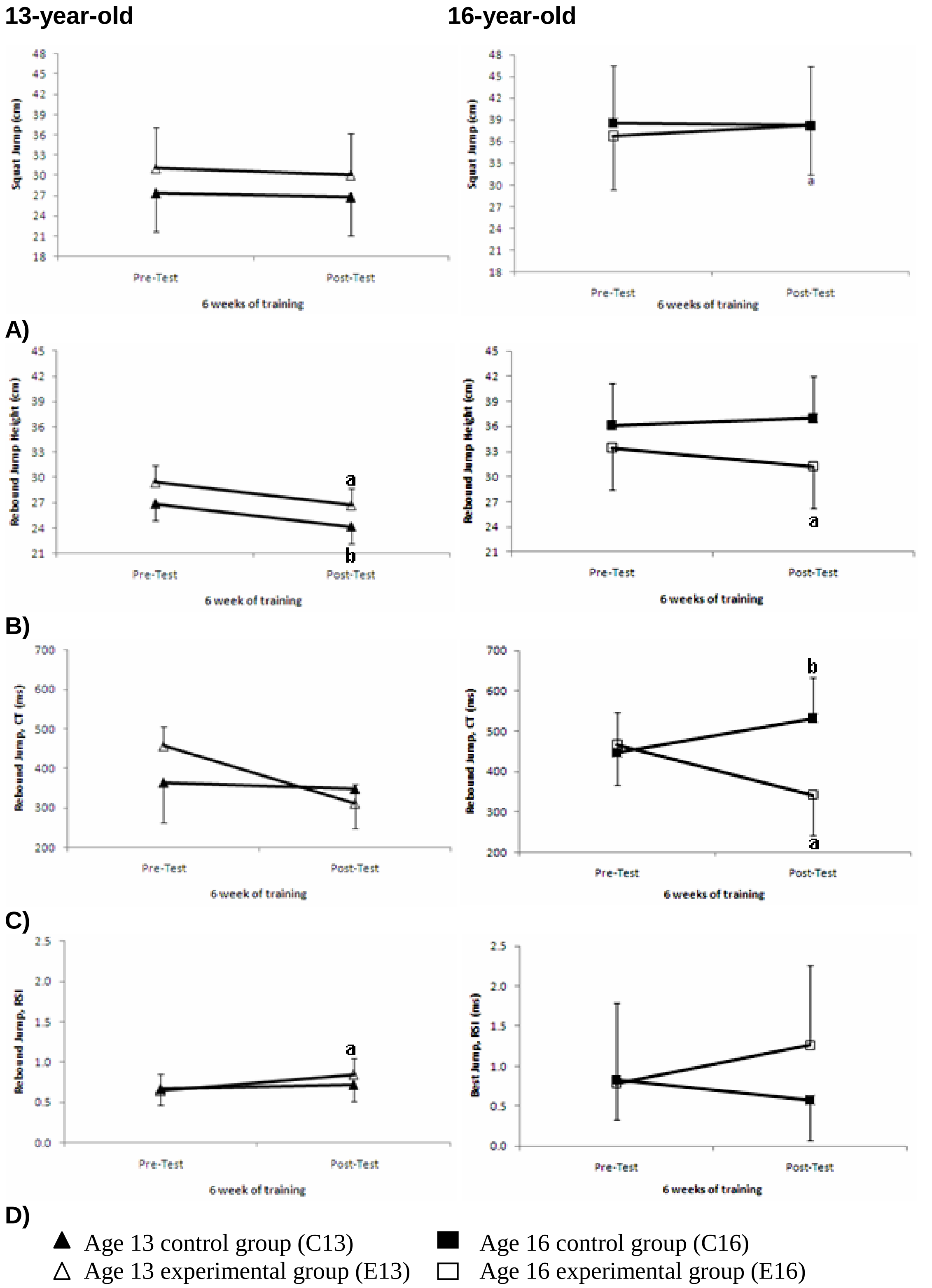


Figure 6.4: Results pre- and post-training of jump tests performance in 13-year-old (left) and 16-year-old (right) silat performers. (A) best squat jump; B) best jump height of rebound jump; C) best contact time (CT) of rebound jump; D) best reactive strength (RSI) of rebound jump; "a" denoting a significant change ($p < 0.05$) in the experimental group and "b" denoting a significant change ($p < 0.05$) in the control group.

6.3.4 Silat-Specific Tests Performance

Main Effects. The two-way analysis of variance (Table 6.5) revealed that there were significance main effects of age on all silat-specific variables (all, $p < 0.05$). The analyses demonstrated the 16-year-old outperformed 13-year-old in all fitness performances. The result also showed there were significance main effects of intervention on total time of 3-kick test ($p = 0.000$), where, the experimental group significantly outperformed the control group performance.

Table 6.5: Main and interaction effects of age, interaction group and time on silat-specifics variables.

Variable	Age	Intervention	Time	Age*Time	Time* Intervention	Age*Time* Intervention
3-Directional Jump						
- total time	0.0005**	0.089	0.044**	0.598	0.170	0.110
3-kick Test						
- total time	0.005**	0.0005**	0.685	0.634	0.419	0.227
20-kick Test						
- total time	0.0005**	0.497	0.177	0.472	0.334	0.704

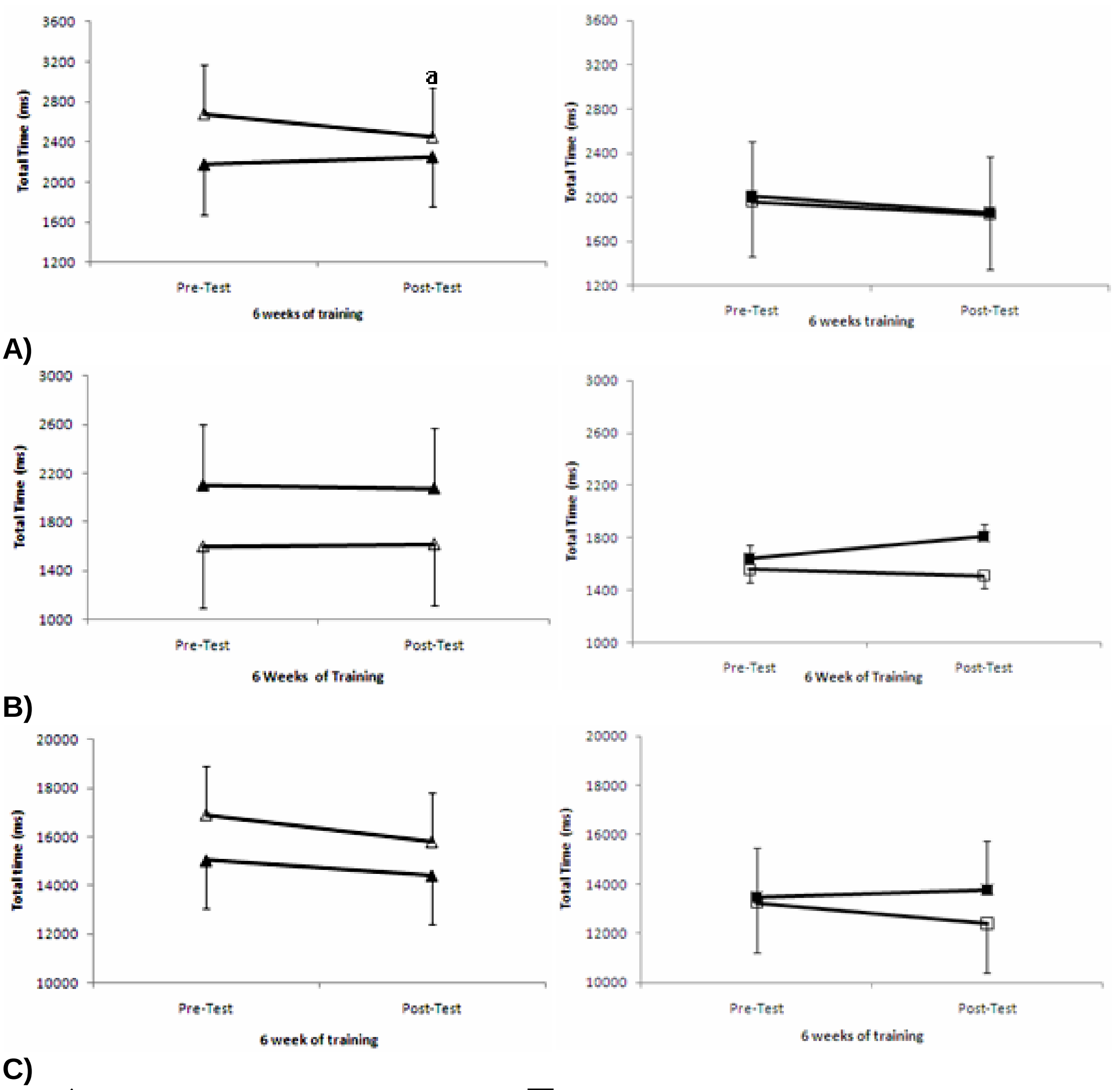
** denoting a significant change ($p < 0.05$); Age=13 and 16-year-old groups; Intervention=control and experimental groups and Time=pre-test and post-test.

Interaction Effects. Table 6.5 shows that there were no significance interaction effects between age with time in all silat-specific variables (all, $p > 0.05$). Similarly, ignoring the effects of age, results showed that there were also no significant interaction effects between intervention with time in any silat-specific performance (all, $p > 0.05$).

Group Effects on Pre- and Post-Test Performance. The overall interactions between age, time and intervention effects (age*time*intervention) showed there were no statistically significant interactions (Table 6.5) in any silat-specific variables (all, $p > 0.05$). However, further analysis showed only 13-year-old in the experimental group demonstrated a significant improvement in 3-directional jump performance ($p =$

0.010). No significant changes in 3 or 20-kick time were observed for any of the groups over the intervention period (Fig 6.5B & C).

13-year-old (left side) **16-year-old (right side)**



▲ Age 13 control group (C13) ■ Age 16 control group (C16)
△ Age 13 experimental group (E13) □ Age 16 experimental group (E16)

Figure 6.5: Results for pre- and post-training of silat-specific performance in 13-year-old (left) and 16-year-old (right) silat performers. (A) 3-directional jump; B) 3-kick test; C) 20-kick test; "a" denoting a significant change ($p < 0.05$) in the experimental group.

6.4 Discussion

As expected the 16-year-old were superior to the 13-year-old in all performance measures except the RSI. Following the intervention period performance was improved for a number of measures for the experimental groups, while the control groups also improved in some measures. While interaction terms were generally non-significant analysis of the individual group responses demonstrated differing results between control and experimental groups across the two age groups for some variables. The control groups demonstrated some improvements in upper body strength and power that were not observed in the experimental groups. The older experimental group improved endurance, squat jump and push-up performance, while the younger experimental group improved RSI, 3DJ and push-up performance. Consequently, the training response appears to be specific to the demands of the training stimulus and is influenced to some degree by the age/maturation of the participants.

The 16-year-old experimental group improved endurance performance due to the exposure to the 6-week training programme, whereas no other group improved this measure. This is likely to occur as a result of the impact of adolescence together with training. Baquet *et al.* (2003) suggest that there is an exponential rise in peak oxygen uptake following peak height velocity and puberty, in what Katch (1983) and Rowland (1997) describe as the ‘‘trigger hypothesis’’. This hypothesis proposed that the marked increase in the potential for aerobic power in more mature males was associated with puberty changes (Naughton *et al.*, 2000). Furthermore, the authors reported that the growth-related improvements in aerobic trainability in well trained male adolescent athletes compared with well-trained preadolescent male populations may be associated with the interactive effects of leaner body composition, proportionally higher muscle mass, higher blood oxygen carrying capacity and larger maximal cardiac output. Where, these adaptations concomitantly relate to increased testosterone, GH and other hormone secretions that occur with maturation in males (Rowland, 1997). Moreover, improvements in maximal oxygen uptake associated with aerobic training involve structural and functional adaptation in the oxygen transport system – lungs, heart, blood, vascular system, and oxidative capacity of skeletal muscle (Malina *et al.*, 2004). Based on the Fick equation, improvements reflects increases in heart rate, stroke volume, or pheripheral arteriovenous (AV) oxygen differences, or their respective determinants (Rowland, 1997). Maximal heart rate does not change after exercise training (Malina *et al.*, 2004). While, maximal stroke volume, blood volume, and oxidative enzymes increase after exercise training of youth (Rowland, 1997), although it may be difficult for prepubertal children to realise these adaptations even with training which is supported by the present study.

Balyi and Way (2009) identified that the trainability of athletes endurance was based on the development age, which means by identifying the tempo of the growth through metric measurements (PHV), training, competition and recovery programmes can be adjusted to the individuals need. Consequently Balyi and Way (2009), Rowland (1997) and Katch (1983) all suggest that endurance will be more trainable during or following the attainment of PHV (compared to pre-PHV), which is supported by the results of the current study. The results of current study suggest the experimental group was aerobically 'responsive' to the current 6-weeks intervention training following the improvement of post-training endurance performance. Thus, the aerobic improvements in adolescent male's silat performers may be related to maturation as well as training. Moreover, this finding also followed the previous finding in Study 2, which found the 16-year-old group performed significantly better than other groups (13 to 15-year-old). Therefore, the period of naturally occurring accelerated adaptation identified in Study 2 does appear to facilitate aerobic trainability, supporting the theory presented in the long-term athlete development model of Balyi and Way (2009). Even though the 13-year-old experimental group were exposed to the same intervention training, the readiness factor (Balyi and Way, 2009) contributed to them being less-responsive to the training intervention due to their immaturity. Tanner (1989) refers to readiness as the critical period in the development of specific behaviour, when experience or training has an optimal effect on development. The same experience, introduced at an earlier or later time, has only, or retards later skill acquisition with a limited effect (Balyi and Way, 2009). Thus, the circuit-training intervention training failed to improve endurance fitness in 13-year-old young silat performers.

Baxter *et al.* (1995) reported that when trained and untrained subjects were compared, the values of aerobic power in the trained subjects were higher at all ages, with the greatest difference found during adolescence. Conversely, the results from this study found that although not statistically significant; the 16-year-old in the experimental group (E16) had lower aerobic fitness than the 16-year-old control group (C16), and although E16 did significantly improve they were at a similar level to the C16 group post-intervention. Bar-Or and Rowland (2004) reported that there were several factors that affect trainability among various body systems and fitness components, including time elapsed from peak height velocity and pre-training fitness level. Therefore, the improvement in aerobic fitness observed for the E16 may also be partly explained by a relatively low initial aerobic fitness for this age group, reflecting the findings of Baquet *et al.* (2003). However, the E16 group had a higher initial yo-yo score than the E13 group, with the latter failing to demonstrate any significant improvement in performance. Consequently, maturation may play a more decisive role than initial fitness in the training response. Tanner (1989) reported that the adolescent spurt in boys results in development of larger hearts as well as larger skeletal muscle, larger lungs, higher blood pressure, lower resting heart rate, a greater capacity of carrying oxygen to blood, and a greater power neutralizing the chemical products of muscular exercise. Moreover, the author also reported that the number of red blood cells and the amount of haemoglobin, the pigments which carry oxygen from lungs to muscle, both increase at adolescent's boys, all of which may have been more adaptable with training in the older training group. Kemper and Verschuur (1987) reported that during puberty there was an increase in maximal aerobic power in boys from 2.2 $L.min^{-1}$ two years before peak height velocity to 3.7 $L.min^{-1}$ two years after peak height velocity. The C16 group was already post-peak height velocity by the time training intervention took place and may have already experienced maximal aerobic development, although there were no maturity differences between C16 and E16. Moreover, a possible reason for the higher initial performance of C16 may be because of high habitual activity of the "control" (Bar-Or and Rowland, 2004). Even though, they did not participate in the intervention programme, these children were all involved in regular silat training and probably other forms of physical activity. Thus aerobic improvements in adolescents may be related to maturation as well as habitual activity and training/training status (Naughton *et al.*, 2000).

There are other instances where the group responses were significant following the intervention period. The squat jump performance showed a significant improvement in the response of the 16-year-old experimental group following the 6-week intervention programme. Even though participants have to raise their own mas it is suggested that improvements in the squat jump may be due to increases in body size or active muscle mass (Van Praagh and Doré, 2002; Beunen, 1997; Blimkie *et al.*, 1998), which are maturation dependent. Similar to the present study, Meylan and Malestesta (2009) reported that there was no plyometric training effect on squat jump tests performance in 13-year-old. Katch (1983) reported that hormonal regulation sets the trigger for the organic adaptations that initiate puberty and determine responses to physical conditioning; where, such an increase in muscle size is related to a significant elevation in male hormonal production (principally testosterone) (Inbar, 1996). Moreover, testosterone induces the development of sexual characteristics (Naughton *et al.*, 2000) and there is a substantial gain in lean body mass during puberty. The anabolic hormones are likely to have been elevated in the older, more mature experimental group when compared to the younger, less mature group, which may have resulted in the older group experiencing greater adaptations to the training programme.

It has been reported that training can induce muscle hypertrophy, which appears to be a more consistent outcome of strength training during adolescence, especially for males (Blimkie and Bar-Or, 1996). The current study showed that the lower body concentric strength was improved following the circuit-training intervention in the 16-year-old (post-puberty) experimental group; but not to the 13-year-old experimental (pre-puberty) group. Similar to endurance, results from Study 2 suggested a possible period of accelerated adaptation in concentric leg strength/power (i.e. squat jump) around the age of 16-year-old. This study supports a greater sensitivity to training during this period immediately post-PHV, probably coinciding with peak weight velocity (Malina *et al.*, 2004). Because strength is determined primarily by two factors; the cross-sectional area of the contracting muscle and number of motor units that are activated at any given time (Bar-Or and Rowland, 2004); the cross-sectional area reflects the size, and to a lesser extent, the number of muscle fibers (Jones *et al.*, 1983). Thus an intensive increase of the cross-sectional area of muscles and muscle fibres occurs in male adolescents; and is correlated to the improvement in muscle strength (Viru *et al.*, 1999). Van Praagh and Doré (2002) reported that muscle cross-sectional area increases exponentially up to 17-year-old and then reaches a plateau from the age of 20 years. Owing to the accelerated increments in strength commonly seen post-PHV as a consequence of increased muscle mass, it is suggested that the secondary window of adaptation for squat jump height development is attributable to muscle mass adaptation post-PHV (Lloyd *et al.*, 2011). The training programme was high-intensity with limited recovery. This would cause high metabolic stress and should provide a stimulus for increased anabolic hormone production and tissue growth. In adults eight weeks of high resistance circuit training has been shown to cause similar hypertrophy gains as traditional resistance training (Alcaraz *et al.*, 2011), suggesting circuit training can elicit gains in muscle size.

The LTAD model states that strength is always trainable but recommends the optimal ‘‘window of trainability’’ for boys is 12–18 months following peak height velocity (Balyi and Hamilton, 2004). However, research examining the optimal ‘‘window of trainability’’ is limited and there appear to be no longitudinal strength training studies that have determined PHV and that have appropriately controlled for growth and maturation (Ford *et al.*, 2011). In terms of increasing maximal muscular strength, short-term circuit weight training programs have compared favourably with traditional weight training programs when untrained subjects are studied (Gettman *et al.*, 1978;

Gettman, 1981). Research has indicated that multiple sets are superior to single sets for maximal strength development (Taskin, 2009), although with an adult population. Nevertheless, whether maximal strength gains are achieved may depend on the ability to sustain a consistent number of repetitions over consecutive sets during training (Taskin, 2009). Bar-Or and Rowland (2004) suggested the increase in muscle strength of children, particularly at the early stages (e.g. first 6-8 weeks) of training, was facilitated by neural and neuromotor changes in children. Whereas, Wilmore *et al*. (2008) suggest that high levels of strength, power and skill are impossible if the child has not reached neural maturity. Myelination of many motor nerves is incomplete until sexual maturity (Viru *et al.*, 1999). Also, muscle fibre conduction velocity has been seen to increase with age in children (De Ste Croix, 2007). Circuit training was able to promote beneficial adaptations in the present study, although these differed for younger and older children, which may reflect differing adaptations in both the muscular and neural system.

This study showed significant improvements in push-up responses of the 13 and 16-year-old experimental groups following the intervention. Therefore, the E13 group were able to show an improvement in push-up performance, despite Study 2 previously suggesting there was very little natural adaptation at this time. The nature of the push-up test is a metabolically demanding test where local/peripheral muscle factors are likely to limit performance. The findings suggest both age groups are able to adapt these mechanisms with training (e.g. lactate tolerance and buffering) to a similar degree, suggesting no association between natural development (observed in Study 2) and trainability. Peripheral adaptations that could facilitate improved performance during the push-up task could include improved energy provision and greater tolerance to fatigue (such as the accumulation of metabolic by-products). Barr-Or and Rowland (2004) suggested various factors determine children's anaerobic performance, with several studies explaining possible mechanisms regarding biochemical changes (Eriksson, 1972; Eriksson *et al.*, 1973; Cadefau *et al.*, 1990; Fournier, 1982) that accompany anaerobic trainability. Eriksson (1980) and Fournier *et al.* (1982) showed that anaerobic enzyme concentration increased in youngsters following training, increasing the ability to utilise anaerobic energy. Based on muscle biopsy data, there was an increase in the activity of anaerobic enzymes such as phosphofructokinase and other glycolytic enzymes (Eriksson, 1972; Eriksson *et al.*, 1973; Cadefau *et al.*, 1990; Fournier, 1982). There is also an increase in resting muscle glycogen level and in maximal muscle lactate. Those data suggested that anaerobic training is accompanied by an increase in glycogen flux. Evidence for a rise in muscle ATP and CP levels at rest, which may facilitate alactic performance, has also been reported (Eriksson, 1972; Eriksson *et al.*, 1973; Cadefau *et al.*, 1990; Fournier, 1982). Whereas, it has been suggested that the biological mechanisms associated with the production of anaerobic work and tolerance to the related acidosis are not fully mature until sometime after the adolescent growth spurt (Inbar, 1996). During maximal anaerobic exercise, muscle lactate accumulates, which relates with an increase in hydrogen ion (H^+) concentration in muscle and body fluids. The muscle cannot buffer all of the H^+ produced, and pH thus falls from about 7.0 to as low as 6.3 after exercise which leads to muscular exhaustion (Malina *et al.*, 2004). This decline in pH, in turn, decreases the capacity to produce and maintain muscle tension. Thus, training is suggested to help both younger and older children to better buffer and resist the development of acidosis as well as allowing those individuals to tolerate a greater build-up of acidosis before fatiguing. Moreover, adaptation which occurs within the muscles may better explain the lower lactate levels and augmented endurance capacity following specific anaerobic training. The data from Study 2 suggested no period of accelerated adaptation in 13 to 16-year-old groups, and results from this study showed both 13 and 16-year-old to be equally trainable with regards to local muscle endurance.

Pate and Ward (1996) suggested that neurological changes for muscle strength trainability can also explain improvements in peak power and, possibly, muscle endurance in children. However, there are no studies that have analysed associations between improvements in the latter functions on the one hand, and electromyography (EMG) and motor unit activation (MUA) on the other, in children or adolescents (Pate and Ward, 1996). Moreover, the cross-sectional area of slow-twitch muscle fibres, as well as some of the fast-twitch fibres, of 16 to 17-year-old boys has been shown to increase by 10% to 30% following a 3-month endurance training (Bar-Or and Rowland, 2004). If the circuit training intervention employed in the present study caused such adaptations then this would be expected to improve push-up performance. Jacobs *et al.*, (1982) reported there was no evidence for a change in fibre type distribution/composition on children as result of training and it may be more likely, given the duration of the intervention, that metabolic adaptations were responsible for the improved push-up performance. Children’s capability for aerobic metabolism turnover is enhanced following endurance training as shown by increased glycogen storage and oxidative enzyme (Eriksson *et al.*, 1974; Eriksson *et al.*, 1971; Fournier *et al.*, 1982), while anaerobic training can increase anaerobic enzyme concentration and metabolism in children (Eriksson, 1980). Similar changes in some muscle enzymes, as well as in muscle lactate, have been shown in young adult Swedish men and women following a 6 week supra-maximal controlled training programme (Jacobs *et al.*, 1987). This suggests that an increase in glycolytic enzymes can result directly from high–intensity power training (Blimkie and Bar-Or, 1996), and this is not affected by age or maturation status. An increase in anaerobic substrates (creatine phosphate, adenosine triphosphate and glycogen), as well as in phosphofructokinase, may result also from a non-specific mix of aerobic and anaerobic training, as shown for 11-13-year-old Swedish boys (Eriksson *et al.*, 1973). Thus, the current finding contributes to the evidence that an increase in glycolytic change is one of the factors that may contribute to training-induced changes in peak muscle power and muscle endurance of children and adolescents (Fournier *et al.*, 1982).

The silat-specific circuit training programme is a form of interval training which consists of series of short-burst, regularly repeated periods of work combined with adequate rest periods. The rest interval during the training, allows for partial restoration of energy stores, slows the accumulation of lactic acid, and delays the onset of fatigue. Although no physiological measures were taken during the training, it is likely that the training would have required the participants to work intensely – with a high heart rate, high metabolic stress (which would be reflected in high lactate levels) and promoting hormonal responses (such as temporarily elevated testosterone or growth hormone), all of these would have promoted adaptations in endurance, squat jump and push-up performance. Thus, it was suggested that during the circuit training programme there were periodic adjustments in work intensity based on training frequency (twice per week) and duration (6-week) that was an adequate stimulus for enhancing training adaptations to the intervention group on the aforementioned variables. This would have been facilitated by the progression and overload of the volume of exercise over the 6-week period.

The current study also revealed that the silat-specific circuit training programme was successful in inducing a significant training effect on RSI and 3-directional jump test performance in the 13-year-old experimental group. The increase in reactive strength corresponds with previous research that has reported improvements, albeit non-significant, in RSI of 13-year-old boys following an 8-week plyometric training programme (Meylan and Malatesta, 2009). Even though participants in the current study undertook limited plyometric drills, it is speculated that the improvement of the RSI can be attributed to neural and neuromotor changes. Hetzler *et al.* (1997) reported that age related differences in anaerobic power cannot explained merely by differences in body size and active muscle mass, suggesting that differences may be explained by qualitative characteristics of the muscle or by the nature of activation of the motor units. One possible process that has been suggested is an increase in motor unit activation (Bar-Or and Rowland, 2004), with RSI performance in childhood suggested to be dependent on maximal motor unit activation (Lloyd *et al*, 2011). It may be that the younger age group had a greater potential to increase motor unit activation as natural development may have resulted in the older group already being able to achieve maximal motor unit recruitment prior to the intervention. Obert *et al.* (2001) reported that maximal power output during all out exercise can be improved in pre-pubertal children after 13-weeks of an aerobic training programme. However, the authors could not identify specific reasons for the large increase in maximal anaerobic power after dominantly aerobic training. The authors reported that several studies have shown neural adaptations in children following several weeks of strength and power training (Blimkie, 1989; McManus *et al.*, 1997; Mercier *et al.*, 1992). These studies reported an enhancement in motor unit recruitment with greater total muscle activation levels and more synchronous activation patterns after training. In the absence of muscle hypertrophy, the authors of these investigation concluded that neurological factors primarily accounted for the better performance reported after training. While, using an interpolated twitch technique, Blimkie (1993) and Ramsay *et al.* (1990) found an approximately 10% increase in the number of activated motor units following 10 weeks of strength training in prepubescent boys. Ozmun *et al.* (1994) reported a 16.8% increase in the integrated electromyogram (EMG) of the elbow flexors in prepubescent girls and boys who trained for 8 weeks. Results from these suggest that training-induced gains in pre-adolescents, especially during the early stages of strength training, are attributable at least in part to increases in motor unit activation (Blimkie and Bar-Or, 1996; Bar-Or and Rowland, 2004). Results of the present study support the ability to make neural control adaptations following training, but these adaptations were limited to the younger age group who are likely to have an immature central nervous system (CNS) that is still developing and may be more trainable compared to older/more mature children.

RSI is an important indicator of the stretch-shortening cycle (SSC), which plays an important role in sport performance (Lloyd *et al.*, 2009; Lloyd *et al.*, 2011). The increased power of the SSC post-training could have been induced by various neuromuscular adaptations, including motor unit activation, the stretch-reflex and the storage and reutilisation of elastic energy. Such adaptations would lead to greater muscle stiffness at ground contact resulting in a fast recoil of the muscle and subsequent better use of the elastic energy; greater muscle activity as a result of an earlier activation of the stretch reflex; and desensitization of the Golgi tendon organs, allowing the elastic component of muscles to undergo greater stretch (Meylan and

Malesta, 2009). Because no physiological measurements (e.g. electromyography, motor units activation, muscle stiffness) were taken in the current study, the underlying adaptations induced by the current training remain hypothetical. However, as RSI is to a large degree dependent on ground contact time, then changes to the contact time (CT) would impact on RSI performance (Lloyd, 2011). The 32% improvement observed for CT for the E13 group would suggest adaptations in the stretch-reflex response, as increasing stretch-reflex contribution is known to reduce ground contact time during rebounding exercise (Oliver and Smith, 2010). However, these adaptations would have been limited to the younger intervention group as E16 showed no improvement in RSI.

Other factors besides increase neuromuscular drive may also play an important role in the determination of training-induced strength and power gains; it has been suggested that part of the performance gain may simply reflect improved motor co-ordination (especially during the initial stages of training) (Blimkie and Bar-Or, 1996). Such a factor might be speculated to underpin the improvement in 3-directional jump performance in E13 following training. The explosiveness of changing direction, agility, balance and co-ordination relates this exercise to demand complex neuromuscular activity and co-ordination. Co-ordination is probably a more important contributor to performance gains in more complex, multi-joint exercises, than in less complex and more isolated actions (Blimkie and Bar-Or, 1996). Ramsay *et al.* (1990) indirectly support this contention, showing that training resulted in larger percent improvements in 1 RM arm curl and leg press strength (specific exercises performed during training), than in non-specific isometric elbow flexion and knee extension strength. However, the magnitude of the total strength gains observed in that study and the increases in strength observed during the second phase of training (when learning and co-ordination effects would be minimal) for many of the strength measures make it unlikely that this is the only factor contributing to increased strength (Ramsay *et al.*, 1990). Thus, improvements in both RSI and the 3-directional jump test in a relatively short period of time and in the absence of improvements in the squat jump, suggests the improvements have more of a neural basis, requiring whole body co-ordination, rapid movement and motor unit recruitment. These gains were only observed in the younger experimental group where the CNS is still likely to be developing and may be more sensitive to training (compared to the older group).

Part of the process of strength training is to increase the nerve's ability to generate constant, high frequency signals that will allow a muscle to contract with maximum speed and force. It is this neural training that may cause several weeks worth of rapid gains in strength, which the level off once the nerve is producing maximum contractions and the muscle reaches its physiological limit. Subsequently, training will cause the muscular strength to increase through myofibrilar or sarcoplasmic hypertrophy and metabolic fatigue becomes the factor limiting contractile force. The 13-year-old might have improved RSI and 3DJ as they had the potential to make improvements in high frequency contractions to improve speed and strength. Conversely, the 16-year-old might not have had much capacity to improve these factors but could improve myofibrilar or sarcoplamis hypeortrophy, resulting in an improved SJ.

As discussed above, the experimental groups made significant gains in several components of fitness following the training programme. However, some changes in the control groups were also observed. Niether of the control groups demonstrated a significant change in yo-yo, squat jump, push-up, RSI or 3-directional jump. This suggests the circuit training was able to promote training gains that were not apparent from silat training alone. Nevertheless, there were significance changes in CT and jumping height in rebound jumps in control groups (13-year-old in jumping height and 16-year-old in contact time of rebound jump performance), however, there was no overall change in the RSI which is the primary indicator of rebound jump test performance. Meanwhile, both control groups showed significant improvements in the explosive medicine ball throw; and the 16-year-old group improved significantly in handgrip performance. It was speculated that these improvement may reflect the fact that the control groups spent more time performing their normal silat training compared to the intervention-group, which may have involved more upper body conditioning than being involved in the circuit training intervention (i.e. more grappling and “catching” sport-specific skills training in silat). The current study is not the only research that has found significant improvements of control groups in paediatric training studies. In a study of the effect of 12 weeks of strength training on anaerobic power in prepubescent males, Hetzler *et al.* (1997) failed to produce significant increases in mean and peak anaerobic power in the experimental groups, but the control group had significant within-group increases in both measures relative to body weight. Moreover, the authors suggested that the control group seemed to be in their adolescent growth spurt while the experimental groups may have already passed theirs. Consequently, the observed gains observed in the control groups may result from a combination of both natural growth and/or their continued involvement in silat training.

6.5 Conclusion

This was the first study to examine the changes in the fitness of young performers following a silat-specific circuit training programme. While the time*intervention interaction demonstrated some positive benefits (over and above the control groups) of the circuit training programme, limited age*time*intervention interactions were found. However, an examination of the individual group responses revealed some differentiated responses. The 16-year-old experimental group showed a significant training response in the yo-yo and squat jump, which is possibly linked to maturational influences combined with the training effect. Therefore, gains in endurance and squat jump are more pronounced in more mature boys and may be associated with hormonal status. While, both 13 and 16-year-old experimental groups improved push-up performance, suggesting there is no age or maturation effect on the trainability of local muscular endurance. Only the 13-year-old experimental group improved significantly post-intervention in RSI and 3-directional jump, suggesting greater neural gains in younger children due to the improved motor co-ordination and activation. Collectively, these findings demonstrate that a 6 week circuit-training programme can promote positive adaptations in silat-specific fitness, and that these training gains may differ depending on age and maturational status.

CHAPTER SEVEN

Study Four: Effect of Circuit Training on Fitness and Match Performance of Young Silat Performers – A Case Study

7.1 Introduction

The scientific approach to understand the demands of combat sports and the physiological characteristics that contribute to success has received a lot of attention for the past 20 years, particularly in those sports included in the Olympic Games (Heller *et al.*, 1998; Kazemi *et al.*, 2006; Smith, 2006; Yoon, 2002; Callister *et al*, 1991; Guidetti *et al.*, 2002; Khanna and Manna, 2006). There are also several other combat sports that have received scientific attention and used an empirical approach to inform training and the fitness requirements of sports such as mixed martial arts (Amtmann *et al*, 2008; Bounty *et al.*, 2011), karate (Francescato *et al.*, 1995; Beneke *et al*, 2004; Doria *et al*, 2009), muay thai (Turner, 2009; Crisafulli *et al.*, 2009), kickboxing (Buse and Santana, 2008; Zabukovec and Tiidus, 1995) and silat (Aziz *et al.*, 2002). Moreover, Douris *et al.* (2004) reported that participation in martial arts increases strength, anaerobic capacity, balance, and flexibility as well as an overall improvement in cardiorespiratory fitness, which is supported by the work of other researchers (Heller *et al.*, 1998; Hain *et al.*, 1999) and in part by Study 3. However, only a few studies have examined young athlete's fitness and training requirements (Violan *et al*, 1997; Melhim, 2001) in combat sports. This is important as compared with training studies in adults, relatively less is known about the trainability of adolescents (Naughton *et al.*, 2000). Importantly, adolescence is a stage of development characterised by unprecedented physiological changes in musculoskeletal, cardiorespiratory and reproductive systems of the body (Naughton *et al.*, 2000). It has also been argued that it is important for coaches to fully maximise a young athlete's potential at every stage of development, as proposed in the Long-Term Athlete Development (LTAD) model (Balyi and Hamilton, 2004). However, to the author's knowledge there is no published research documenting adolescent's physical characteristics and training in silat. Consequently, the research presented throughout this thesis provides valuable information regarding the fitness characteristics of male and female silat performers aged 13 to 16-year-old (Study 2) and also the effect of a silat-specific training programme on the fitness development of young silat performers.

Study 2 provided the evidence that silat is characterized by well-developed endurance, upper and lower body strength and power and to some degree speed of kicking. However, there were differences in the responses of males and females; which are likely due to gender-specific maturational differences. The older/more mature boys outperformed their younger counterparts on a number of measures of physical fitness (grip strength, medicine ball throw, push-ups, squat jump and endurance). Thus, improvements in boys were concomitant with maturational factors such as hormone development, which leads to increased muscle mass and internal organ size (Viru *et al*., 1999) providing strength and endurance benefits respectively. Results from Study 2 agreed with general developmental patterns (Beunen and Malina, 1988; Malina *et al*., 2004) and suggested that training adaptations in the males might be maximised around the time of and just proceeding PHV, as this represented a period of accelerated adaptation.

It was then shown in Study 3 that six weeks of silat-specific circuit training provided significant improvements in several fitness variables. The improvements observed across a number of groups were dependent on the type of training employed (circuit training versus traditional silat training) and the age/maturation status of the participants. Thus, Study 3 concluded that improvements in fitness following a circuit training intervention appeared to be related to age and maturation, whereas the traditional silat training may be better at improving upper body strength and power.

Study 3 demonstrated improvements in fitness from a group response. Following a circuit training programme gains in endurance and squat jump are more pronounced in more mature boys and may be associated with hormonal status, while gains in jumps requiring high levels of co-ordination suggest greater neural gains in younger children. As coaching is a deliberate act of intervention in sport with the intention of improving performance (Brown and Hughes, 1995), any improvements in performance (or fitness) will attract coaches interest, particularly at an individual level. It has been reported that most training studies are able to report gains in fitness in the sample populations involved in those studies (Obert *et al*., 2001; Kotzamanidis, 2006; Hunter *et al*., 1987). However, in sports (particularly in silat), the coach is often most interested in gains in competitive performance. This is true as the most content valid way to measure skill is through game play (Brown and Hughes, 1995). In individual sports, such as silat, coaches are likely to be most interested in the individual response to training and any transference into competition, but research (e.g. Keren and Epstein, 1981; Fournier *et al*., 1982; Hunter *et al*., 1987; Mosher *et al*., 1994; Hetzler *et al*., 1997; Izumi *et al*., 1996; Obert *et al*., 2001; Kotzamanidis, 2006; Teng *et al*., 2008; Buchheit *et al*., 2008; Baudry and Roux; 2009; Meylan and Malatesta, 2009; Granacher *et al*., 2011) tends to focus on a group response and ignores individual responses and the transference of improved fitness into competition.

While Study 3 demonstrated a circuit training programme improved fitness based on a group analysis this does not mean that all individuals would have benefitted equally, or that any gains in fitness would help competitive performance. Due to the individual variability inherent to athletic performance, it is important for coaches to determine the strength and weaknesses of each exponent and identify what factors training should focus on to enhance performance in silat competition (i.e. the ability of kicking continuously). What research often fails to do is establish whether any improvement in fitness (following a training intervention) actually translates to improved competitive performance. This is evident throughout the scientific literature in martial arts (Thomas *et al*., 1989; Aziz *et al*., 2002; Heller *et al*., 1998; Lin *et al*., 2004; Yoon, 2002; Thompson *et al*., 1991; Chia *et al*., 2006; Borkowski *et al*., 2001; Teng *et al*., 2008) and sport in general (Hughes, 1994; Montgomery *et al*., 2010; Hunter *et al*., 1987; Mosher *et al*., 1994; Hetzler *et al*., 1997; Izumi *et al*., 1996; Obert *et al*., 2001; Kotzamanidis, 2006; Meylan and Malatesta, 2009; Granacher *et al*., 2011). Therefore objective measures are required to enable the coach to understand whether individual improvements in fitness have a positive impact on competitive performance. The above points are important as in many sports physical fitness may not be the primary determinant of success in youth sports (Reilly *et al*., 2000; Burgess and Naughton, 2010; Bailey *et al*., 2010), so by simply improving fitness may not guarantee improved competitive performance. Moreover, the reason research tends not to report on the transference of improved fitness to competitive performance is because it is difficult to do.

Improvements in a number of fitness components following a plyometric programme have been shown to directly improve competitive performance in a 3 km run (Spurrs *et al*., 2002). However, whether gains in fitness translate to improved competitive performance in sports requiring more of a skill element is less clear. A study by

Krustrup *et al*. (2003) has shown that improving endurance (yo-yo) allowed footballers to complete more high-intensity during a match, which is associated with crucial aspects of match-play. Furthermore, the test itself seems to have construct validity, evaluating the athlete's ability to repeatedly perform intense exercise and recovery from intensive exercise. Compared to conventional treadmill and $\dot{V}O_{2\,max}$ testing, the yo-yo intermittent recovery test was correlated to high-intensity exercise performance during a match (Krustrup *et al*., 2003). A case study approach may allow for a more detailed analysis of individual responses and transference of fitness to competition, and also provides an approach that is more "real-world" and more likely to be employed by coaches. It is not known if this "transference" will differ between individuals of differing age, who may experience different fitness training gains (as reported in Study 3), which may have different effects on competitive performance.

Developing a sport-specific training programme to enhance physical fitness for competition in the young silat performers has never been researched before; such an approach may be applicable to coaching to develop specific silat training programme, particularly in young athletes. Implementing this approach is useful to the silat coach for examining individual responses to any specific intervention or training programme. Moreover, a case study can help the silat coach to evaluate the relationship between training programme stress (intensity, frequency, duration, density and specificity) and the training outcome (competitive performance). However, it is not known if improving fitness can enhance an exponent's performance in silat competition. Further research is required in order to examine whether improvements made throughout a training programme can help improve competitive performance. In particular whether improved fitness allows an exponent to maintain a greater work/complete a greater number of strikes and better avoid being hit, both of which contribute to winning a match.

7.1.1 Aims of The study

The aims of the study were:

- To use a case study approach to describe the activity pattern of individual exponents during competitive fights completed before and after a 6 week circuit training programme.
- To examine the above responses in 13-year-old and 16-year-old exponent.

7.2 Methodology

7.2.1 Participants

Four silat exponents aged 13 (*N*=2) and 16-year-old (*N*=2) served as participants for this study. All participants were from the same population that underwent the training programme described in Study 3. Exponents were chosen based on their age, maturation, weight, competitive standard none had participated in an official silat match, and initial fitness performance (Table 7.1). For each age there was one control and one experimental participant. Biological maturity was assessed via the non-invasive technique proposed by Mirwald *et al.* (2002) using measures of standing height, sitting height, age and body mass. Descriptions of individual characteristics are presented in Table 7.1. None of the participants reported injury at the time of sparring, and all were involved in regular silat training. All information letters and assent forms outlining the study details and scope of the child's involvement were handed out to the children. Written informed assent was obtained from the child as well as the consent of the parent/guardian consent. Participants were asked to wear their silat uniform with footwear and to avoid drinking, eating and participating in any exercise activities up to two hours before sparring. All procedures were granted ethical approval by the University Research Ethics Committee.

Table 7.1: Descriptive details for all participants involved in the case study.

Group	Height (cm)	Arm Length (cm)	Sitting Height (cm)	Body Mass (kg)	Age (years)	Estimated age at PHV (years)	Years from PHV
C13	138.3	64.4	71.4	29.65	12.33	14.53	-2.20
E13	143.0	65.2	72.0	31.75	12.92	15.04	-2.12
C16	158.5	78.1	83.3	75.70	15.67	14.50	1.17
E16	169.2	82.1	87.0	84.25	15.83	14.13	1.70

C13 = age 13 control group; E13 = age 13 experimental group; C16 = age 16 control group; E16 = age 16 experimental group

7.2.2 Procedures

The participants took part in Study 3 and followed all the activities described in the training programme. In addition, the participants in the current case study were paired (based on age) and required to spar under competition rules before and after the training programme. The sparring took place indoors on the silat matt with the same dimensions as a silat olahraga ring and followed all the rules of a silat olahraga competition (Anuar, 1987). A qualified silat instructor was appointed as referee for the match. The participants performed a 15-minute warm-up before being allowed to fight. All matches were held between 1800 – 2100 hours and the temperature ranged from 27-30°C and humidity was between 64-70%. The sparring consisted of 3 rounds of 2 minutes, each followed by 1-minute of recovery, during which the subject passively rested at their own corner. The stoppages by the referee are not included in the actual bout time, so the actual duration of each round and thus total match time is usually longer than the two and six minutes schedules, respectively (Aziz *et al*., 2002). The round consisted of a series of attack and defensive actions, and only strikes with either the arms or legs are considered legal. The exponents were verbally encouraged to perform maximally through the match. Each match was recorded using a video camera (JVC, Everio model). Each participant was required to attend 1 silat match during the pre- and post-training programme. Participants were advised not to eat at least 2-hours before the silat match. The pre-matches were held 2-days before the starts of the circuit training, while the post-matches were organised 6-days (which included 2 days of post-test fitness testing) after the 6-weeks of training. All matches were converted into .mpg files and analysed using the same procedure used in Study 1 (pp. 115).

7.2.3 Statistical Analyses

All the raw data generated by the FOCUS X2 (Elite Sport Analysis, Delgaty Bay, Scotland) as used in the Study 1 (pp. 113-127) was exported into a Microsoft Excel Spreadsheet and then transferred into SPSS for more detailed analysis. The system was used to identify 14 different types of event or action performed by both exponents as well as the start and end of action periods. Information could be entered into the computer system using a 'Mouse', via representation on the screen of the silat match, and specially designed screen functions for each exponent (experimental or control group), action (14 different types of actions) and outcome (4 different types of outcomes). The display in the computer split the action into 14 cells of silat actions such as block and kick, block and punch, block and swipe, block, catch, dodge, fake kick, fake punch, kick, *others*, punch, self-release, swipe and topple down categories. The distribution of outcomes are hit target, miss opponent, hit elsewhere, and none or none available and were analysed and used as an index of performance. Statistical analysis was conducted using Statistical Package for Social Scientists, version 14.0 (SPSS, Chicago, IL). Inferences regarding the magnitude of the difference in individuals fitness scores pre-post training were based on an estimated smallest worthwhile change (SWC) as purported by Batterham and Hopkins (2006). The SWC was calculated for each fitness variable using data for 13 and 16-year-old pooled from Study 2 and Study 3 (pre-training). This pooling provided a larger sample to estimate the SWC for each age group. The SWC was calculated using the method proposed by Hopkins (2002). Whereby, 0.2 of the between-subject standard deviation (SD) for each age group was used to represent the SWC. The SWC was then expressed as a percentage (%) of the mean for each group. A change in fitness > SWC in this study was deemed as worthwhile.

7.3 Results

7.3.1 Fitness Performance of 13-year-old

The pre-and post-training fitness of the 13-year-old control (C13) and experimental (E13) exponents is shown in Table 7.2. The result shows that the SWC of 13-year-old participants (appendix T) is 5.53% in handgrip, 11.75% in push-ups, 5.45% in medicine ball throw (MedBall), 12.8% in yo-yo intermittent endurance test (yo-yo), 4.46% in squat jump (SJ), 5.14% in jumping height of rebound jump (RJH), 7.64% in reactive strength index (RSI) and 6.12% in contact time (CT) of rebound jump (RJ), 4.28% in 3-directional jump (3DJ), 6.30% in 3-kick test (3KT) and 4.5% in 20-kick tests (20KT).

The fitness variables of the E13 showed a positive change ≥ SWC in push-ups, RSI and CT of RJ, 3DJ, 3KT and 20KT tests; a trivial change (i.e. change < SWC) in handgrip, MedBall and yo-yo performance; and, a negative (unwanted) change $\geq$ SWC in SJ and RJH. Meanwhile, the results of the C13 showed a positive change $\geq$ SWC in yo-yo, RSI and CT of RJ; a trivial change (i.e. change < SWC) in handgrip, MedBall, SJ, 3KT and 20KT; and, a negative (unwanted) change $\geq$ SWC in push-ups, RJH and 3DJ.

Table 7.2: Pre- and post-training fitness of the control and experimental 13-year-old participants.

Fitness Variable	Control participant (*N= 1*)				Experimental participant (*N= 1*)			
	Pre-test	*Post-test*	*Differences*	*Changes (%)*	*Pre-test*	*Post-test*	*Differences*	*Changes (%)*
HANDGRIP (N)	222.61	221.63	-0.98	-0.4	223.59	219.67	-3.92	-1.8
PUSHUP	33	23	-10	-30.3[b]	10	27	17	170.0[a]
MEDBALL (cm)	148.0	147.6	-0.4	-0.3	148.0	153.0	5.0	3.4
YOYO (m)	840	1600	760	90.5[a]	680	760	80	11.8
SJ (cm)	36.96	37.36	0.40	1.1	36.02	32.27	-3.75	-10.4[b]
RJH (cm)	33.88	29.92	-3.97	-11.7[b]	32.48	28.74	-3.74	-11.5[b]
RJRSI	0.77	1.75	0.98	127.3[a]	0.81	1.34	0.53	64.8[a]
RJCT (ms)	447	170	-277	62.1[a]	361	177	-184.5	51.1[a]
3DJ (ms)	1828	2046	218	-11.9[b]	2311	2146	-165	7.1[a]
3KT (ms)	2028	1914	-114	5.6	2427	1535	-892	36.8[a]
20KT (ms)	16568	16112	-456	2.8	13152	12182	-970	7.4[a]

a = a positive change $\geq$ SWC; b = a negative (unwanted) change $\geq$ SWC. Negative value of differences in RJCT, 3DJ, 3KT & 20KT means improvement in the score and Changes (%); MEDBALL = medicine ball throw; RJH = rebound jump height; RJCT= rebound jump contact time; RJRSI=rebound jump reactive strength index; 3DJ=3-directional jump; 3KT=3-kick test; 20KT=20-kick test.

7.3.2 Fitness Performance of 16-year-old

The pre-and post-training fitness of the 16-year-old control (C16) and experimental (E16) exponents is shown in Table 7.2. The result shows that the SWC of 16-year-old (Appendix U) participants is 3.10% in handgrip, 7.35% in push-ups, 4.50% in medicine ball throw (MedBall), 11.64% in yo-yo intermittent endurance test (yo-yo), 3.92% in squat jump (SJ), 5.08% in jumping height of rebound jump (RJH), 4.07% in reactive strength index (RSI) and 5.13% in contact time (CT) of rebound jump (RJ), 6.02% in 3-directional jump (3DJ), 7.57% in 3-kick test (3KT) and 2.98% in 20-kick tests (20KT).

The fitness variables of the E16 showed a positive change ≥ SWC in handgrip, push-ups, MedBall, RSI and CT of RJ; a trivial change (i.e. change < SWC) in yo-yo performance, SJ, 3DJ, 3KT and 20KT tests; and, a negative (unwanted) change ≥ SWC in RJH. Meanwhile, the results of the C16 showed a positive change ≥ SWC in handgrip, push-ups and 3DJ; a trivial change (i.e. change < SWC) in Medball, yo-yo, SJ, and CT of RJ; and, a negative (unwanted) change ≥ SWC in RJH, RSI of RJ, 3KT and 20KT tests.

Table 7.3: Pre- and post-training fitness of the control and experimental 16-year-old participants.

Fitness Variable	Control participant (*N= 1*)				Experimental participant (*N= 1*)			
	Pre-test	*Post-test*	*Differences*	*Changes (%)*	*Pre-test*	*Post-test*	*Differences*	*Changes (%)*
HANDGRIP (N)	361.87	374.61	12.74	3.5[a]	322.64	366.77	44.13	13.7[a]
PUSHUP	31	37	6	19.4[a]	14	18	4	28.6[a]
MEDBALL (cm)	305.7	312.3	6.6	2.2	194.7	284.9	90.2	46.3[a]
YOYO (m)	400	400	0	0.0	440	440	0	0.0
SJ (cm)	23.74	24.28	0.54	2.3	26.74	26.29	-0.45	-1.7
RJH (cm)	24.25	20.68	-3.57	-14.7[b]	25.84	22.19	-3.65	-14.1[b]
RJRSI	0.47	0.41	-0.06	-12.8[b]	0.45	0.51	0.06	12.2[a]
RJCT (ms)	521	497	-24	4.7	454	426	-27.5	6.1[a]
3DJ (ms)	2867	2441	-426	14.9[a]	2646	2573	-73	2.8
3KT (ms)	2034	2190	156	-7.7[b]	2299	2455	156	-6.8
20KT (ms)	13865	21634	7769	-56.0[b]	16592	16881	289	-1.7

a = a positive change ≥ SWC; b = a negative (unwanted) change ≥ SWC. Negative value of differences in RJCT, 3DJ, 3KT & 20KT means improvement in the score and Changes (%); MEDBALL = medicine ball throw; RJH = rebound jump height; RJCT= rebound jump contact time; RJRSI=rebound jump reactive strength index; 3DJ=3-directional jump; 3KT=3-kick test; 20KT=20-kick test.

7.3.3 Match Performance

7.3.3.1 Competition Performance Pre- and Post-Training in 13-year-old Participants

The pre- and post-match information can be observed in Table 7.4 and 7.5. The overall frequency highlights the increase of total frequency of actions post-training (207 actions) compared to pre-training (170 actions) with both exponents E13 (70 to 95 actions) and C13 (81 to 100 actions) performing more total actions post-training. Overall, there was decrease in all silat action variables (blocks, punches, and kicks) in the post-training match except in other activities (dodge, catch, and off- fight contact actions/low intensity activities [*others*]), which shows a big increase from 28 to 73 actions. The E13 performed 15 more kicking actions and 20 more other actions (dodges) in the post-training match. Whereas, the C13 performed more punches (increased by 2 actions), blocks (increased by 4 actions) and other (dodges) actions in the post-training match compared the pre-training match. The E13 shows a decrease in the number of blocks (decreased by 7 actions) and punches (decreased by 3 actions), while C13 shows a bigger decreases in kicks, with a reduction of 19 actions post-training compared to the pre-training match.

Table 7.5 shows the increase in the number of total successful 'hit target' outcomes pre- and post-training in E13 (from 17 to 28 actions) or C13 (from 15 to 40 actions). The number of successful block performance in E13 decreased (decreased 6 actions) along with the total number of block actions post-training (Table 7.4). Even though there was an increase in the overall frequency of kicks due to the training intervention in E13; the successful number of kicks decreased by 3 actions. There was an increase in the number of 'miss opponent' (35 actions kick outcomes in E13.

Table 7.4: Pre- and post-training competition overall frequency of events during round 1, 2 and 3 for the 13-year-old group.

Action	Pre-Training Overall Frequency			Total	Post-Training Overall Frequency			Total
	EG	*CG*	*Others*	Frequency	*EG*	*CG*	*Others*	Frequency
Block	9	5	0	**14**	2	9	0	**11**
Kick	56	64	0	**120**	71	45	0	**116**
Punch	3	5	0	**8**	0	7	0	**7**
Other	2	7	19	**28**	22	39	12	**73**
Total	70	81	19	**170**	95	100	12	**207**

* EG = Experimental group silat exponent; CG = control group silat exponent; *Others* = means off fight-contact actions or low intensity activities performed by both exponents; Other = any silat actions other than block, kick and punch

Table 7.5: Pre- and post-training competition overall outcomes of events during round 1, 2 and 3 for the 13-year-old group.

Action	Pre-Training Overall Outcomes							Total Outcomes	Post-Training Overall Outcomes							Total Outcomes
	Hit elsewhere		*Hit target*		*Miss opponent*		*None*		*Hit elsewhere*		*Hit target*		*Miss opponent*		*None*	
	EG	*CG*	*EG*	*CG*	*EG*	*CG*			*EG*	*CG*	*EG*	*CG*	*EG*	*CG*		
Block	2	0	7	5	0	0	0	**14**	1	8	1	1	0	0	0	**11**
Kick	21	28	8	5	23	24	11	**120**	2	1	5	2	58	35	13	**116**
Punch	0	0	0	1	2	2	3	**8**	0	0	0	3	0	3	1	**7**
Other	0	1	2	4	0	2	19	**28**	0	0	22	34	0	5	12	**73**
Total	23	29	17	15	25	28	33	**170**	3	9	28	40	58	43	26	**207**

* EG = Experimental group silat exponent; CG = control group silat exponent; Other = any silat actions other than block, kick and punch; None = means action that did not count as an outcome by the researcher; Hit elsewhere = any attacking or defensive silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area); Miss opponent = any attacking or defensive silat actions that miss the 'target' or failed to deliver points. None = any attacking or defensive silat actions that did not contribute to point score.

7.3.3.2 Competition Performance Pre- and Post-Training in 16-year-old Participants

The pre- and post-match training information can be observed in table 7.6 and 7.7. The overall frequency of the pre- and post-training events between both silat exponents shows that there were decreases in the total frequency of actions post-training (135-actions) compared to pre-training (222-actions). The overall frequency of kicks showed an increase (increased by 20-actions) compared to other silat activities (decrease in block, punch and other actions) post-training match. The overall performance of the experimental exponent (E16) decreased by 23-actions across all silat actions (block, punch and other actions) except in kicks, which increased from 37 to 63-actions post-training. Overall performance of the control exponent (C16) decreased by 54 actions (block, kick and punch) except in other actions (catch and topple down), which was increased by 4 to 10-actions following the training programme.

Table 7.7 shows the decrease in the number of successful 'hit target' outcomes pre- and post-training either in E16 (from 44 to 4 actions) or C16 (from 38 to 19 actions). There was a decrease in the number of successful hit outcomes in blocks (decreased by 26 actions), punches (decreased by 12 actions) and other actions (decreased by 2 actions); while there was no change in the number of successful kick outcomes in E16 in post-training match. There were increases in the number of successful kicks (increased 1-action) and other actions (increased 2-action) of C16 post–training. However, there were decrease in both successful blocks (decreased by 7 actions) and punches (decreased by 15 actions) post-training compared to the pre-training match performance.

Table 7.6: Pre- and post-training competition overall frequency of events during round 1, 2 and 3 for the16-year-old group.

Action	Pre-Training Overall Frequency			Total Frequency	Post-Training Overall Frequency			Total Frequency
	EG	*CG*	*Others*		*EG*	*CG*	*Others*	
Block	35	22	0	**57**	7	9	0	**16**
Kick	37	39	0	**76**	63	33	0	**96**
Punch	25	43	0	**68**	2	2	0	**4**
Other	3	4	14	**21**	0	10	9	**19**
Total	100	108	14	**222**	72	54	9	**135**

* EG = Experimental group silat exponent; CG = control group silat exponent; *Others* = means off fight-contact actions or low intensity activities performed by both exponents; Other = any silat actions other than block, kick and punch

Table 7.7: Pre- and post-training competition overall outcomes of events during round 1, 2 and 3 for the 16-year-old group.

Action	Pre-Training Overall Outcomes							Total Outcomes	Post-Training Overall Outcomes							Total Outcomes
	Hit elsewhere		*Hit target*		*Miss opponent*		*None*		*Hit elsewhere*		*Hit target*		*Miss opponent*		*None*	
	EG	*CG*	*EG*	*CG*	*EG*	*CG*			*EG*	*CG*	*EG*	*CG*	*EG*	*CG*		
Block	4	4	28	16	3	2	0	**57**	2	0	2	9	3	0	0	**16**
Kick	14	8	1	3	22	27	1	**76**	39	2	1	4	23	27	0	**96**
Punch	2	0	13	16	9	24	4	**68**	0	0	1	1	1	1	0	**4**
Other	0	0	2	3	1	1	14	**21**	0	0	0	5	0	5	9	**19**
Total	20	12	44	38	35	54	19	**222**	41	2	4	19	27	33	9	**135**

* EG = Experimental group silat exponent; CG = control group silat exponent; Other = any silat actions other than block, kick and punch; None = means action that did not count as an outcome by the researcher; Hit elsewhere = any attacking or defensive silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area)'; Miss opponent = any attacking or defensive silat actions that miss the 'target' or failed to deliver points. None = any attacking or defensive silat actions that did not contribute to point score.

7.4 Discussion

For analysis purposes, each participant was treated as a single subject design case study. Advantages of this design were such that observed changes in data obtained could be more confidently attribute to specific interventions for each individual (Brown and Hughes, 1995). Both qualitative and quantitative data (as in this study) are regarded as legitimate sources of information in case study designs (Smith, 1988).

Early observation of pre-training of fitness performance showed that both control and experimental groups of 13 and 16-year-old had similar pre-test values for numbers of variables. However, the C13 performed better in push-ups, yo-yo and 3DJ; whereas E13 in 20KT. The C16 performed better in push-ups, medicine ball throw and 20KT. Post-training results showed the improvement (a positive change > SWC) in fitness performance of E13 was better than C13 in upper body muscular endurance and lower body endurance and agility. The E16 improved upper body performance in isometric strength, muscular endurance and power with addition in lower body RSI. The C13 improved more than E13 in endurance and lower body RSI, while the C16 more in upper body isometric strength and muscular endurance and lower body agility in post-training. Overall, changed in fitness did not reflect group responses in Study 2 with post-training fitness showed all participants experienced some positive gains (i.e. > SWC) in performance in current study.

7.4.1 Effect of Training on Match Performance in 13-year-old Participants

The analysis of match performance of the 13-year-old participants before and after the 6-weeks silat-specific training programme will be explained based on two elements; frequency and outcomes of the silat actions in the match. In this study the following observations were made:

1. ***Other action***. The study shows a large improvement (160% increase) post-test in other actions in both participants. Here, the other actions referred to any silat actions other than blocking, kicking and punching (i.e. low intensity actions, catching, dodging, swiping, self-release or topple down actions). Further analysis on the match (Appendix P and Q) shows that the dominant action of the other actions was the dodge. During the pre-test match there were no dodge actions applied during the match, this suggests both E13 and C13 exponents had not been exposed to this defensive movement yet by their coach. The increase of (the E13 increased by 22-actions and C13 by 32-actions) dodge actions in both participants was likely due to the introduction of this technique by the silat coach during the 6-week training programme. Therefore, technical training at this young age may give more of an impact on match performance than physical conditioning. The importance of evading/dodging strikes in a silat match is one of the defensive skills that require exponents to avoid being hit; moving the body quickly either to the left, right or retreating. There are 10 techniques related to evading/dodging techniques in silat olahraga that have been discussed in detailed by Anuar (1993). This post-match match analysis showed that both exponents have the ability to evade the strike from their opponent well with 100% success of this action (Appendix Q). Thus, current study shows that dodge or evading skills are the best defensive technique in 13-year-old group and can be learnt during a 6 week training period. Moreover, both the C13 and E13 improved aspects of fitness that may be associated with improved movement patterns, with improvements in RSI and 3DJ greater than the SWC. However, it seems much more likely that the improvement in dodging was due to this skill being taught to participants during the normal silat training.

2. ***Block action***. There was a 21% decrease in the number of blocking actions pre- to post-training. The percentage of successful blocking actions dropped from 85% in the pre-training match to 18% post-training match. There was an increase in number of blocks in C13 but not in E13 (5 to 9 for C13 and 9 to 2 for E13). As the E13 improved their dodging skills post- intervention period, they became less reliant on the need to block. Moreover, as a consequence of E13 increasing the number of kick actions, C13 was required to increase the number of dodge and blocking actions in the post-training. This is similar with the results in Study 1, where when one exponent is dominant in attack, the other opponent has to defend to avoid being hit. Therefore, increasing the number of kicks made E13 more dominant in the post-training match (E13 won the post-training match).

3. ***Punch action***. There was a 12.5% decrease in the number of punches in the post-training match. However, there was an increase in the number of successful punches of from 12.5% to 42.8% in C13, while there was no punch action in post-test match in E13. It was suggested that the increase in punches was due to decrease in the number of kicks in C13, reflecting a change in fighting/style tactics post-training interventions. This again suggests that skill/tactical coaching, or adapting to an opponent's style (i.e. as E13 increase kicks, C13 increase punches in post-training match) may have more of an influence on competition performance than the physical conditioning. However, E13 did make large improvements in their 3KT and some gains in 20KT following the circuit training, and this may have encouraged them to be more reliant on kick actions when attacking their opponent.

4. ***Kick action***. The results show that there was 3% decrease in overall kick frequency post-training. The overall outcome shows that the successful kicks that hit the target

was better in the pre-training match (11%) compare to post-training match (7%). This was partly due to the improvements made by both participations at dodging/evading, consequently it became more difficult for them to hit their opponents target area during the silat match.

It is suggested that due to the circuit training E13 (improved 3DJ, 3KT and 20 KT) benefited from silat-specific fitness gains, consequently increasing the amount of kicks in the post-training match compared to the C13 (small improvement in 3KT and 20KT) suggest some transference of improved fitness to competition in E13. Nevertheless, the small improvement made by E13 in 20KT may have allowed him to kick more in the post-training match. It is also suggested that the big improvement in RSI may have helped C13 to avoid or dodge kick strikes by E13.

5. ***Low-intensity action (others)***. There was also a decrease in the number of low-intensity actions in the post-training match of 13-year-old. This decrease might due to less disruption of the match, with less actions of catch, no self-release and swipe occurring during the post-training match, no referee judgement was needed to stop the fight and the match continued without any disruption. It is also suggested that improved in whole body (yo-yo) or local muscular (push-up) endurance observed post-training, allowing participants to maintain a greater work rate and complete a greater total number of high-intensity actions (increase from 151 in pre-training to 195 actions in post-training match).

6. ***Overall outcomes***. The current study shows that there was an increase in ‘hit target’ overall outcomes, increasing from 18.8% to 32.8% pre- to post-training match.

However, analysis showed that there were only increases in punch (increased by 2-actions) and other (increased by 36-actions) activities. Conversely, there were decreases of some hit target outcomes; 83% on block and 46% on kick. These results suggested that the decrease of successful blocking actions was due to the increase of other activities (e.g. dodge).

During the pre-training match E13 and C13 did not perform any successful dodge, but E13 successful dodged 22 times and C13 32 times in the post-training match (Appendix Q). Moreover, the ability of both exponents to dodge attacks (e.g. kick strikes) raised the 'miss opponent' outcomes (93-actions) post-training. This is explained by other results, which showed that there was no dodge action in the pre-training match, most kicks landed either hit elsewhere or were successfully blocked by the other exponent.

7. ***Overall analysis***. Overall analysis of both matches in the 13-year-old group suggested that the E13 performed more kicks and evading actions while C13 increased block and dodge/evading actions in the post-training match. It is speculated that two reasons influenced this outcome; Firstly, the silat syllabus emphasizes basic blocking techniques (hand-block) should be coached during the first three months of the silat training programme. Secondly, both silat exponents benefited from the silat training/coaching and consequently improved dodging/evading actions. Furthermore, the circuit training may have promoted the physical conditioning of E13, with improved kick test performance reflected in increased kicking contribution in the post-training match, requiring C13 to block more.

7.4.2 Effect of Training on Match Performance in 16-year-old Participants

As per the 13-year-old group the analysis of match performance of the 16-year-old group will be explained based on two elements (frequency and outcomes). In this study the following observations were made:

1. ***Other actions***. The study shows a decrease post-training in other actions in the experimental (decrease to zero action) but not in control participants (increase 150%). The C16 performed more actions in other (increased by 6-actions), which relates the improvement of topple down and catch abilities within the silat training (Appendix S). Both E16 and C16 improved aspects of fitness that may be associated with improved catching and topple down techniques, with improvements in handgrip strength greater than the SWC. It is likely the improvement in catching was due to this silat skill being taught to C16 during the normal silat training.

2. ***Block action***. Study 1 highlighted that 11% of the total frequency of activities during a silat match between young adults were blocks. While, the current results shows 8% (pre-test) and 5% (post-test) for 13-year-old and 26% (pre-test) and 12% (post-test) of 16-year-old groups. These values support the importance of this defensive technique in a silat match. A single block action does not deliver a point-score in a silat match, but any block technique (either with hand or leg) that is followed with a legal strike that hits the target (i.e. punch, kick, or topple down) will be awarded an extra bonus point. The results of the current study also reflects that the numbers of block actions can be as high as 26% (pre-training 16-year-old) when both athletes rely more on kick strikes and decrease as low as 5% (post-training 13-year-old) when the exponents improved other skills such as catching or dodging. Thus, it is speculated that the

number of block actions in the current study moves close to adults (12% in post-match 16-year-old and 11% in Study 1) once the exponents increased age, training history, and improvements of other attacking and defensive techniques in silat.

3. ***Punch action***. Early observation shows that the biggest decrease (94%) of match actions was in the punch. It was observed that C16 produced more punches than E16 in the pre-training match. However, this is not the case in the post-training match as there was a big decrease in the overall frequency of punching for both exponents (E16 decreased from 25 to 2 actions and C16 decreased from 43 to 2 actions in pre- to post-training match). Kazemi *et al*. (2006) reported that success in competition is indeed a combination of physical attributes, talent, skill, technique, determination, psychological preparedness and tactical or strategy. Thus, it was speculated that changes in match tactics/strategy (Kazemi *et al*., 2006; Crisafulli *et al*., 2009) influenced the frequency and outcomes of the fights.

   Both the E16 and C16 improved aspects of fitness that may be associated with improved upper body attacking and defensive skills, with improvements in handgrip, push-ups and medicine ball throws greater than SWC. However, it seems much more likely that the improvement in the fitness tests failed to influence the match outcomes in the number of punches thrown.

4. ***Kick action***. The biggest increase of the post-match performance was kick action, with an increase in frequency in E16 (70% increase) but not in C16 (15% decrease). Similar with the younger group, the E16 performed 88% of his total action with kicks. However, even with the improvement in frequency of kick, there was no improvement

in the number of successful hits with kick actions. There was only an increase in the number of kicks that hit elsewhere. While both E13 and E16 increase kick frequency, E16 did not increase 20KT performance, speculating that a change in tactics had more of an influence in the 16-year-old fight.

5. ***Low-intensity action (others)***. There was a 36% decrease in low-intensity events post-intervention. The reasons for this decrease similar with what was observed in the 13-year-old match, where due to less disruption of the match, with less actions of successful topple down (all topple down actions were unsuccessful), no self-release and swipe occurring during the post-training match no referee judgement was needed to stop the fight.

6. ***Overall frequency and outcomes***. In contrast to the 13-year-old group, the pre-post match data shows that E16 decreased 28% and C16 decreased 50% in the overall frequency of silat actions. The pre- to post-test match of E16 shows a 100% decrease in other actions, 92% in punch, and 80% in block performance but an increase in kicks (increased by 70%). Meanwhile, C16 shows a decrease in all silat actions (block [decreased 59%], punch [decreased 95%] and kicks [decreased 15%]) except in other actions (catch and topple down). The outcomes of the other actions shows C16 successfully implemented the catch techniques (5 actions) in post-test match but failed in all topple down activity which also known as 'miss opponent' (Appendix S).

   The current study shows that there was decrease in the overall 'hit target' outcomes, which is shown by the 72% decrease in this category in the post-training match. Details showed that there was a decrease in block (decreased by 75%) and punch (decreased by 93%) actions. Conversely, there was a small increase of hit target outcomes by 1-action in kick. There was also no improvement of the numbers of other actions (any silat actions other than block, kick, punch and low intensity activity [*others*]) between pre and post-test match. These results suggested that the decrease (28 to 2 actions pre-post training) of the successful blocking activities were due to the changing strategy by the experimental participant (E16), which performed more kicks in post-training match. The number of kicks performed by E16 increased from 37 – 63 pre-post training. Thus, it was speculated that this changed influenced the number and types of activities performed by E16 and also C16. Due to the increased number of kicks by E16, the control group exponent tended to catch and topple down the kicks performed by E16, which is supported by the results. However, the result shows only 5% of the kicks performed by both exponents hit the target while the other kicks miss opponent or hit elsewhere. These interpretations suggest limited transference of fitness into competition over the intervention period, with match tactics seeming to have a greater influence on competition performance in the older group.

7. ***Overall analysis***. Overall analysis of both matches in the 16-year-old group suggested that the E16 performed more kicks while C16 increased catching and topple down actions in the post-intervention match. It is speculated that three reasons influence this outcome. Firstly, it was speculated that both E16 (silat training and intervention) and C16 (silat training) responded to the training programme due to several improvements made in fitness test performance post-training. However, the improvements observed in upper body fitness performance post-training did not transfer to combative performance in the silat match for E16 with a decrease in the number of punches thrown observed. Secondly, the C16 benefited from traditional silat training by

improving catch and topple down actions. Thirdly, it is speculated that other factors relating to knowledge, skill and performance (Thomas and Thomas, 1994) contributes to current outcomes which become more decisive than physical fitness performance, with participants changing tactics pre- to post-training.

7.4.3 General Issues of 13 and 16-year-old in Silat Match Performance

There are several points that are important to be addressed in this study based on all the aforementioned discussion on the effect of silat-specific circuit training in two 13 and 16-year-old boys. This study highlights the individual responses to the specific intervention training on the performance of fitness on competitive performance. Even though some individuals performed better or improved their fitness more (than an opponent), it does not necessarily mean they can transfer those characteristic into silat. This is important as while on a group basis most 13-year-old exponents improved muscular endurance, lower body strength and motor coordination and most 16-year-old benefitted from increased endurance, concentric strength and muscular endurance as stated in Study 3, there is considerable individual variability within the group response. This can be observed from the individual fitness data reported in the present study. The younger experimental participant responded well to the training with some improvement in fitness performance that can be transferred to match performance. This can be seen by the improvements in RSI, 3KT and 20KT in E13 that may have transferred to an improvement of the number of kicks and ability to evade an attack during the post-training match. Whereas, the improvement made by the 16-year-old participants in the fitness tests failed to explain the decrease of several fighting actions in the silat match (i.e. punch action in C16 and E16). It was speculated that tactical aspects might be more decisive than physical fitness. This is important especially to coaches that quantify their athletes performance based on physical fitness performance, as clearly performance is a multidisciplinary concept (Oliver, 2010). Moreover, what has the researcher showed throughout the applied methodology in this study might be useful to coaches to replicate those methods to targeted individuals, in order to predict the effectiveness of a training programme on fitness and match performance. Also, the applied nature of this study might be taking into coaching perspectives how effectively training is transferred to competitive performance. Two aspects that the coaches need to aware of are; do not rely solely on fitness data in order to predict match performance and second, there are technical and tactical issues in the silat match that need to be put into consideration in order to understand the factors that influence competitive match performance. For example, a previous study showed that aerobic power in light weight senior Indian male boxers was 58.30 $\pm$ 2.2 $mL \cdot kg^{-1} \cdot min^{-1}$ (Khanna and Manna, 2006), even though the junior boxer can easily reach that level of endurance, it does not mean the junior can have similar skills and technical abilities to compete with his senior counterpart.

Technically, one interesting point to highlight was that Study 1 showed that the percentage of punch and kick actions contributed around 57% of the overall match frequency. But the current study shows that the amount of both actions in 13-year-old contributed 75% in pre-test and 59% in post-training matches; whereas the 16-year-old contributed 65% in pre-test and 74% during the post-training matches. These results suggests the 13-year-old groups rely more on both actions during the pre-test match but adaptation to other skills such as dodge and catch post-training match. This change is speculated to result from the technical coaching received by both participants during the intervention period. Furthermore, the decrease of punch actions in E13 did not mean that the exponent lacked upper body skill or the ability to perform a strike, but the adaptation to lower body endurance gains during the intervention might influence E13 to perform more kicks and dodge during the latter match. It has been reported that children performances differences tend to be less skill related and more knowledge based (French and Thomas, 1987; McPherson and Thomas, 1989). Both skill and knowledge increase as a result of practice, experience and maturation, however younger children demonstrate less variation in skill than older children and adults (Thomas and Thomas, 1994). Thus, E13 performed more kicks and dodge actions compare to other silat skill due to the above factors. It would be suggested for E13 to practice punching technique in training to aid further development.

Meanwhile, a large increase of kick actions was found in E16 but not in C16. However, the data of post-training fitness did not support the improvement gains in kicks in the post-training match. It was speculated that this increase was related to knowledge, skill and performance as described by Thomas and Thomas (1994). They described that novices lack declarative knowledge such as goals and subgoals of the game, rules of the game, offensive and defensive strategies, terminology and etiquette. E16 successfully punched his opponent 13/25 times compared to only 1/37 kicks in the pre-training match. Therefore, the incapability of E16 to recognise his appropriate skill in the post-training match resulted in a poor performance with only 1 successful kick from 63 kicks applied and 1/2 punch. Thus, the inability for E16 to determine punching as an appropriate skill that can contribute points in the post-training match was a limitation of his performance. Novices often do not know which skills to execute or when to execute a skill (Thomas and Thomas, 1994).

Tactically, compared to 13-year-old performance, a change of strategy is speculated to have influenced the frequency and outcomes in the post-training match of the 16-year-old. Even though E16 improved in all upper body performance tests there was a decrease in the number of block and punch actions, suggesting that there was no influence of physical conditioning on silat match performance. Moreover, the increases in kicks by E16 suggest the opportunity for C16 to implement more catch and topple down actions to gain more points during the post-test match. These activities happened particularly because E16 used a different strategy (using kicks instead of punch) than that adopted in the pre-training match.

The current study did not provide the points scored for each exponent in all matches. But in order to give a better understanding about the match performance the author thought that this point need to be raised in order to understand the importance of selecting a proper silat skill (i.e. punch, kicks, block + punch, dodge + punch and etc.) in order to score points in silat match. The ability for silat exponents to score maximum points during 3-rounds of a fight is critical to win the silat match match (Anuar, 1993). In silat, any legal/clear points (hit the target) with punch (1 point), kicks (2 points) and topple down (3 points) will help to increase the overall points scored (Anuar, 1992). Moreover, any clear defensive action followed by legal/clear point will be awarded an extra point (i.e. 1+2 points for any successful block or dodge followed by successful kick to the body-target). Thus, the current study found that several steps need to be taken in order to compete in silat match. Firstly, silat exponents must have the skill to be able to perform these actions, then they must have the fitness to be able to perform them throughout a match, then they must have the tactical knowledge to understand how to best use their skills and fitness to their advantage. Thus, the importance of game analysis (overall outcome) as showed in current study, will determine the effectiveness of every attacking and defensive action implemented in the match. For example in both exponents there was an increase of successful actions from pre- to post-training match in 13-year-old in the dodge action compare to any other silat skills. This concludes that there were more successful actions that are considered as non-contributing points rather than score point actions (e.g. legal/clear punch or kick) in 13-year-old group.

The use of notational analysis in the current study has set up a glimpse of the practical implications of determining an athlete's performance during a silat match following an intervention. Even though there are limited studies using the same approach as used by researcher in the current study, there are a few previous that have similarities with the current approach; such as in squash (Murray *et al*., 1998 and Brown and Hughes, 1995). Murray *et al*. (1998) used detailed quantitative feedback between match performances to monitor (elite vs sub elite) the effect on performance following 8-weeks of a specific on court training programme. The training programme established from the findings of the first week of match performance of elite and sub elite and training diaries were kept and psychological questionnaires administrated at the start and end of the study. The detail of the training programme was outline and the results shows descriptive patterns of play and winner/errors distributions of shot types in squash (i.e. drive, drop, boast, lob, volley short and volley long). The similarity between the current study and Murray *et al*. (1998) was that the design of the study was descriptive and qualitative, there was a training programme developed, there were outcomes that describe the performance of the participants in both studies and both studies used recorded video performance as main resource to analyse performance in the game. However, the authors did not report the details of the training study but did report that participants that spent the most hours in training, had the best outcome results in the elite group but not in the sub elite group (positive response due to the training even at least hours of training). So, training volume is less important in sub-elite as in this study.

Brown and Hughes (1995) compared the effects of quantitative feedback group (computerised analysis) and qualitative feedback (video analysis) group between a training and control group and found no significant difference in the level of improvements, unforced error distributions in squash and no significant difference in the level of improvements within individuals. Only one experimental group showed significant improvement in unforced error distributions over the of 6-months period of the study. The authors did not describe the training programme but highlight the importance of frequency in responsive training. Compared to current silat study, there was insufficient frequency of training (module keep changing for every 2 weeks based on performance skills) that can influenced significant changed in squash performance. Both studies (Murray *et al*., 1998; Brown and Hughes (1995) highlighted the difficulty of using performance analysis to prove the effectiveness of real world interventions due to all the uncontrollable factors that also have an influence on performance.

7.5 Conclusion

This was the first case study to examine the changes in competitive match performance of four young performers from experimental and control groups following a silat-specific circuit training programme. However, there was no conclusion regarding individual fitness gains into competitive silat performance with varied results in some fitness improvements (i.e. > SWC) in all 13 and 16-year-old participants. The younger experimental exponent showed a changed in combative match performance with increases in kick and dodge/evade actions and with more successful evading actions. This improvement was suggested to be associated with a training improvements in upper body endurance (push-ups) and power (medicine ball throw), lower body strength (RSI), kicking speed-endurance (20KT), kick speed (3KT) and agility (3-directional jump) which promoted relates to increase of kicks and dodge actions during a silat match. The older experimental exponent showed gains in isometric strength (handgrip), upper body endurance and power, and lower body strength but did not transfer this positive improvement into match performance, probably due to the tactical strategy during the silat match. Both C13 and E13 increased in dodge particularly due to the technical training. Kick tests was discussed as the only transferred to competition. Gains in fitness may have some positive influence in performance in younger silat athletes. However, it is suggested that all silat fitness testing protocols could be used as valuable elements of information to evaluate an athlete's performance, although other important factors also need to be considered.

CHAPTER EIGHT

Summary

8.1 Introduction

The main purpose of this chapter is to consider the findings from Study 1(a, b), Study 2, Study 3 and Study 4 and the implications of those studies to current research. Moreover, the purpose of the thesis is to contribute the knowledge of coaching science in the combat sport of silat. The research itself used a number of interlinking studies (Figure 1.4, pp. 17) that have provided further information of physiological demands and characteristics, fitness development and trainability, and also transference fitness into competitive performance in youth silat. Study 1 successfully characterised the demands of silat with frequent bouts of high-intensity anaerobic work interspersed with low-intensity activity. This was concluded using performance analysis techniques (time motion and notational analysis) informed by the literature review. This adds to information on the physiological demands of silat previously reported by Aziz *et al*., (2002). Moreover, the information gathered from the literature review and Study 1 finding provided subsequent information on developing silat-specific fitness protocol for fitness testing of 13 to 16-year old male and female silat exponents in Study 2. The study suggests a period of acceleration adaptation that occurred in male silat exponents due to the improvement in their fitness at or post-PHV, whereas, the females showed no change in performance with advancing age across any of the age groups. The observed responses are likely to be associated with gender-specific maturation and the findings (acceleration adaptation and silat-specific fitness protocols) were useful when devising training programmes to maximise fitness development in youth silat in Study 3. Information from the literature review and study 1 helped to inform the design of the circuit training programme in study 3, while data gathered in study 2 allowed the theory of accelerated adaptation influencing trainability during childhood to be tested.. The study shows that gains in endurance (yo-yo IE1) and squat jump were more pronounced in more 16-year-old silat exponents and might be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in 13-year-old young silat exponents. Moreover, both experimental groups were able to improve push-up performance, suggesting similar local muscular adaptation. It was suggested that silat-specific circuit training improvements appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power. Following the results from Study 3, a case study approach has been used to allow detailed analysis on individual responses (contrast to group responses in Study 3) in order to determine transference of fitness to competition in Study 4. A technique (notational analysis) developed in Study 1 was used to describe the detailed activity that occurs during the fight time of silat bout between matched- pairs of participants of 13 and 16-year-old of control and experimental group. Study 4 shows that the frequency of actions during competition generally decreased for both older participants, suggesting limited fitness transference to competition. Whereas, both 13-year-old groups (experimental and control) improved the ability to evade their opponents attacks, reflecting response to technical coaching. Therefore, fitness gains together with technical coaching may transfer to competition in younger exponents, while alterations in strategy may have been more decisive in the older group. Consequently the detailed programme of research presented in this thesis has provided novel information on a number of issues related to fitness development in youth silat.

The first part of this chapter explains the purpose of the research and the summary of the findings from each of the four studies. The second part of the chapter discusses the implications of the findings and how it expands on the knowledge and the value of the expansions to coach education. Moreover, the findings will provide information that will facilitate the future coaching of young silat athletes. Finally, discussion of the strength and limitations of the research will be presented.

8.2 Summary of Main Findings

A primary purpose of this thesis was to describe the characteristics of silat competition to allow the identification and development of suitable fitness tests, which can then be used to track the fitness development and trainability of youth silat performers. In the first part of study one (see Chapter 4), 62.6% of a silat match was shown to involve action periods ranging from under 6 s to over 12 s with recoveries ranging from under 4 s to over 20 s. Thus, silat exponents must be prepared for short recovery bouts after bursts of activity, irrespective of the duration of the burst of action. Meanwhile, the second part of study one (Chapter 5) provides a detailed description of the demands of the silat-sport and supports the development of specific training programmes. The approach used can be applied to other sports; work and rest periods can be investigated to give a greater understanding of the type and frequency of action within work periods. Thus, study one identified typical demands and movement patterns of silat matches, such as work to rest ratios (time-motion analysis) and types of activities through performance analysis. The study provided useful information for further identification and development of fitness protocols in Study 2.

In Study 2 (Chapter 6), two-new silat-specific tests were found to be reliable for youth silat physiological characteristic of performance, which can be used to evaluate an athlete's ability to perform rapid repeated kicking and movement-agility exercises. Moreover, novel data has been presented which is useful for benchmarking fitness in youth silat. Being involved in silat did allow female exponents to maintain their fitness, whereas, male exponents improved their fitness at or post-PHV, suggesting periods of accelerated adaptation for some variables in boys. These gender-specific differences are primarily attributed to differing maturational processes and the findings may be useful when devising training programmes to maximise fitness development in youth silat, as in Study 3.

Based on the information gathered in Study 1 and 2, a silat-specific circuit training programme was developed in order to investigate the trainability of youth male silat athletes in Study 3 (Chapter 7). It is clear that gains in endurance and squat jump are more pronounced in more mature children and may be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in younger children. Both experimental groups were able to improve push-up performance, suggesting similar local muscular adaptation. Improvements following silat-specific circuit training appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power. In order to examine the usefulness of these training activities into improving competitive performance, one individual from each group was selected for a case study (13 and 16-year-old experimental group versus control group) in Study 4.

Based on the Study 3 training approach, a case study was undertaken in Study 4 (Chapter 8) to analyse the competitive performance of a few selected participants before and after the training programme. All individual participants made some improvements in fitness that would be considered worthwhile, although individual responses did not necessarily reflect the group responses reported in Study 3. Improved kick test performance may have transferred to improve kicking frequency in competition in E13, while both E13 and C13 may have benefited from some technical coaching on how to evade their opponent. Neither of the 16-year-old participants demonstrated changes in competitive performance that would demonstrate transference of improved fitness to performance. This suggests factors other than fitness development may be more crucial in influencing match performance. Implications of the studies are now considered and recommendations are made.

8.3 Comments and Recommendations

In the process of conducting the research in this thesis, several issues arose that were deemed to be important in relation to the development and trainability of youth silat performers. Determining the work and rest ratio and detailing activities that occur during a silat match in Study 1 will allow a detailed description of the demands of silat, as well as offering valuable information on developing specific silat training programmes. The use of general and specific silat fitness tests throughout the thesis has demonstrated the ability to measure these variables in adolescents. The use of these tests was able to identify periods of accelerated adaptation in Study 2, while Study 3 was able to provide empirical evidence to examine whether or not such periods affected trainability (in some instances it did, but in others it did not). Results from Study 3 and 4 highlight the difference responses to the silat training programme among the silat performers, either in fitness or competitive match performance, confounded by several influencing factors such as age and maturational status, traditional silat training, individual variability, and tactical and technical approach. The major implications derived from each study are outlined below.

8.3.1 Comments and Recommendations from Study One (a): Distribution of Fight and Break Time in International Silat Matches

- The average work to rest ratio found in 7 silat matches was approximately 2:1 (15:8 s) and should be considered when devising conditioning programmes. The work periods that occur during a silat match cannot be considered as isolated bursts from which the exponents will get full recovery. It is recommended that silat exponents develop both aerobic (off-contact low intensity action) and anaerobic (in-contact high-intensity bursts) metabolic systems in order to cope with the demands of the competition.

- Silat exponent must be prepared for random amount of recoveries after burst irrespective of the duration of the burst of action, suggesting possibility for periods of high metabolic stress.

8.3.2 Comments and Recommendations from Study One (b): Activity Profile during Action Time in National Silat Competition

- The best silat skills in a silat match can be describe into two categories; the most frequency silat actions and the most successful outcome that contributes to silat scoring points. The most frequency actions were kicks. Whereas, the most successful actions that contribute to the point score were punches. Meanwhile, the best defensive actions is a block, while, kicking is the best skill for attacking actions. Even though blocking was the best skill for defensive technique, precautious need to be taken into consideration to avoid injuries. It is was reported that even in non-contact martial arts training, enthusiastic blocking technique may lead to bruising of the forearms in children (Zetaruk, 2009). Thus, it is suggested that using dodge or parry technique can help young silat exponent (i.e. 13-year-old) to avoid injury in competitive match.

- Based on the statistical counts, both exponents performed more high-intensity than low-intensity actions in the match. The adaptation to numerous high-burst actions alternating with low intensity actions may accommodate silat exponents to adjust with this intermittent environment in silat match. Thus, this must be taken into consideration when constructing silat-specific training programme.

8.3.3 Comments and Recommendations from Study Two: The Physiological and Performance Characteristics of Youth Silat Performers

- Results of Study 2 provide a data base of physical fitness in youth silat and may be useful for benchmarking, talent identification and tracking talent development in silat.

- The two new silat-specific tests were found to be reliable for youth silat performers where can be used to evaluate exponent's ability to perform rapid kick and agility-moves exercises. Whereas, the general measures of physical fitness distinguished across age groups in a males better than silat-specific exercises. Therefore, physical fitness tests may be more useful in identifying differences between individuals.

- Gender-specific differences were attributed to differing maturational processes and the findings showed that the fitness of females did not change with age for any variable in youth silat performance; however, being involved in silat did allow female exponents to maintain their fitness. Furthermore, periods of accelerated adaptation were suggested to exist for power, muscular endurance, lower body power, and endurance which showed significant gains after 15-year-old in boys. Using the theory employed in the LTAD model this may suggest a window of opportunity for maximising training gains in youth silat athletes, however, further evidence regarding this is presented in Study 3.

8.3.4 Comments and Recommendations from Study Three: Effect of Circuit Training on Fitness Development in Youth Silat

- The popular LTAD model (Balyi and Hamilton, 2000; 2002; 2004) is theory based. Empirical evidence presented in Study 3 demonstrates that while some trainability may exist this is not always the case and it is not always aligned with naturally occurring accelerated adaptation. Therefore, caution should be taken if implementing the LTAD model.

- A six-week training programme can promote positive adaptation in silat-specific fitness. Trainability gains in endurance and squat jump are more pronounced in more mature children (over 16-year-old) and may be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in younger children (13-year-old). Circuit training can allow a training method whereby the physiological demands of a sport, such as silat, can be replicated in terms of intensity and exercises/movements. This type of training is also time efficient and should help to provide variety for child athletes.

- Improvements following silat-specific circuit training appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power.

8.3.5 Comments and Recommendations from Study Four: Effect of Circuit Training on Fitness and Match Performance of Young Silat Performers – A Case Study

- The individual fitness response did not necessarily follow the group response. Coaches should be cautious of expecting all individuals in a group to exhibit similar changes in fitness.

- Improvements in fitness following silat-specific circuit training may have helped to improve silat performance in a younger participant, with increased kick test performance during the competitive silat match. Therefore, physical conditioning may have some transference to performance in young participants.

- Irrespective of the circuit training both 13-year-old participants improved their dodging/evading technique, which supports the benefits of traditional silat coaching to improve competitive performance.

- Both E13 and C13 showed some gains. Therefore, tactical and technical training may be more influential on match performance in 16-year-old boys.

- This study demonstrated that a case study approach can be practically implemented and similar approaches should be used by coaches to understand both individual responses and transference of fitness into performance.

8.4 Strengths and Limitations

1. The approach used in the first study (a) successfully classified both action and break periods of silat match. However, it failed to allow the researcher to discriminate between different bursts (either high or low intensity actions) in works periods. The use of Focus X2 system successfully discrimination between high or low intensity action periods performed by exponents in a silat match in Study 2 and 4.

2. Study 1 was performed on adult athletes. However, this was done as the goal is to develop the junior exponent into a successful adult competitor. Also data from study four was subsequently analysed and supported the data reported in Study 1.

3. Maturation was not directly measured in current research (maturity offset error). The current thesis examined the fitness developmental (Study 2) trends in youth silat performers, and reported data in relation to stages of maturation. In order to assess maturation, the predictive equation as proposed by Mirwald *et al*. (2002) was used. Whilst this is an accepted form of assessing maturation status in children and adolescents, it must be recognised that the prediction equation increases in accuracy as subjects approach PHV, and reduces in accuracy the further a participant is away from their PHV (Gunter *et al*., 2008). Therefore, the findings of Study 2 must be accepted with caution.

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APPENDICES

Appendix A

Basic Silat Posture during Attack and Defensive Movements

FIGURE 1A: *PASANG* POSITION (DEFENSIVE)

FIGURE 2A: PUNCHING (ATTACKING)

FIGURE 3A: KICKING (FRONT KICK) (ATTACKING)

FIGURE 4A: *SCISSOR* STRIKE (ATTACKING)

FIGURE 5A: SWEEPING FROM THE GROUND (ATTACKING)

FIGURE 6A: CATCHING (DEFENSIVE)

FIGURE 7A: TOPPLE DOWN (ATTACKING)

FIGURE 8A: BLOCKING THE LEG STRIKE (DEFENSIVE)

FIGURE 9A: BLOCKING THE HAND STRIKE (DEFENSIVE)

*** Dodge, self-release, block and punch, block and kick, block and sweep, *sikap pasang*, *pola langkah* and more techniques related to silat olahraga actions can be found in Silat Olahraga manual by Anuar (1993).**

The agenda of silat is to differentiate between silat competition and other sports combat competition (e.g. taekwondo, karate, kick boxing) it is important for every coach and fighter understand the mechanism of scoring points of silat competition. Besides, it also aims to display the high quality of silat competition. Thus the understanding of the silat scoring system or points is very important especially in helping coaches to determine which attack and defensive movements that can give more benefits and chances to their fighter to win in competition. Figure 2.04 (pp. 37) shows area that allowed and non-allowed to score points in silat competition. The point for attacking and defensive movement will be given as below:

1. **(a)** ***The act of parrying***: This is assessed when a fighter succeeds in aborting his opponent's attack with techniques of self defense, resisting and diverting the direction of the attack, ending in his attack on the target of the opponent. One mark will be given for succession of parrying the attack from other opponent's plus extra mark (depends on the strike) for landing a strike on the target.

   (b) ***The act of dodging***: This is assessed when a fighter succeeds in freeing himself from an attack by using a defense technique. An act of dodging that assessed is one mark that results in an attack of the target. One mark is given for an act of dodging, and the attack on the target is assessed according to the type of attack made. An attack with the hand gets him one mark. This, added to an act of dodging, gets him two marks. Same process happened to the act of parrying too. However there is no mark for fighters that succeed parrying or dodging his opponent's strike but failed to make counter-strike that land the attack on the target.

2. ***An attack with hand***: This is assessed if it is strong, effective and gets at the target via any technique. This hand attack is not accompanied by grips or prevented when the opponent dodges.

3. ***An attack with leg***: This is assessed in whatever forms as long as it gets at the target. This leg attack is not accompanied by grips or prevented when the opponent dodges.

4. ***The fall technique***: This is assessed when part of the opponent's body touches the floor. The opponent falls not through any unfair wrestling and clinching and the other fighter is able to defend himself and does not fall. The technique of causing the opponent to fall as well as the holding of the opponent's body should be the effort of every defense to an attack.

5. ***The clinching technique:*** This is assessed when the fighter manages to enfeeble the opponent. This technique should not injure any joints and the opponent must not able to counter-attack with his hands and legs for five counts. If the opponent manages to free himself and gets at the target a number of times, the marks given to him will be that for one count.

Appendix B

- **UWIC Participant Assent Form. Research Project: Fitness Characteristics of Youth Silat Competitors (Study 2).**

UWIC Participant Assent Form

RESEARCH PROJECT: FITNESS CHARACTERISTICS OF YOUTH SILAT COMPETITORS

UREC Protocol Number: EX0018

Principal Investigator: Mohamad-Nizam Mohamed-Shapie

Principal Supervisor: Dr Jon Oliver

Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

I confirm that I have read and understand the information sheet dated .... for the above study and fully understand what it entails. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. I understand that I am entitled to ask any further questions at any time throughout the duration of the study.

I understand that:

- ✓ I have volunteered to participate in the study on my own accord, and that I am entitled to leave the study at any time should I wish to without any repercussions.
- ✓ I will be required to attend the requisite number of Silat testing sessions in order to complete the research project.
- ✓ As an active member of the research cohort, personal data (age, weight, height, gender, main activity participated in) will be collected and I will have to complete a series of fitness tests.
- ✓ All personal information and research data collected during the study will be kept in a secure location within the university grounds for a period of 7 years. The results of the study may be published in the future, however my anonymity will be maintained at all times.
- ✓ I understand that relevant sections of any of research notes and data collected during the study may be looked at by responsible individuals from UWIC for monitoring purposes, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.
- ✓ I agree to take part in the above study.

Signed (parent/guardian): Print Name:	Date:
Signed (participant): Print Name:	Date:

Appendix C

- **UWIC Participant Assent Form. Research Project: Fitness Characteristics of Youth Silat Competitors (Study 2) (Malay).**

Borang Persetujuan Penyertaan

PROJEK KAJIAN: CIRI-CIRI KECERGASAN PARA PETANDING MUDA SILAT OLAHRAGA

Nombor Protokol UREC: EX0018

Pengkaji Utama: Mohamad-Nizam Mohamed-Shapie

Ketua Pengkaji: Dr Jon Oliver

Maklumat Perhubungan: momohamedshapie@uwic.ac.uk atau joliver@uwic.ac.uk

Saya mengesahkan bahawa saya telah membaca dan memahami segala butiran maklumat yang dinyatakan dalam kertas maklumat bertarikh .... untuk kajian di atas dan memahami sepenuhnya segala tangunggannya. Saya juga mempunyai dan menggunakan peluang yang diberikan untuk mempertimbangkan segala informasi, menanyakan soalan-soalan dan telahpun mendapat jawapannya yang benar-benar memuaskan hati saya. Saya memahami yang saya berhak untuk menanyakan sebarang soalan pada bila-bila masa sepanjang kajian ini dijalankan

Saya memahami bahawa:

- ✓ Saya secara sukarela menyertai kajian ini di atas kemahuan saya sendiri, dan saya berhak untuk meninggalkan kajian ini pada bila-bila masa sekiranya saya mahu tanpa sebarang akibat atau tindakan yang akan dikenakan terhadap saya.
- ✓ Saya dikehendaki untuk menghadiri beberapa sessi kajian Silat untuk melengkapkan projek kajian ini.
- ✓ Sebagai sukerelawan yang aktif dalam kajian ini, data-data peribadi (umur, berat, tinggi, jantina, aktiviti yang sering diceburi) akan dikumpul dan Saya dikehendaki untuk melengkapkan beberapa siri ujian kecergasan.
- ✓ Segala maklumat peribadi dan data kajian yang dikumpul semasa kajian ini dilakukan akan disimpan di tempat yang selamat dan dilindungi di dalam kawasan universiti selama tempoh 7 tahun. Keputusan kajian ini mungkin akan diterbitkan di masa hadapan, namun identiti saya akan tetap dirahsiakan.
- ✓ Saya memahami bahawa terdapat bahagian-bahagian yang berkaitan pada nota kajian dan data yang dikumpul semasa kajian dilakukan boleh dilihat semula oleh individu-individu yang bertanggungjawab untuk tujuan pengawasan, yang mana sememangnya berkaitan dengan penyertaan saya dalam kajian ini. Saya memberi kebenaran untuk individu-individu ini untuk melihat rekod saya.
- ✓ Saya bersetuju untuk menyertai kajian di atas.

Tandatangan (ibu bapa/penjagan):	Tarikh:
Nama Penuh:	
Tandatangan (peserta):	Tarikh:
Nama Penuh:	

<u>Appendix D</u>

- **Information Sheet – Request for Volunteers. Research Project: Fitness Characteristics of Youth Silat Competitors (Study 2).**

INFORMATION SHEET – REQUEST FOR VOLUNTEERS

RESEARCH PROJECT: FITNESS CHARACTERISTICS OF YOUTH SILAT COMPETITORS

UREC protocol number: EX0018
Principal Investigator: Mohamad-Nizam Mohamed-Shapie
Principal Supervisor : Dr. Jon Oliver
Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

Dear Student,

Purpose of letter

This letter provides information about research project conducted in School of Sports, University of Wales Institute, Cardiff. The purpose of this letter is to provide you with information about the research project to allow you to decide whether or not you would like to volunteer to participate in the project. As a volunteer your participation in the project would be entirely voluntary and you would be able to withdraw from the project at any time.

Aims of research

There is no study that specific to youth silat performer in Silat. Therefore, the aim of the research is to identify fitness characteristics that distinguish Silat competitors of different age, maturation and standards. It is important to determine the standards of fitness among the youth's silat performers so that will give the silat coaches the tools to control the training process and to identify potential talent.

What will happen if you decide to volunteer?

You will be asked to attend two sessions. During each session you will perform a warm-up followed by a number of performance test. The test includes vertical jump, squat jump, 3-directional jump, kicking speed tests, grip strength test, medicine ball throw test and yoyo test. In the first session we will also collect some descriptive data of body size (height, weight, belt rank, competition level). A few volunteers may also be asked to attend two additional optional sessions to repeat the kicking speed and directional jumping tests; this will be to help us determine how consistent results in these tests are. All testing will take place during your normal silat coaching hours at your normal training venue.

What type of participants do we want?

We want to recruit participants from age 13 to 18 years old who are actively involved in Silat, particularly in Silat Olahraga.

What are the risks of participating in the study?

The risk of the participating in the study is minimal. The test procedures are very brief and you will be given a full recovery between efforts. There are always some risks when performing any exercise. The worst is fatigue from the procedures. This can be avoiding by having a proper warm-up before every session.

Benefits to the participants

You will be given a record of your performance during test, which will help you understand more about your abilities as a silat competitor. This will provide you with information about your Silat abilities in speed and power activities, which may help your sporting and/or exercise involvement in, and outside, of school. It will also provide you with a hands-on experience of modern-day sport science fitness testing, otherwise unavailable to other schools in Malaysia.

Benefits to us, the research team

By completing the research, you will provide the research team with relevant data which will be used to complete Mohamad Nizam's PhD thesis (the principal investigator). More importantly the findings of the study will provide the research team with important new information to publish in Internationally-renowned sport science journals.

What will happen to the information collected?

Everyone that takes part in the study will receive their own results for the tests that they complete. All information collected and results will be held at the University and will only accessible by research team. Copies of all the data collected during the testing period will be stored centrally within a secure holding location in UWIC for up to a period of 7 years. Only the principle researcher and his supervisory team will be able to access the data once stored in UWIC. Results of this study may be published but any data included will in no way be linked to any specific participant.

What next?

Questions are always welcome at any time. You may contact either me or Dr. Jon Oliver on the above e-mail. Having discussed this matter with your parent/guardian, and if you like to take part in the study, please complete the Informed Consent Form and Physical Activity Readiness Questionnaire included with this information sheet and return to Mr. Shahiid (Silat Centres of Excellence Manager) as soon as possible.

This project has been approved by UREC (University Research Ethics Committee).

Many thanks,

Signature

Mohamad-Nizam Mohamed-Shapie MSc
PhD Researcher (Exercise Physiology)
Principle Investigator
Cardiff School of Sport
University of Wales Institute, Cardiff

Appendix E

- **Information sheet – request for volunteers. Research Project: Fitness Characteristics of Youth Silat Competitors (Study 2) (Malay).**

KERTAS MAKLUMAT – KETERANGAN UNTUK PARA SUKARELAWAN

PROJEK KAJIAN: CIRI-CIRI KECERGASAN PARA PETANDING MUDA SILAT OLAHRAGA

UREC protocol number: EX0018
Pengkaji Utama: Mohamad-Nizam Mohamed-Shapie
Ketua Pengkaji: Dr. Jon Oliver
Maklumat Lanjut: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

Salam Sejahtera,

Tujuan Surat Ini
Surat ini menyediakan maklumat lanjut mengenai projek kajian yang akan dilakukan oleh Pusat Sukan, University of Wales Institute, Cardiff. Tujuan surat ini adalah untuk memberikan anda lebih informasi mengenai kajian ini bagi membolehkan anda memilih untuk sama ada anda menyertai projek ini secara sukarela ataupun tidak. Sebagai peserta, penyertaan anda di dalam projek ini adalah secara sukarelawan dan anda boleh menarik diri daripada projek ini pada bila-bila masa sahaja.

Matlamat Kajian Ini
Tidak terdapat sebarang kajian yang khusus di dalam Silat terhadap para petanding muda. Oleh yang demikian, matlamat kajian ini adalah untuk mengenalpasti ciri-ciri kecergasan yang dapat membezakan para petanding Silat pada peringkat umur yang berbeza, kematangan dan peringkat prestasi. Ia adalah penting untuk menentukan tahap prestasi kecergasan di antara atlit-atlit muda agar dapat memberikan kemudahan kepada para jurulatih untuk mengawal proses latihan serta mengenalpasti potensi bakat yang ada.

Apa yang akan terjadi sekiranya anda bersetuju menjadi peserta kajian ini?
Anda akan diminta untuk menghadiri 2 sessi. Setiap sessi anda akan melakukan latihan memanaskan badan diikuti dengan beberapa ujian kecergasan. Antaranya adalah lompat vertical, lompat squat, lompatan 3 arah, ujian kecepatan tendangan, ujian kekuatan genggaman, ujian balingan 'medicine ball' dan ujian yoyo. Dalam sessi pertama kami akan mengumpulkan beberapa data diskriptif seperti saiz badan (tinggi, berat, peringkat bengkung, tahap pertandingan). Beberapa orang peserta akan diminta untuk menghadiri dua lagi sessi tambahan secara sukarela untuk melakukan ujian kelajuan tendangan dan ujian lompatan; ini akan membantu kami untuk menentukan tahap kosisten keputusan yang diperolehi daripada ujian-ujian yang dijalankan. Semua ujian akan diadakan semasa waktu normal latihan silat biasa diadakan.

Apakah jenis peserta yang kami mahu?
Kami mahu mencari para peserta berumur di antara 13 hingga 18 tahun yang aktif di dalam Silat, terutamnya Silat Olahraga.

Apakah risiko-risiko yang dihadapi apabila menyertai kajian ini?
Risiko untuk menyertai kajian ini adalah minimum. Semua prosedur ujian-ujian yang dijalankan adalah mudah dan anda akan diberikan waktu rehat yang cukup di antara suatu

ujian yang dijalankan. Sememangnya sentiasa terdapat risiko apabila menjalankan sesuatu senaman. Risiko yang paling teruk adalah kepenatan daripada prosedur-prosedur yang dilakukan. Ini dapat dielakkan dengan membuat senaman memanas badan yang teratur untuk setiap sessi.

Kelebihan-kelebihan kepada peserta
Anda akan diberikan rekod prestasi anda semasa ujian dijalankan, di mana akan membantu anda untuk memahami dengan lebih lanjut mengenai keupayaan anda sebagai petanding silat. Ianya memberikan anda lebih pemahaman akan kebolehan anda dalam aktiviti-aktiviti melibatkan kekuatan dan kelajuan, di mana ia mungkin membantu penglibatan anda dalam aktiviti sukan dan/atau apa-apa aktiviti yang anda sertai, sama ada di dalam ataupun di luar sekolah. Ia juga akan menyediakan anda peluang untuk merasai ujian kecergasan sains sukan moden, yang mana tidak terdapat di mana-mana sekolah di Malaysia.

Kelebihan-kelebihan kepada kami, pasukan kajian kami
Dengan menghadiri kajian ini, anda akan memperuntukan kepada pasukan pengkaji dengan data yang releven yang akan digunapakai untuk melengkapkan tesis PhD Mohamad Nizam (pengkaji utama). Lebih penting lagi adalah keputusan daripada kajian ini akan menyediakan maklumat penting yang terkini kepada pasukan pengkaji yang bakal diterbitkannya di dalam journal-journal sains sukan terkenal antarabangsa.

Apa yang akan terjadi kepada maklumat yang dikutip?
Setiap peserta yang mengambil bahagian dalam kajian ini akan menerima keputusan masing-masing yang telah mereka hadiri. Semua maklumat dan keputusan yang dikumpul akan disimpan di universiti dan hanya boleh dilihat oleh pasukan pengkaji. Semua salinan data yang dikumpul akan disimpan secara berpusat di dalam kawasan terjamin di dalam UWIC sehingga tempoh 7 tahun. Hanya pengkaji utama dan pasukan penyelianya sahaja dibenarkan untuk melihat data yang disimpan di UWIC. Keputusan kajian ini mungkin akan diterbitkan tetapi mana-mana data yang diterbitkan tidak akan dihubungkan dengan mana-mana peserta secara khusus.

Tindakan seterusnya?
Sebarang soalan dialu-alukan pada bila-bila masa. Anda boleh menghubungi saya atau Dr. Jon Oliver pada email di atas. Apabila anda telah berbincang dengan ibu bapa/penjaga anda mengenai perkara ini, dan jika anda bersetuju untuk menyertai kajian ini, silat lengkapkan Borang Persetujuan Penyertaan dan Soal Selidik Kesediaan Aktiviti Kecergasan yang dilampirkan sekali dengan kertas maklumat ini dan serahkan kepada En. Shahiid (Pengurus Pusat Cemerlang Silat) dengan kadar segera.

Projek ini telah diluluskan oleh UREC (University Research Ethics Committee / Ahli jawatankuasa Etika Penyelidikan Universiti).

Sekian, Terima kasih.

Tandatangan

Mohamad-Nizam Mohamed-Shapie MSc
Penyelidik PhD (Fisiologi Senam)
Pengkaji Utama
Cardiff School of Sport
University of Wales Institute, Cardiff

Appendix F

- **Physical Activity Readiness Questionnaire (PAR-Q).**

Physical Activity Readiness Questionnaire (PAR-Q)

Participants name…………………………………………………………………………………

Please circle the answers to the following questions:

1	Do you have asthma or any breathing problems?	Yes / No
2	Has your doctor ever said you have heart trouble ?	Yes / No
3	Do you frequently suffer from pains in the chest ?	Yes / No
4	Do you often feel faint or have spells of severe dizziness ?	Yes / No
5	Has a doctor ever said your blood pressure was too high ?	Yes / No
6	Has a doctor ever said that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise ?	Yes / No
7.	Is there a good physical reason not mentioned here why you should not take part in a fitness test ?	Yes / No
8.	Are you **un**accustomed to vigorous exercise ?	Yes / No

If you have answered yes to any of these questions, please add details below. Similarly, if there are any situations which will prevent you from exercising write them here (or let us know if they arise through the experiment).

If your situation changes regarding your responses to these questions, please notify the appropriate staff/ Researcher member.

Signed (participant)………………………………………………….

Signed (investigator)……………………………………………….

Date………………………………………………….

Appendix G

- **Physical Activity Readiness Questionnaire (PAR-Q) (Malay).**

Soalan-Soalan Persediaan Aktiviti Kecergasan

Nama Peserta………………………………………………………………………………

Sila bulatkan jawapan untuk soalan-soalan berikut:

1	Adakah anda menghidap asma atau masalah sesak nafas?	Ya / Tidak
2	Adakah doktor pernah menyatakan yang anda mempunyai masalah jantung?	Ya / Tidak
3	Adakah anda berulangkali menghadap sakit di bahagian dada?	Ya / Tidak
4	Adakah anda selalu berasa hendak pitam atau pening kepala?	Ya / Tidak
5	Adakah doktor pernah menyatakan tekanan darah anda terlalu tinggi?	Ya / Tidak
6	Adakah doktor pernah menyatakan anda menghadapi masalah tulang atau sendi seperti arthritis yang semakin teruk disebabkan senaman, atau akan menjadi lebih teruk jika anda bersenam.	Ya / Tidak
7.	Adakah terdapat sebarang alasan munasabah yang tidak dinyatakan di sini yang menyatakan yang anda tidak boleh mengambil bahagian dalam ujian kecergasan ini?	Ya / Tidak
8.	Adakah anda **TIDAK** biasa dengan senaman berat?	Ya / Tidak

Sekiranya anda menjawab Ya untuk soalan-soalan ini yang memerlukan maklumat tambahan, sila tulis di bawah. Begitu juga sekiranya terdapat mana-mana situasi yang menghalang anda daripada menjalankan aktiviti fizikal, sila tulis di sini (atau beritahu kami sekiranya terdapat sebarang isu atau masalah ketika ujian dijalankan).

Sekiranya situasi anda berubah berkenaan maklum balas terhadap soalan-soalan ini, sila beritahu pegawai yang dilantik / ahli penyelidik.

Tandatangan (peserta)………………………………………………….

Tandatangan (pengkaji)……………………………………………….

Tarikh…………………………………………………….

<u>Appendix H</u>

- **Risk Assessment (RA99).**

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 1

WORK ACTIVITY: **Yo-yo Test**

HAZARD IDENTIFIED:

- Strain or muscle injuries from improper running technique
- Risk of vomiting and fainting during or post exercise
- Risk of falling or fainting as a result of blood pooling or fatigue

EXISTING RISK RATING: 8

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Proper instruction on form and technique.
- Instruct the subject to stop after reaching volitional exhaustion
- Ensure the subject walks slowly after the end of the test to prevent blood pooling
- Make sure the subject feels fit and able to perform the exercise

RISK RATING WITH CONTROLS APPLIED: 4

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 2

WORK ACTIVITY: **Medicine Ball Chest Throw**

HAZARD IDENTIFIED:

- Slipping or falling of the ball on limbs while trying to throw the ball
- Strain or muscle injuries from improper use of technique
- Hygiene

EXISTING RISK RATING: 4

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Proper instruction on form and technique, especially on holding and throwing the ball.
- Make sure the subject feel fit to perform the exercise.
- Ensure the ball is the standard 2 kg medicine ball.

RISK RATING WITH CONTROLS APPLIED: 2

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 3

WORK ACTIVITY: **Grip Strength**

HAZARD IDENTIFIED:

- Strain or muscle injuries from improper use of technique

EXISTING RISK RATING: 4

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Correct instruction on form and grip technique.
- Make sure the subject feel fit to perform the exercise.

RISK RATING WITH CONTROLS APPLIED: 2

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 4

WORK ACTIVITY: **Press-Up**

HAZARD IDENTIFIED:

- Risk of strain or muscle injuries from improper use of technique
- Risk of tripping or twisting

EXISTING RISK RATING: 4

PERSON AT RISK: STUDENT X STAFF X OTHERS X

CONTROLS TO BE APPLIED:

- Make sure the subject feel fit to perform the exercise.
- Perform warm-up exercise

RISK RATING WITH CONTROLS APPLIED: 2

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 5

WORK ACTIVITY: **Counter-Movement Jump**

HAZARD IDENTIFIED: 8

- Strain or muscle injuries from improper technique
- Risk of tripping or twisting lower limb
- Mat slipping during use
- Dizziness due to physical exertion

EXISTING RISK RATING: 6

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Proper instruction on form and technique, especially on landing technique.
- Make sure the subject feels fit to perform the exercise.
- Ensure floor is suitable use i.e. level and enough grip so as not to cause the mat slip.
- Ensure the jump mat is in safe position to use. i.e. enough space to use the equipment safely.
- Perform warm-up exercise

RISK RATING WITH CONTROLS APPLIED: 4

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 6

WORK ACTIVITY: **Squat Jump**

HAZARD IDENTIFIED: 8

- Strain or muscle injuries from improper technique
- Risk of tripping or twisting lower limb
- Mat slipping during use
- Dizziness/fainting due to physical exertion

EXISTING RISK RATING: 6

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Proper instruction on form and technique, especially on landing technique.
- Make sure the subject feels fit to perform the exercise.
- Ensure floor is suitable use i.e. level and enough grip so as not to cause the mat slip.
- Ensure the jump mat is in safe position to use. i.e. enough space to use the equipment safely.
- Perform warm-up exercise

RISK RATING WITH CONTROLS APPLIED: 4

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 7

WORK ACTIVITY: **3-directional Jump**

HAZARD IDENTIFIED: 8

- Strain, muscle or non-muscular injuries from improper technique
- Risk of tripping/falling/ twisting lower limb
- Mat slipping during use
- Dizziness/fainting due to physical exertion

EXISTING RISK RATING: 8

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Proper instruction on form and technique, especially on landing technique.
- Make sure the subject feels fit to perform the exercise.
- Ensure floor is suitable use i.e. level and enough grip so as not to cause the mat slip.
- Ensure the jump mat is in safe position to use. i.e. enough space to use the equipment safely.
- Perform warm-up exercise
- Advise subject on correct technique and demonstrate.

RISK RATING WITH CONTROLS APPLIED: 6

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 8

WORK ACTIVITY: **3-kick test**

HAZARD IDENTIFIED: 8

- Strain, muscle or non-muscular injuries from improper technique
- Risk of tripping/falling/ twisting lower limb
- Mat slipping during use
- Dizziness/fainting due to physical exertion

EXISTING RISK RATING: 8

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Make sure the subject feels fit to perform the exercise.
- Ensure floor is suitable use i.e. level and enough grip so as not to cause the mat slip.
- Ensure the jump mat is in safe position to use i.e. enough space to use the equipment safely.
- Perform warm-up exercise
- Advise subject on correct kicking technique and demonstrate.

RISK RATING WITH CONTROLS APPLIED: 6

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

RISK ASSESSMENT (RA99)

SCHOOL/SECTION AREA: Sport/Physiology Lab ASSESSMENT NO: 9

WORK ACTIVITY: **20-kick test**

HAZARD IDENTIFIED: 8

- Strain, muscle or non-muscular injuries from improper technique
- Risk of tripping/falling/ twisting lower limb
- Mat slipping during use
- Dizziness/fainting due to physical exertion

EXISTING RISK RATING: 8

PERSON AT RISK: STUDENT [X] STAFF [X] OTHERS [X]

CONTROLS TO BE APPLIED:

- Make sure the subject feel fit to perform the exercise.
- Ensure floor is suitable use i.e. level and enough grip so as not to cause the mat slip.
- Ensure the jump mat is in safe position to use i.e. enough space to use the equipment safely.
- Perform warm-up exercise
- Advise subject on correct kicking technique and demonstrate.

RISK RATING WITH CONTROLS APPLIED: 6

ASSESSORS:- MOHAMAD-NIZAM MOHAMED-SHAPIE DATE 01.04.2009

REVIEW DATE 01.04.2009

Appendix I

- **Fitness Test Form.**

Fitness Test Form

Subject: ____________________ No: ________ Date: _____________

Age: __________________ years Gender: _______ Technician: _________

Height : ______________ cm
______________ in
Arm Length : ________ cm
________ in
Weight : _______ kg
_______ lb

Sitting Height: ________ cm
________ in
Leg Length : ________ cm
________ in

Muscular Strength: **HAND GRIP TEST** Dominant/Average/Combined

	Trial 1 (kg)	Trial 2 (kg)	Trial 3 (kg)	Best (kg)
LEFT				
RIGHT				

Muscular Endurance: **PUSH UP** One Minute

Reps

Muscular Strength : **MEDICINE BALL THROW** Distance

Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)	Best (kg)

Muscular Endurance : **YO-YO TEST** Maximal

Level

Muscular Strength: **REBOUND JUMP** Sub maximal

Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)

Muscular Strength: **SQUAT JUMP** Sub maximal

Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)

PILOT STUDY

Speed: **3 - DIRECTIONAL JUMP**

Trial 1 (ms)	Trial 2 (ms)	Trial 3 (ms)

Speed: **3 – KICK TEST**

Trial 1 (ms)	Trial 2 (ms)	Trial 3 (ms)

Speed: **20 – KICK TEST**

Trial 1 (ms)	Trial 2 (ms)	Trial 3 (ms)

Appendix J

- **Information Sheet – Request for Volunteers. Research Project: Circuit Training in Youth Silat Exponent (Study 3).**

INFORMATION SHEET – REQUEST FOR VOLUNTEERS

RESEARCH PROJECT: CIRCUIT TRAINING IN YOUTH SILAT EXPONENT

UREC protocol number: **09.12.2P**
Principal Investigator: Mohamad-Nizam Mohamed-shapie
Principal Supervisor : Dr. Jon Oliver
Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

Dear Student,

Purpose of letter
This letter provides information about research project conducted in School of Sports, University of Wales Institute, Cardiff. The purpose of this letter is to provide you with information about the research project to allow you to decide whether or not you would like to volunteer to participate in the project. As a volunteer your participation in the project would be entirely voluntary and you would be able to withdraw from the project at any time.

Aims of research
There is no study that specific to fitness training methodology of youth silat performer in Silat. Therefore, the aim of the research is to understand the responses of youth silat performers to specific fitness regimes that will help coaches to better train their athletes.

It is important to determine the specific training system that will improve young athlete's technical and physical skills in Silat, especially in athletes who have limited time for training.

What will happen if you decide to volunteer?
This training programme will take place for 8 weeks. You will be asked to attend two sessions a week. You will undergo several fitness tests during the first week of the training programme for the purposes of familiarization and pre-fitness test session.

During each session you will perform a warm-up followed by a number of performance test and exercises that specific to silat sports. The test includes vertical jump, squat jump, 3-directional jump, kicking speed tests, grip strength test, medicine ball throw test and yoyo test. In the first session we will also collect some descriptive data of body size (height, weight, belt rank, competition level).

While during the second to seventh week you will need to complete specific silat circuit training. The test involves of sprinting, burpee, sit up, push up, back extension, step test, cross over jump and broad jump for first session. While in second session you will have to complete the more specific circuit training exercise in silat such as punching, front kick, side kick, high kick with bare feet and also back kick for left and right side.

On the eighth week you need to perform a same fitness test protocol that you had done on the first week for post fitness test. All testing will take place during your normal silat coaching hours at your normal training venue.

However, if you were asked to be in the **CONTROL** group, you will only need to undergo the fitness tests on the first and last week of the training programme. You will not need to attend the circuit training activities during the silat training.

What type of participants do we want?
We want to recruit participants from age 13 to 17 years old who are actively involved in Silat, particularly in Silat Olahraga.

What are the risks of participating in the study?
The risk of the participating in the study is minimal. The test procedures are very brief and you will be given a full recovery between efforts. There are always some risks when performing any exercise. The worst is fatigue from the procedures. This can be avoiding by having a proper warm-up before every session.

Benefits to the participants
You will be given a record of your performance during test, which will help you understand more about your abilities as a silat competitor. This will provide you with information about your Silat abilities in speed and power activities, which may help your sporting and/or exercise involvement in, and outside, of school. It will also provide you with a hands-on experience of modern-day sport science fitness and training testing, otherwise unavailable to other schools in Malaysia.

Benefits to us, the research team
By completing the research, you will provide the research team with relevant data which will be used to complete Nizam's PhD thesis (the principal investigator). More importantly the findings of the study will provide the research team with important new information to publish in Internationally-renowned sport science journals.

What will happen to the information collected?
Everyone that takes part in the study will receive their own results for the tests that they complete. All information collected and results will be held at the University and will only accessible by research team. Copies of all the data collected during the testing period will be stored centrally within a secure holding location in UWIC for up to a period of 7 years. Only the principle researcher and his supervisory team will be able to access the data once stored in UWIC. Results of this study may be published but any data included will in no way be linked to any specific participant.

What next?
Questions are always welcome at any time. You may contact either me or Dr. Jon Oliver on the above e-mail. Having discussed this matter with your parent/guardian, and if you like to take part in the study, please complete the Informed Consent Form and Physical Activity Readiness Questionnaire included with this information sheet and return to Mr. Shahiid (Silat Centres of Excellence Manager) as soon as possible.

This project has been approved by UREC (University Research Ethics Committee).

Many thanks,

Signature

Mohamad-Nizam Mohamed-Shapie MSc
PhD Researcher (Exercise Physiology)
Principle Investigator
Cardiff School of Sport
University of Wales Institute, Cardiff

Appendix K

- **UWIC Participant Assent Form. Research Project: Circuit Training In Youth Silat Exponent (Study 3).**

UWIC Participant Assent Form

RESEARCH PROJECT: CIRCUIT TRAINING IN YOUTH SILAT EXPONENT

UREC Protocol Number: **09.12.2P**

Principal Investigator: Mohamad-Nizam Mohamed-Shapie

Principal Supervisor: Dr Jon Oliver

Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

I confirm that I have read and understand the information sheet dated .... for the above study and fully understand what it entails. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. I understand that I am entitled to ask any further questions at any time throughout the duration of the study.

I understand that:

- ✓ I have volunteered to participate in the study on my own accord, and that I am entitled to leave the study at any time should I wish to without any repercussions.
- ✓ I will be required to attend the requisite number of Silat testing sessions in order to complete the research project.
- ✓ As an active member of the research cohort, personal data (age, weight, height, gender, main activity participated in) will be collected and I will have to complete a series of fitness tests and circuit training exercises (ONLY FOR EXPERIMENTAL GROUP).
- ✓ All personal information and research data collected during the study will be kept in a secure location within the university grounds for a period of 7 years. The results of the study may be published in the future, however my anonymity will be maintained at all times.
- ✓ I understand that relevant sections of any of research notes and data collected during the study may be looked at by responsible individuals from UWIC for monitoring purposes, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.
- ✓ I agree to take part in the above study.

Signed (parent/guardian): Print Name:	Date:
Signed (participant): Print Name:	Date:

Appendix L

- **Information Sheet – Request for Volunteers. Research Project: Effect of Circuit Training on Fitness and Match Performance of Youth Silat Performers (Case Study) (Study 4).**

INFORMATION SHEET – REQUEST FOR VOLUNTEERS

RESEARCH PROJECT: EFFECT OF CIRCUIT TRAINING ON FITNESS AND MATCH PERFORMANCE OF YOUTH SILAT PERFORMERS (CASE STUDY)

UREC protocol number: 09.12.2P
Principal Investigator: Mohamad-Nizam Mohamed-shapie
Principal Supervisor : Dr. Jon Oliver
Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

Dear Student,

Purpose of letter

This letter provides information about research project conducted in School of Sports, University of Wales Institute, Cardiff. The purpose of this letter is to provide you with information about the research project to allow you to decide whether or not you would like to volunteer to participate in the project. As a volunteer your participation in the project would be entirely voluntary and you would be able to withdraw from the project at any time.

Aims of research

There is no study that specific to fitness training methodology of youth silat performer in Silat. Therefore, the aim of the research is to understand the responses of youth silat performers to specific fitness regimes that will help coaches to better train their athletes.

It is important to determine the specific training system that will improve young athlete's technical and physical skills in Silat, especially in athletes who have limited time for training.

What will happen if you decide to volunteer?

If you were chosen to be in this study, you will be asked to attend two sessions of sparring. You also will be tested on sparring on 3 separate occasions during the silat training in **first week and eighth week of silat training programme**. Each sparring will be recorded by videos for 3 X 2 minute bout. The sparring will be contested with other contestants that involve in this case study. Each pair of sparring will be matched on same competition standards, size, maturity and fitness level.

All testing will take place during your normal silat coaching hours at your normal training venue. You also will need to spar with the same participant that you fight on the first week (same protocols) of the training programme.

What type of participants do we want?

We want to recruit participants from age 13 and 16 years old who are actively involved in Silat, particularly in Silat Olahraga.

What are the risks of participating in the study?

The risk of the participating in the study is minimal. The test procedures are very brief and you will be given a full recovery between efforts. There are always some risks when performing any exercise. The worst is fatigue from the procedures. This can be avoiding by having a proper warm-up before every session.

Both silat exponents will be wearing the safety head guard, knee shin guard and hand guard during the sparring. You also will be wearing silat body protector during the sparring. The researcher will be the *wasit* or referee during the fight. This will help the students to fight confidently and all the false techniques and mistakes will be taken an action immediately during the fight.

Benefits to the participants

You will be given a record of your performance during test, which will help you understand more about your abilities as a silat competitor. This will provide you with information about your Silat abilities in speed and power activities, which may help your sporting and/or exercise involvement in, and outside, of school. It will also provide you with a hands-on experience of modern-day sport science fitness and training testing, otherwise unavailable to other schools in Malaysia.

This will build your confidence to further your silat lessons for future achievements.

Benefits to us, the research team
By completing the research, you will provide the research team with relevant data which will be used to complete Nizam's PhD thesis (the principal investigator). More importantly the findings of the study will provide the research team with important new information to publish in Internationally-renowned sport science journals.

What will happen to the information collected?
Everyone that takes part in the study will receive their own results for the tests that they complete. All information collected and results will be held at the University and will only accessible by research team. Copies of all the data collected during the testing period will be stored centrally within a secure holding location in UWIC for up to a period of 7 years. Only the principle researcher and his supervisory team will be able to access the data once stored in UWIC. Results of this study may be published but any data included will in no way be linked to any specific participant.

What next?
Questions are always welcome at any time. You may contact either me or Dr. Jon Oliver on the above e-mail. Having discussed this matter with your parent/guardian, and if you like to take part in the study, please complete the Informed Consent Form and Physical Activity Readiness Questionnaire included with this information sheet and return to Mr. Shahiid (Silat Centres of Excellence Manager) as soon as possible.

This project has been approved by UREC (University Research Ethics Committee).

Many thanks,

Signature

Mohamad-Nizam Mohamed-Shapie MSc
PhD Researcher (Exercise Physiology)
Principle Investigator
Cardiff School of Sport
University of Wales Institute, Cardiff

Appendix M

- **UWIC Participant Assent Form. Research Project: Effect of Circuit Training on Fitness and Match Performance of Youth Silat Performers (Case Study) (Study 4).**

UWIC Participant Assent Form

RESEARCH PROJECT: EFFECT OF CIRCUIT TRAINING ON FITNESS AND MATCH PERFORMANCE OF YOUTH SILAT PERFORMERS (CASE STUDY)

UREC Protocol Number: **09.12.2P**

Principal Investigator: Mohamad-Nizam Mohamed-Shapie

Principal Supervisor: Dr Jon Oliver

Contact details: momohamedshapie@uwic.ac.uk or joliver@uwic.ac.uk

I confirm that I have read and understand the information sheet dated .... for the above study and fully understand what it entails. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. I understand that I am entitled to ask any further questions at any time throughout the duration of the study.

I understand that:

- ✓ I have volunteered to participate in the study on my own accord, and that I am entitled to leave the study at any time should I wish to without any repercussions.
- ✓ I will be required to attend the requisite number of Silat testing sessions in order to complete the research project and also ready to compete in 6 sparring sessions (3 for pre training and 3 in post training) with other participant. I know the consequences for any injuries and already taken the precautions on this issue.
- ✓ I allow the research team to make all the record of my image, sound and footage during the research and sparring sessions for the purpose of this research using a video camera.
- ✓ I also allow the research team to record and distribute my video to public and proper channel such as non-profit research, education research and any sports segment relating on silat training system and exercises.
- ✓ All personal information and research data collected during the study will be kept in a secure location within the university grounds for a period of 7 years. The results of the study may be published in the future, however my anonymity will be maintained at all times.
- ✓ I understand that relevant sections of any of research notes and data collected during the study may be looked at by responsible individuals from UWIC for monitoring purposes, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.
- ✓ I agree to take part in the above study.

Signed (parent/guardian): Print Name:	Date:
Signed (participant): Print Name:	Date:

Appendix N

Study 3 : Pre and post tests statistics of E13 (Red) Vs C13 (Blue)

Action	Red		Blue		*Others*		Total		
	pre	*post*	*pre*	*post*	*pre*	*post*	*pre*	*post*	
Block & Kick	1	0	0	0	0	0	**1**	**0**	decrease
Block & Punch	0	0	0	0	0	0	**0**	**0**	-
Block & Swipe	0	0	0	0	0	0	**0**	**0**	-
Block	8	2	5	9	0	0	**13**	**11**	decrease
Catch	1	0	3	7	0	0	**4**	**7**	increase
Dodge	0	22	0	32	0	0	**0**	**54**	Increase
Fake Kick	4	6	7	7	0	0	**11**	**13**	increase
Fake Punch	1	0	2	1	0	0	**3**	**1**	decrease
Kick	52	65	57	38	0	0	**109**	**103**	decrease
Others	0	0	0	0	19	12	**19**	**12**	decrease
Punch	2	0	3	6	0	0	**5**	**6**	increase
Self Release	0	0	0	0	0	0	**0**	**0**	-
Swipe	0	0	0	0	0	0	**0**	**0**	-
Topple Down	1	0	4	0	0	0	**5**	**0**	decrease
Total	70	95	81	100	19	12	**170**	**207**	increase

***Others** = means low intensity activities

Appendix O

Study 3: Pre and post tests statistics of E16 (Red) Vs C16 (Blue)

Action	Red		Blue		*Others*		Total		
	pre	*post*	*pre*	*post*	*pre*	*post*	*pre*	*post*	
Block & Kick	6	5	5	0	0	0	11	5	decrease
Block & Punch	4	1	7	0	0	0	11	1	decrease
Block & Swipe	0	0	0	0	0	0	0	0	-
Block	25	1	10	9	0	0	35	10	decrease
Catch	0	0	1	5	0	0	1	5	increase
Dodge	2	0	2	0	0	0	4	0	decrease
Fake Kick	0	0	1	0	0	0	1	0	decrease
Fake Punch	1	0	3	0	0	0	4	0	decrease
Kick	37	63	38	33	0	0	75	96	decrease
Others	0	0	0	0	14	9	14	9	decrease
Punch	24	2	40	2	0	0	64	4	decrease
Self Release	0	0	0	0	0	0	0	0	-
Swipe	0	0	0	0	0	0	0	0	-
Topple Down	1	0	1	5	0	0	2	5	Increase
Total	100	72	108	54	14	9	222	135	decrease

***Others** = means low intensity activities

Appendix P

STUDY 3: GAME 1 of E13 (RED) VS C13 (BLUE)

Actions	OVERALL OUTCOMES									Grand Total	TOTAL FREQUENCY		
	Hit Elsewhere		*Hit Target*		*Miss Opponent*		*None*				*Total*	*Total*	*Total*
	Red	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*N/A*		*Red*	*Blue*	*N/A*
Block	1	0	7	5	0	0	0	0	-	**13**	8	5	-
Block & Kick	1	0	0	0	0	0	0	0	-	**1**	1	0	-
Block & Punch	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Block & Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Kick	21	28	8	5	23	24	0	0	-	**109**	52	57	-
Fake Kick	0	0	0	0	0	0	4	7	-	**11**	4	7	-
Punch	0	0	0	1	2	2	0	0	-	**5**	2	3	-
Fake Punch	0	0	0	0	0	0	1	2	-	**3**	1	2	-
Others	0	0	0	0	0	0	0	0	19	**19**	0	0	19
Catch	0	1	1	2	0	0	0	0	-	**4**	1	3	-
Dodge	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Self Release	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Topple Down	0	0	1	2	0	2	0	0	-	**5**	1	4	-
Total	**23**	**29**	**17**	**15**	**25**	**28**	**5**	**9**	**19**	**170**	**70**	**81**	**19**

*** RED = Experimental group silat exponent; BLUE = control group silat exponent; *Others* = means low intensity activities; Hit elsewhere = any silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area); Miss opponent = any silat actions that miss the 'target' or failed to deliver points. None and N/A= any attacking or defensive silat actions that did not contributes to point score.**

Appendix Q

STUDY 3: GAME 2 of E13 (RED) VS C13 (BLUE)

Actions	OVERALL OUTCOMES									Grand Total	TOTAL FREQUENCY		
	Hit Elsewhere		*Hit Target*		*Miss Opponent*		*None*				*Total*	*Total*	*Total*
	Red	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*N/A*		*Red*	*Blue*	*N/A*
Block	1	8	1	1	0	0	0	0	-	**11**	2	9	-
Block & Kick	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Block & Punch	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Block & Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Kick	2	1	5	2	58	35	0	0	-	**103**	65	38	-
Fake Kick	0	0	0	0	0	0	6	7	-	**13**	6	7	-
Punch	0	0	0	3	0	3	0	0	-	**6**	0	6	-
Fake Punch	0	0	0	0	0	0	0	1	12	**1**	0	1	-
Others	0	0	0	0	0	0	0	0	-	**12**	0	0	12
Catch	0	0	0	2	0	5	0	0	-	**7**	0	7	-
Dodge	0	0	22	32	0	0	0	0	-	**54**	22	32	-
Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Self Release	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Topple Down	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Total	**3**	**9**	**28**	**40**	**58**	**43**	**6**	**8**	**12**	**207**	**95**	**100**	**12**

*** RED = Experimental group silat exponent; BLUE = control group silat exponent; *Others* = means low intensity activities; Hit elsewhere = any silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area)'; Miss opponent = any silat actions that miss the 'target' or failed to deliver points. None and N/A= any attacking or defensive silat actions that did not contributes to point score.**

Appendix R

STUDY 3: GAME 1 of E16 (RED) VS C16 (BLUE)

Actions	OVERALL OUTCOMES									Grand Total	TOTAL FREQUENCY		
	Hit Elsewhere		*Hit Target*		*Miss Opponent*		*None*				*Total Red*	*Total Blue*	*Total N/A*
	Red	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*N/A*				
Block	0	0	24	10	1	0	0	0	-	**35**	25	10	-
Block & Kick	4	3	0	1	2	1	0	0	-	**11**	6	5	-
Block & Punch	0	1	4	5	0	1	0	0	-	**11**	4	7	-
Block & Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Kick	14	8	1	3	22	27	0	0	-	**75**	37	38	-
Fake Kick	0	0	0	0	0	0	0	1	-	**1**	0	1	-
Punch	2	0	13	16	9	24	0	0	-	**64**	24	40	-
Fake Punch	0	0	0	0	0	0	1	3	-	**4**	1	3	-
Others	0	0	0	0	0	0	0	0	14	**14**	0	0	14
Catch	0	0	0	1	0	0	0	0	-	**1**	0	1	-
Dodge	0	0	2	2	0	0	0	0	-	**4**	2	2	-
Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Self Release	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Topple Down	0	0	0	0	1	1	0	0	-	**2**	1	1	-
Total	**20**	**12**	**44**	**38**	**35**	**54**	**1**	**4**	**14**	**222**	**100**	**108**	**14**

*** RED = Experimental group silat exponent; BLUE = control group silat exponent; *Others* = means low intensity activities; Hit elsewhere = any silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area); Miss opponent = any silat actions that miss the 'target' or failed to deliver points. None and N/A= any attacking or defensive silat actions that did not contributes to point score.**

Appendix S

STUDY 3: GAME 2 of E16 (RED) VS C16 (BLUE)

Actions	OVERALL OUTCOMES									Grand Total	TOTAL FREQUENCY		
	Hit Elsewhere		*Hit Target*		*Miss Opponent*		*None*				*Total*	*Total*	*Total*
	Red	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*N/A*		*Red*	*Blue*	*N/A*
Block	0	0	1	9	0	0	0	0	-	**10**	1	9	-
Block & Kick	2	0	0	0	3	0	3	0	-	**5**	5	0	-
Block & Punch	0	0	1	0	0	0	0	0	-	**1**	1	0	-
Block & Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Kick	39	2	1	4	23	27	0	0	-	**96**	63	33	-
Fake Kick	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Punch	0	0	1	1	1	1	0	0	-	**4**	2	2	-
Fake Punch	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Others	0	0	0	0	0	0	0	0	9	**9**	0	0	9
Catch	0	0	0	5	0	0	0	0	-	**5**	0	5	-
Dodge	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Swipe	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Self Release	0	0	0	0	0	0	0	0	-	**0**	0	0	-
Topple Down	0	0	0	0	0	5	0	0	-	**5**	0	5	-
Total	**41**	**2**	**4**	**19**	**27**	**33**	**3**	**0**	**9**	**135**	**72**	**54**	**9**

*** RED = Experimental group silat exponent; BLUE = control group silat exponent; *Others* = means low intensity activities; Hit elsewhere = any silat actions that miss or did not successfully hit the 'target'; Hit target = any successful attacking or defensive silat actions (some contributes to scoring points; but some did not) or any silat actions that hit the 'target (scoring point area); Miss opponent = any silat actions that miss the 'target' or failed to deliver points. None and N/A= any attacking or defensive silat actions that did not contributes to point score.**

Appendix T: Pre- and post-training fitness of the control and experimental 13-year-old participants

Fitness Variable	Control group performance (*N= 1*)				Experimental Group Performance (*N= 1*)				Overall 13 year A & B
	Pre-test	*Post-test*	*Differences*	*Changes (%)*	*Pre-test*	*Post-test*	*Differences*	*Changes (%)*	*SWR (% change)*
HANDGRIP (kg)	222.61	221.63	-0.98	-0.4	223.59	219.67	-3.92	-1.8	5.5
PUSHUP	33	23	-10	-30.3[b]	10	27	17	**170.0**[a]	11.8
MEDBALL (cm)	148.0	147.6	-0.4	-0.3	148.0	153.0	5.0	3.4	5.5
YOYO (m)	840	1600	760	**90.5**[a]	680	760	80	11.8	12.8
SJ (cm)	36.96	37.36	0.40	1.1	36.02	32.27	-3.75	-10.4[b]	4.5
RJH (cm)	33.88	29.92	-3.97	-11.7[b]	32.48	28.74	-3.74	-11.5[b]	5.1
RJRSI	0.77	1.75	0.98	**127.3**[a]	0.81	1.34	0.53	**64.8**[a]	7.6
RJCT (ms)	447	170	-277	**62.1**[a]	361	177	-184.5	**51.1**[a]	6.1
3DJ (ms)	1828	2046	218	-11.9[b]	2311	2146	-165	**7.1**[a]	4.3
3KT (ms)	2028	1914	-114	5.6	2427	1535	-892	**36.8**[a]	6.3
20KT (ms)	16568	16112	-456	2.8	13152	12182	-970	**7.4**[a]	4.5

a = a positive change $\geq$ SWC; b = a negative (unwanted) change $\geq$ SWC. Negative value of differences in RJCT, 3DJ, 3KT & 20KT means improvement in the score and Changes (%); MEDBALL = medicine ball throw; RJH = rebound jump height; RJCT= rebound jump contact time; RJRSI=rebound jump reactive strength index; 3DJ=3-directional jump; 3KT=3 kick test; 20KT=20 kick test. A = 13-year-old fitness data (study 2) and B = 13-year-old pre-test training data (study 3).

Appendix U: Pre- and post-training fitness of the control and experimental 16-year-old participants

Fitness Variable	Control group performance (*N= 1*)				Experimental Group Performance (*N= 1*)				Overall 16 year C & D
	Pre-test	*Post-test*	*Differences*	*Changes (%)*	*Pre-test*	*Post-test*	*Differences*	*Changes (%)*	*SWR (% change)*
HANDGRIP (kg)	361.87	374.61	12.74	**3.5**[a]	322.64	366.77	44.13	**13.7**[a]	3.1
PUSHUP	31	37	6	**19.4**[a]	14	18	4	**28.6**[a]	7.4
MEDBALL (cm)	305.7	312.3	6.6	2.2	194.7	284.9	90.2	**46.3**[a]	4.5
YOYO (m)	400	400	0	0.0	440	440	0	0.0	11.6
SJ (cm)	23.74	24.28	0.54	2.3	26.74	26.29	-0.45	-1.7	3.9
RJH (cm)	24.25	20.68	-3.57	-14.7[b]	25.84	22.19	-3.65	-14.1[b]	5.1
RJRSI	0.47	0.41	-0.06	-12.8[b]	0.45	0.51	0.06	**12.2**[a]	4.1
RJCT (ms)	521	497	-24	4.7	454	426	-27.5	**6.1**[a]	5.1
3DJ (ms)	2867	2441	-426	**14.9**[a]	2646	2573	-73	2.8	6.0
3KT (ms)	2034	2190	156	-7.7[b]	2299	2455	156	-6.8	7.57
20KT (ms)	13865	21634	7769	-56.0[b]	16592	16881	289	-1.7	2.98

a = a positive change $\geq$ SWC; b = a negative (unwanted) change $\geq$ SWC. Negative value of differences in RJCT, 3DJ, 3KT & 20KT means improvement in the score and Changes (%); MEDBALL = medicine ball throw; RJH = rebound jump height; RJCT= rebound jump contact time; RJRSI=rebound jump reactive strength index; 3DJ=3-directional jump; 3KT=3 kick test; 20KT=20 kick test. C = 13-year-old fitness data (study 2) and D = 13-year-old pre-test training data (study 3).

Appendix V

- **Refereed abstract, Paper & Presentations**

CARDIFF SCHOOL OF SPORT · YSGOL CHWARAEON CAERDYDD

DISTRIBUTION OF FIGHT TIME AND BREAK TIME IN INTERNATIONAL SILAT COMPETITION

Mohamad Nizam Mohamed Shapie[1,2,3] Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]

[1]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.
[3]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia.

Introduction

Silat is a traditional martial art of that has evolved in Indonesia, Malaysia and Brunei Darussalam. Silat has evolved into a formal martial art that is now officially included in the South East Asia Games. Performance analysis has been used as a research tool to investigate various aspects of different combat sports. In professional boxing, Hughes and Franks (2004) described a system for analysis of punch types used. Other combat sports where performance analysis has investigated the action of competitors include Taekwondo (Wojtaś *et al.*, 2007) and mixed martial arts (Williams and O'Donoghue, 2006). Time-motion analysis is an objective observational analysis technique used to investigate work-rate in sport and exercise (O'Donoghue, 2008). The simplest computerised analysis system records periods of work and rest perceived by the observer (O'Donoghue *et al.*, 2005a). There is little work on work-rate in martial arts, especially Silat. The purpose of this investigation was to identify periods of fight time and break time within rounds of international Silat contests.

Methods

Publicly available video recordings of 7 male silat matches were used in the current investigation. The matches consisted of three 2 minute rounds and were from 5 different weight divisions ranging from 45-50kg to 75-80kg. All 7 matches went the full distance. The POWER system (O'Donoghue *et al.*, 2005a) was used to enter the start of all periods of action and breaks between the action that occurred within the matches. A DVD of the contest under investigation was viewed on a television or microcomputer while a separate computer was used to execute the data entry component of the POWER system. Each contest was entered twice by the primary author to test the reliability of the method. The data entered for two of the rounds had a good strength of agreement between independent observations ($0.61 \le k \le 0.80$) while the remaining 19 rounds had a very good strength of agreement between independent observations ($k \ge 0.81$).

A series of Friedman tests were used to compare several frequency, duration and percentage time variables of interest between the 3 rounds of a contest. The POWER system determined the number of action periods of 7 different durations (0-2s, 2-4s, 4-6s, 6-8s, 8-10s, 10-12s and 12s+) and break periods of 8 different durations (0-2s, 2-4s, 4-8s, 8-12s, 12-20s, 20-45s, 45-90s and 90s+) as well as combinations of action periods and the break periods that followed them. A chi square test of independence was used to determine if there was an association between the duration of a period of action and the duration of the recovery period that followed it.

Results

The mean for the two observations for each contest were determined and are presented in Table 1. There was no significant difference between the 3 rounds for the frequency of fight periods (p = 0.084), the duration of fight periods (p = 0.050), the duration of break periods (p = 0.867) or the percentage of round time spent in fight action (p = 0.368). The maximum duration of an action period observed in a contest ranged from 14.34s in a 70-75 kg contest to 68.25s in a world championship match. In a round, there were 0.8±0.6 action periods of under 2s, 1.1±0.8 of 2-4s, 5.1±9.2 of 4-6s, 4.3±5.8 of 6-8s, 3.9±3.2 of 8-10s, 3.0±1.8 of 10-12s and 11.9±5.2 action periods of 12s or longer. There were 1.8±1.2 break periods of 0-2s, 1.9±0.4 of 2-4s, 9.4±5.6 of 4-8s, 10.9±8.6 of 8-12s, 4.4±3.4 of 12-20s, 0.9±1.2 of 20-45s and 0.0±0.0 break periods of 45s or longer. There was no significant association between the duration of a period of action and the duration of the break which followed it ($\chi^2_8 = 13.0$, p = 0.113).

Table 1. Work and rest periods performed in each round

Performance Indicator	Round 1	Round 2	Round 3	All Rounds
Frequency of fight periods	9.3±4.2	10.0±5.6	10.7±5.0	30.0±14.4
Mean duration of fight periods (s)	16.0±6.2	17.0±11.1	13.0±4.4	15.3±6.7
Mean duration of break periods (s)	8.6±0.5	8.5±2.5	8.1±1.8	8.4±1.3
%Time spent in fight mode	63.8±10.5	63.2±16.6	60.8±13.3	62.6±12.8

Discussion

There are similar activity breakdowns between the 3 rounds of contests which is explained by the short duration of the contest (6 minutes) in comparison to the duration of team games such as soccer where fatigue has been observed between the first and second halves (Bangsbo *et al.*, 1991). The results suggest that there are a full range of fight periods from under 6s to over 12s. Furthermore, almost all break periods are under 20s. This has implications for the training of the energy systems required in international Silat competition with aspiring international competitors and their coaches needing to be aware of the requirements of the sport. Spencer *et al.* (2004) developed the concept of repeated work bouts in team games, recognising that players often have to perform multiple burst of activities without complete recovery in between. Hughes *et al.* (2005) undertook a laboratory study that showed that the power output of a series of ten 6s bursts was influenced by the duration of the recovery period in between. Therefore, the action periods that occur in silat cannot be considered as isolated bursts from which contestants will get full recovery. It is most likely that a the energy required for the action periods within silat matches at this level is derived from a combination of anaerobic and aerobic sources. This is because there are action periods of over 12s and because there are very short recoveries between some of the shorter action periods.

During the observational analysis process, it was apparent that the activity periods do not involve a consistent work-rate. There was usually a period of low intensity positioning prior to engaging the opponent followed by higher intensity action until a break was necessitated. Therefore, it is necessary for future research to characterise in detail the nature of action periods within silat matches. This should involve analysis of footstep movements (Richers, 1995), agility requirements (Bloomfield *et al.*, 2004) and specific silat attack and defence skills that are performed. Such detailed analysis will require the use of a commercial video analysis system such as those used to analyse speed agility quickness requirements of sport (Bloomfield *et al.*, 2004).

Unlike team games, where periods of high intensity activity of over 2s are a tiny minority of high intensity bursts, there were over 11 per 6 minute silat contest in the current investigation. Indeed, periods of action can last for over 1 minute. Therefore, there is a need for an improved version of the POWER system that can allow some discrimination between different bursts in this higher duration category. Ideally, such an improved version would permit the user to identify the durations of periods of action and periods of recovery of interest and then the system would analyse the observed activity according to this classification.

Conclusion

In conclusion, 62.6% of silat matches involves silat action with action periods ranging from under 6s to over 12s with recoveries ranging from under 4s to over 20s. Fighters must be prepared for short recoveries after burst irrespective of the duration of the burst of action. Further research is needed to characterise the activity within action periods.

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DISTRIBUTION OF FIGHT TIME AND BREAK TIME IN INTERNATIONAL SILAT COMPETITION

Mohamad Nizam Mohamed Shapie[1,2,3], Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]

[1]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia.
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.
[3]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia

Time-motion analysis has been applied to the investigation of work-rate in team and individual sports (O'Donoghue, 2008). However, there is little work on work-rate in martial arts. The purpose of this investigation was to identify periods of fight time and break time within rounds of international Silat contests. The POWER system (O'Donoghue *et al*., 2005) was used to enter the start of all periods of action and breaks between actions that occurred within 7 international Silat matches that went the full distance of 3 rounds. Each contest was entered twice to test the reliability of the method. The data entered for two of the rounds had a good strength of agreement between independent observations ($0.61 \le \kappa \le 0.70$) while the remaining 19 rounds had a very good strength of agreement between independent observations ($\kappa \ge 0.81$). The mean of the values for the two observations for each contest were determined and are presented in Table 1. A Friedman test revealed no significant difference between the 3 rounds for the frequency of fight periods (p = 0.084), the duration of fight periods (p = 0.050), the duration of break periods (p = 0.867) or the percentage of round time spent in fight action (p = 0.368). There were 0.8±0.6 fight periods of under 2s, 1.1±0.8 of 2-4s, 5.1±9.2 of 4-6s, 4.3±5.8 of 6-8s, 3.9±3.2 of 8-10s, 3.0±1.8 of 10-12s and 11.9±5.2 fight periods of 12s or longer. There were 1.8±1.2 break periods of 0-2s, 1.9±0.4 of 2-4s, 9.4±5.6 of 4-8s, 10.9±8.6 of 8-12s, 4.4±3.4 of 12-20s, 0.9±1.2 of 20-45s and 0.0±0.0 break periods of 45s or longer. These results suggest that there are a full range of fight periods from under 6s to over 12s. Furthermore, almost all break periods are under 20s. This has implications for the training of the energy systems required in international Silat competition with aspiring international competitors and their coaches needing to be aware of the requirements of the sport.

Table 1. Summary of Analysis

Performance Indicator	Round 1	Round 2	Round 3	All Rounds
Frequency of fight periods	9.3±4.2	10.0±5.6	10.7±5.0	30.0±14.4
Mean duration of fight periods (s)	16.0±6.2	17.0±11.1	13.0±4.4	15.3±6.7
Mean duration of break periods (s)	8.6±0.5	8.5±2.5	8.1±1.8	8.4±1.3
%Time spent in fight mode	63.8±10.5	63.2±16.6	60.8±13.3	62.6±12.8

Reference

O'Donoghue, P.G. (2008), Time-motion analysis, In: The Essentials of Performance Analysis: An Introduction (Edited by Hughes, M.D. and Franks, I.M.), London: Routledge, pp. 180-205.

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MOHAMAD NIZAM MOHAMED SHAPIE, JON OLIVER, PETER O'DONOGHUE AND RICHARD TONG

Distribution of fight time and break time in international Silat competition

1. Introduction

Silat is a traditional martial art of that has evolved in Indonesia, Malaysia and Brunei Darussalam. Silat has evolved into a formal martial art that is now officially included in the South East Asia Games. Performance analysis has been used as a research tool to investigate various aspects of different combat sports. In professional boxing, Hughes and Franks (2004) described a system for analysis of punch types used while in amateur boxing Coalter *et al*. (1998) investigated the validity of the computerised scoring system used. Other combat sports where performance analysis has investigated the action of competitors include Taekwondo (Wojtaś *et al*., 2007) and mixed martial arts (Williams and O'Donoghue, 2006). Time-motion analysis is an objective observational analysis technique used to investigate work-rate in sport and exercise (O'Donoghue, 2008). The simplest computerised analysis system records periods of work and rest perceived by the observer (O'Donoghue *et al*., 2005a). This coarse classification of activity has the advantage of improved reliability over time-motion analysis methods where a greater number of movement classes are used. This kind of time-motion analysis has been applied to the investigation of work-rate in netball (O'Donoghue, 2004), soccer (O'Donoghue *et al*., 2005b) and Gaelic football (O'Donoghue and King, 2005). However, there is little work on work-rate in martial arts, especially Silat. The purpose of this investigation was to identify periods of fight time and break time within rounds of international Silat contests.

2. Methods

Publicly available video recordings of 7 male silat matches were used in the current investigation. The matches consisted of three 2 minute rounds and were from 5 different weight divisions ranging from 45-50kg to 75-80kg. All 7 matches went the full distance. The POWER system (O'Donoghue *et al*., 2005a) was used to enter the start of all periods of action and breaks between the action that occurred within the matches. A DVD of the contest under investigation was viewed on a television or microcomputer while a separate computer was used to execute the data entry component of the POWER system. Each round was entered as a separate match period, with all 21 rounds of recorded data being summarised within a single Microsoft Excel spreadsheet for further processing and subsequent statistical analysis when loaded into SPSS (SPSS Inc., Chicago, Il, USA). Each contest was entered twice by the primary author to test the reliability of the method. The data entered for two of the rounds had a good strength of agreement between independent observations (0.61 ≤ □ ≤ 0.80) while the remaining 19 rounds had a very good strength of agreement between independent observations (□ ≥ 0.81).

A series of Friedman tests were used to compare several frequency, duration and percentage time variables of interest between the 3 rounds of a contest. The POWER system determined the number of action periods of 7 different durations (0-2s, 2-4s, 4-6s, 6-8s, 8-10s, 10-12s and

12s+) and break periods of 8 different durations (0-2s, 2-4s, 4-8s, 8-12s, 12-20s, 20-45s, 45-90s and 90s+) and well as combinations of action periods and the break periods that followed them. A chi square test of independence was used to determine if there was an association between the duration of a period of action and the duration of the recovery period that followed it. It was necessary to merge some classes of break and some classes of action period to ensure that there was an expected frequency of at least 5.0 in at least 80% of the cells of the cross-tabulation of action and break period entered into the chi square test.

3. Results

The mean for the two observations for each contest were determined and are presented in Table 2. There was no significant difference between the 3 rounds for the frequency of fight periods ($p = 0.084$), the duration of fight periods ($p = 0.050$), the duration of break periods ($p = 0.867$) or the percentage of round time spent in fight action ($p = 0.368$). The maximum duration of an action period observed in a contest ranged from 14.34s in a 70-75 kg contest to 68.25s in a world championship match. In a round, there were 0.8±0.6 action periods of under 2s, 1.1±0.8 of 2-4s, 5.1±9.2 of 4-6s, 4.3±5.8 of 6-8s, 3.9±3.2 of 8-10s, 3.0±1.8 of 10-12s and 11.9±5.2 action periods of 12s or longer. There were 1.8±1.2 break periods of 0-2s, 1.9±0.4 of 2-4s, 9.4±5.6 of 4-8s, 10.9±8.6 of 8-12s, 4.4±3.4 of 12-20s, 0.9±1.2 of 20-45s and 0.0±0.0 break periods of 45s or longer.

Table 1: Work and rest periods performed in each round

Performance Indicator	Round 1	Round 2	Round 3	All Rounds
Frequency of fight periods	9.3±4.2	10.0±5.6	10.7±5.0	30.0±14.4
Mean duration of fight periods (s)	16.0±6.2	17.0±11.1	13.0±4.4	15.3±6.7
Mean duration of break periods (s)	8.6±0.5	8.5±2.5	8.1±1.8	8.4±1.3
%Time spent in fight mode	63.8±10.5	63.2±16.6	60.8±13.3	62.6±12.8

Table 2 shows the total number of action periods and following break periods of different durations recorded for all of the contests. The values used were the means of the 2 observations for each contest. There was no significant association between the duration of a period of action and the duration of the break which followed it ($\chi^2_8 = 13.0$, $p = 0.113$).

Table 2: Duration of activity periods and the break periods that followed them

Duration of action period	Duration of following recovery					
	0-4s	4-8s	8-12s	12-20s	20s or longer	All Breaks
0-6s	11.5	9.0	18.0	6.0	3.0	47.5
6-12s	6.5	28.0	29.5	12.5	1.5	78.0
12s or longer	7.5	29.0	27.5	12.0	1.5	78.5
All Actions	25.5	66.0	76.0	30.5	6.0	204.0

4. Discussion

There are similar activity breakdowns between the 3 rounds of contests whic is explained by the short duration of the contest (6 minutes) in comparison to the duration of team games such as soccer where fatigue has been observed between the first and second halves (Bangsbo et al., 1991). The results suggest that there are a full range of fight periods from under 6s to over 12s. Furthermore, almost all break periods are under 20s. This has implications for the training of the energy systems required in international Silat competition with aspiring international competitors and their coaches needing to be aware of the requirements of the sport. Spencer et al. (2004) developed the concept of repeated work bouts in team games, recognising that players often have to perform multiple burst of activities without complete recovery in between. Hughes et al. (2005) undertook a laboratory study that showed that the power output of a series of ten 6s bursts was influenced by the duration of the recovery period in between. Therefore, the action periods that occur in silat cannot be considered as isolated bursts from which contestants will get full recovery. It is most likely that a the energy required for the action periods within silat matches at this level is derived from a combination of anaerobic and aerobic sources. This is because there are action periods of over 12s and because there are very short recoveries between some of the shorter action periods.

During the observational analysis process, it was apparent that the activity periods do not involve a consistent work-rate. There was usually a period of low intensity positioning prior to engaing the opponent followed by higher intensity action until a break was necessitated. The research situation here is similar to the analysis of tennis rallies. Rally durations have been used to give an indication of the demands of tennis on different surfaces (O'Donoghue and Liddle, 1998). However, the activity that is performed within rallies varies between the court surfaces (Richers, 1995). Therefore, it is necessary for future research to characterise in detail the nature of action periods within silat matches. This should involve analysis of footstep movements (Richers, 1995), agility requirements (Bloomfield *et al*., 2004) and specific silat attack and defence skills that are performed. Such detailed analysis will require the use of a commercial video analysis system such as those used to analyse speed agility quickness requirements of sport (Bloomfield *et al*., 2004).

Unlike team games, where periods of high intensity activity of over 2s are a tiny minority of high intensity bursts, there were over 11 per 6 minute silat contest in the current investigarion. Indeed, periods of action can last for over 1 minute. Therefore, there is a need for an improved version of the POWER system that can allow some discrimination between different bursts in this higher duration category. Ideally, such an improved version would permit the user to identify the durations of periods of action and periods of recovery of interest and then the system would analyse the observed activity according to this classification.

Authors

MOHAMAD NIZAM MOHAMED SHAPIE[1,2,3], JON OLIVER[2], PETER O'DONOGHUE[2] AND RICHARD TONG[2]: [1]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia., [2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK. [3]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia

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Activity during action time in international Silat competition

Mohamad Nizam Mohamed Shapie[1,2,3], Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]
[1]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.
[3]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia.

Introduction

The distribution of fight time and break time has been determined for National Silat competition (Shapie *et al.*, , 2008). Typically 62.6% of the bout is spent in fight time with 30.0 action periods of 15.3 s being performed with break periods averaging 8.4 s. This suggests that Silat exponents are accustomed to numerous of high force intensity action alternating with lower intensity movements throughout match. This information gives an indication of the nature of work and recovery periods within this level of the sport. However, the intensity of the work periods within any sport depends on the nature of the activity being performed. Therefore, the purpose of the current case study was to describe the detailed activity that occurs during the fight time of a Silat bout.

Methods

A DVD recording of a single national bout was entered into the Focus X2 system (Elite Sports Analysis, Delgaty Bay, Scotland) and the system used to identify 14 different types of event performed by the 2 contestants as well as the start and end of action periods.

An intra-operator reliability study revealed that the strength of agreement for action was moderate (k = 0.44), the athlete performing the action was moderate (k = 0.47) and the outcome of an action was fair (k = 0.25). The chronologically recorded sequence of events was exported into Microsoft Excel for further analysis.

The events were classified into 3 broad types : Block, Kick and Other.

Results

Table 1 shows the actions performed during the contest and their outcomes. Clearly the table indicates that kick and punch were the two important skills that needed by the Silat exponent. Table 2 shows the frequency profile of the 2 contestants. A chi square test of independence revealed that the two contest performed a different profile of actions during the bout ($\chi^2_2 = 39.8$, $p < 0.001$) with the blue contestant performing more kicks and less blocks proportionately than the red contestant. The match was won by the blue contestant. A chi square test of independence also revealed no significant association between an action performed by a contestant and the previous action that they performed ($\chi^2_4 = 7.6$, $p = 0.108$). The red contestant performed 0.34 events per s of fight time while the blue contestant performed 0.33.

Table 1. Actions and outcomes recorded.

Action	Outcome				
	Hit elsewhere	Hit Target	Miss opponent	N/A	Total
Block & Kick	8		1		9
Block & Punch		1	1		2
Block & Swipe	1				1
Block		14			14
Catch		3	2		5
Dodge				1	1
End Round				3	3
Flick Kick				6	6
Flick Punch				3	3
Kick	76	13	12		101
Others				48	48
Punch	4	28	2		34
Self release		3			3
Start Action				31	31
Start Break				31	31
Start Round				3	3
Swipe	1		4		5
Topple		1	3	1	5
Total	90	63	25	127	305

Table 2. Frequency profile of two contestants

Contestant	Block	Kick	Other	Total
Blue	5	76	35	116
Red	21	31	69	121
Total	26	107	104	237

Discussion

The data about the nature of the activity performed within fight periods can be combined with the analysis done by Shapie *et al.* (2008) to provide a detailed description of the demands of the sport and assist in the development of specific training programmes. The approach used here would be useful to apply to other sports whose work and rest periods have been investigated to give a greater understanding of the type and frequency of action within the work periods.

The match shows that 44.3% of the actions were contributed by kick and punch actions. These indicated that a good ability of kicking and punching are important for every contestant that involve in Silat competition. Interestingly , 82.6% of the punch hit the target. While, only 12.9 % of the kick hit the target. Thus it is important to know that punching is the most important skill that identical for Silat exponent because of high percentage of hitting the target.

Others actions contribute of 20.3% of the actions. Here the *others* actions was the *off fight-contact* actions that performed by silat exponents once the referee has started the fight and also after performed more than 4 kinds of attack and defence in a row between both of the exponents. The aerobic sources contribute to the energy required during the *off fight-contact* period in a round of Silat match. Off fight-contact actions is a low intensity event where both of the silat exponents performing low activity actions such as "*sikap pasang*" posture or coming close to each other using Silat step pattern "*pola langkah*".

Block techniques is the common actions in Silat with 100% hit target. This mean both of the silat exponent are good in using blocking techniques in dealing with any attacks. The red exponents work action (121 actions) was greater than blue exponents (116 actions). It was also showed that the red exponents less kick compare to blue exponent. This is identical for this match as the red exponent was shorter than blue exponent. Thus, the perfect skill for red exponent was to score point using hand (to close the reach from being kick). In contrast, the blue exponent strike more using kick. With 2:1 ratio of work to rest in Silat match, it is important to determine the perfect skills that contribute to score points besides developing the energy system that involved in Silat competition.

Conclusion

The results of this study complement those of the broad work and rest study undertaken by Shapie *et al.* (2008). It is recommended that those developing conditioning elements of training programmes for Silat athletes are aware of the frequency and spread of durations of action and rest periods within Silat bouts as well as the nature of the activity that is performed within the action periods. The approach adopted in the current paper should be used to explore the nature of work performed in other sports where the frequency and duration of high intensity activity periods fails to provide sufficient information to fully characterise the demands of the sport.

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Activity during Action Time in International Silat Competition

Mohamad Nizam Mohamed Shapie[1,2,3], Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]

[1]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia.
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.
[3]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia

The distribution of fight time and break time has been determined for international Silat competition (Shapie *et al*., 2008). Typically 62.6% of the bout is spent in fight time with 30.0 action periods of 15.3s being performed with break periods averaging 8.4s. This information gives an indication of the nature of work and recovery periods within this level of the sport. However, the intensity of the work periods within any sport depends on the nature of the activity being performed. Therefore, the purpose of the current case study was to describe the detailed activity that occurs during the fight time of a Silat bout. A DVD recording of a single international bout was entered into the Focus X2 system (Elite Sports Analysis, Delgaty Bay, Scotland) and the system used to identify 14 different types of event performed by the 2 contestants as well as the start and end of action periods. An intra-operator reliability study revealed that the strength of agreement for action was moderate (κ = 0.44), the athlete performing the action was moderate (κ = 0.47) and the outcome of an action was fair (κ = 0.25). The chronologically recorded sequence of events was exported into Microsoft Excel for further analysis. The events were classified into 3 broad types as shown in Table 1. A chi square test of independence revealed that the two contest performed a different profile of actions during the bout ($\chi^2_2 = 39.8$, $p < 0.001$) with the red contestant performing more kicks and less blocks proportionately than the blue contestant. A chi square test of independence also revealed no significant association between an action performed by a contestant and the previous action that he performed ($\chi^2_4 = 7.6$, p = 0.108). The mean fight time duration in the current case study of 11.5s was slightly lower than the value of 15.3 s reported by Shapie *et al*. (2008) while the recoveries of 12.2 s were slightly longer. However there was a full range of fight period durations from 2.4s to 27.6s. The number of events performed per second of fight time ranged from 0.1 event per s in one fight period to 1.2 events per s in another with a mean of 0.7 events being performed per s by the 2 contestants. The red contestant performed 0.34 events per s of fight time while the blue contestant performed 0.33. The data about the nature of the activity performed within fight periods can be combined with the analysis done by Shapie *et al*. (2008) to provide a detailed description of the demands of the sport and assist in the development of specific training programmes. The approach used here would be useful to apply to other sports whose work and rest periods have been investigated to give a greater understanding of the type and frequency of action within the work periods.

Table 1. Actions performed during an international Silat match

Contestant	Block	Kick	Other	Total
Blue	5	76	35	116
Red	21	31	69	121
Total	26	107	104	237

Reference:

1. Shapie, M.N.M., Oliver, J., O'Donoghue, P.G. and Tong, R. (2008). Distribution of fight time and break time in international silat competition. Paper presented at the World Congress of Performance Analysis of Sport 8, Magdeburg, September.

FITNESS CHARACTERISTICS OF YOUTH SILAT PERFORMERS

Mohamad Nizam Mohamed Shapie[1, 2, 3], Jon Oliver[1]✉, Peter O'Donoghue[1] and Richard Tong[1]

[1]Cardiff School of Sport, University of Wales Institute Cardiff, United Kingdom, [2]Sport Centre, University of Malaya, Malaysia, [3]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia.

Running Head: Fitness in youth silat

ABSTRACT

Background and Purpose**:** Despite gaining international recognition, researched focused on silat is limited. The primary purpose of this research was to profile the physiological characteristics of young silat athletes. ***Method*****:** Eight motor performance tests, including two newly developed silat-specific tests were administrated to a sample of 178 young participants (96 males and 82 females) aged 13 to 16 years. The tests were squat, rebound and a three-directional jump, grip strength, medicine ball throw, push-ups, yo-yo endurance and a 20-kick test. ***Result*****:** Overall results showed that male participants outperformed the female participants for most tests, the fitness characteristics of females did not change with age for any variable (all $p > 0.05$), while males tended to improve their fitness with advancing age/maturation. Females were significantly more advanced, by about 2 years in the estimated age from peak height velocity (PHV) compared to the males (1.1 ± 0.7 versus -0.9 ± 1.1 y from PHV, $p<0.05$). Measures of isometric strength (grip strength), upper body power (medicine ball throw) and endurance (push-ups), lower body power (squat-jumps), and endurance (yo-yo test) showed significant (all $p<0.05$) gains after 15 years-old in males. ***Conclusion and discussion*****:** Original data is presented that could be useful for benchmarking fitness in youth silat. Being involved in silat allowed female participants to maintain their fitness, whereas male participants improved their fitness at or post PHV. These gender-specific differences are attributed to differing maturational processes and the findings may be useful when devising training programmes to maximise fitness development in youth silat.

Key Words: Maturity, physiological assessment, sports demands, combat sports, silat

AFFECT OF INTERVENTION CIRCUIT TRAINING ON FITNESS DEVELOPMENT IN YOUTH SILAT

Mohamad Nizam Mohamed Shapie[1, 2, 3], Jon Oliver[1]✉, Peter O'Donoghue[1] and Richard Tong[1]

[1]Cardiff School of Sport, University of Wales Institute Cardiff, United Kingdom, [2]Sport Centre, University of Malaya, Malaysia, [3]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia.

Running Head: Circuit training in youth silat

ABSTRACT

***Background and purpose*:** The purpose of this study was to determine the effect of age and maturation on 6 weeks of silat-specific circuit training (SSCT). ***Method*:** Thirteen (n=26) and 16 year (n=21) old boys participated in SSCT twice weekly during their normal silat lessons, while control groups (CG) of 13 (n=26) and 16 year (n=14) olds continued with their normal training. Pre-to-post tests included squat (SJ), rebound and three-directional jumps (3DJ), grip strength (HG), medicine ball throw (MedBall), 60 s push-ups (PU), yo-yo endurance and a 20-kick test. ***Result*:** The older intervention group (EG) demonstrated significant (all $p<0.05$) gains in endurance (566 ± 4 m), SJ (1.4 ± 0.5 cm) and PU (9 ± 1 reps). The younger EG also significantly (all $p<0.05$) improved PU performance (12 ± 2 reps), together with reactive strength index (RSI) (0.20 ± 0.10) and 3DJ (0.23 ± 0.08 s). Significant (all $p<0.05$) improvements in MedBall were observed in the older (28 ± 18 cm) and younger (34 ± 7 cm) CG, while the older group also improved HG (2.6 ± 2.0 kg). ***Conclusion and discussion*:** Gains in endurance and SJ are more pronounced in more mature children and may be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in younger children. Both EGs were able to improve PU performance, suggesting similar local muscular adaptation. Improvements following SSCT appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power.

Key Words: Circuit training, martial arts, age, maturation

FITNESS CHARACTERISTICS OF YOUTH SILAT PERFORMERS

Mohamad Nizam Mohamed Shapie[1,2,3], Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]

[1]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Wales, CF23 6XD UK
[3]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia

Introduction

- Silat is a martial art of East Asian origin that can have both artistic and contact variations; with the contact version similar to both judo and taekwondo in that it is weight-classified, unarmed and full contact (Aziz *et al*., 2002), but with unique movement patters and scoring systems (Shapie *et al*., 2008, 2009).
- Little is known about the physical and physiological characteristics that distinguish younger and older silat competitors, or how these develop with age and maturation.
- Identifying sport-specific fitness trends across youth Silat performers will enable identification of those traits which are most important to performance, helping to inform training.
- Therefore, the aims of the study are to profile the fitness characteristics of both male and female youth Silat athletes aged between 13 and 16 years old.

Methods

- Eight motor performance tests, including two newly developed silat-specific tests (20-kick test [20KT], CV = 6.83% and three-directional jump [3DJ], CV = 9.00%) were administrated to a sample of 178 young participants (96 males and 82 females) aged 13 to 16 years.
- The tests were squat (SJ), rebound (RJ) and a 3DJ, grip strength, medicine ball throw, (MedBall) push-ups (PU), yo-yo endurance and a 20KT. Maturation was estimated as time from peak height velocity, using anthropometric measures and the equations proposed by Mirwald *et al*. (2002).
- Performance data was analysed using a two way ANOVA using a 2 X 4 model (gender * age group). Significant main and interaction effects were further explored using a Bonferroni post-hoc adjustment

Results

- Table 1 shows the overall results showed that male participants outperformed the female participants for most tests, the fitness characteristics of females did not change with age for any variable (all, p >0.05), while males tended to improve their fitness with advancing age/maturation.
- Females were significantly more advanced, by about 2 years in the estimated age from peak height velocity (PHV) compared to the males (1.1 ± 0.7 versus -0.9 ± 1.1 y from PHV, p<0.05).
- Measures of isometric strength (grip strength), upper body power (medicine ball throw) and endurance (push-ups), lower body power (squat-jumps), and endurance (yo-yo endurance test) showed significant (all, p<0.05) gains after 15 year olds in males.

Table 1. Physical and performance characteristics of male and female silat exponents aged 13-16 years old.

Variable	Male	Female
Body Weight (kg)	49.6 ± 12.7	48.1 ± 8.6
Height (cm)	155.3 ± 9.3*	152.0 ± 5.4
Sitting Height (cm)	77.0 ± 5.4*	75.9 ± 3.5
Years from peak height velocity (PHV)	-0.9 ± 1.1*	1.1 ± 0.7
Grip Strength (kg)	32.2 ± 7.9*	24.8 ± 4.0
Med Ball (cm)	260 ± 65*	238 ± 43
Yoyo (m)	1135 ± 609*	684 ± 278
Push- ups	29 ± 13*	26 ± 9
Squat Jump (cm)	32.7 ± 7.50*	23.35 ± 4.73
RJ height (cm)	26.31 ± 7.61*	20.72 ± 5.01
RJ Contact Time (ms)	343 ± 104*	286 ± 79
RJ Reactive Strength Index (RSI)	0.73 ± 0.17	0.71 ± 0.16
3DJ (ms)	3.10 ± 0.49	3.13 ± 0.54
20KT(ms)	14.88 ± 2.98*	16.31 ± 2.29

*Significant difference between males and females (p < 0.05)

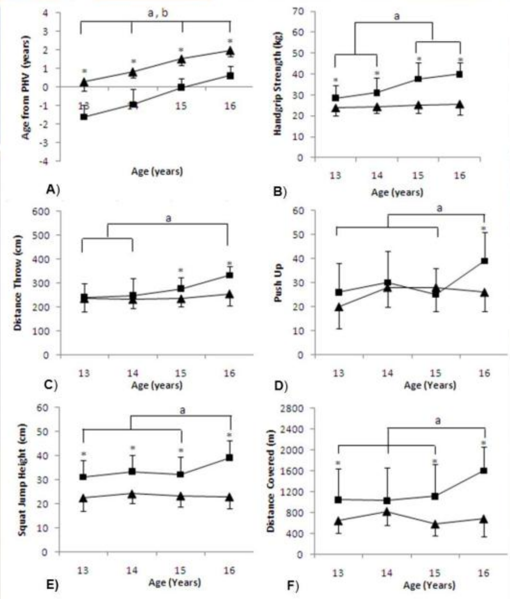

Figure 1. Results for (males ■ and females ▲) estimated age from peak height velocity (A) and variables demonstrating significance age*gender interactions. B) handgrip strength; C) medicine ball throw; D) push-ups; E) squat jump; F) Yo-yo endurance. *Significant difference between males and females in the same age group (p < 0.05); ᵃSignificant difference between age groups for the males; (p < 0.05); ᵇSignificant difference between age groups for the females; (p < 0.05).

Discussion

- Boys showed an improvement in a number of the variables when comparing the older age groups to the younger age groups. The observed responses are likely to be associated with gender-specific maturation; the youngest female groups were already estimated to be around peak height velocity, whereas the boys did not achieve this status until the 15 year age group.
- Improvements are likely to be associated with maturational factors such as hormone development that leads to increased muscle mass and internal organ size (Viru *et al*., 1999) providing strength and endurance benefits, respectively. Such hormonal responses at puberty are critical in improving performance and allowing training adaptations.

Conclusion

- Original data is presented that could be useful for benchmarking fitness in youth silat.
- Being involved in silat allowed female participants to maintain their fitness, whereas male participants improved their fitness at or post-PHV.
- These gender-specific differences are attributed to differing maturational processes and the findings may be useful when devising training programmes to maximise fitness development in youth silat

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Contact Information: Mohamad Nizam Mohamaed Shapie iijam@um.edu.my

AFFECT OF CIRCUIT TRAINING ON FITNESS DEVELOPMENT IN YOUTH SILAT

University of Malaya

Mohamad Nizam Mohamed Shapie[1,2,3], Jon Oliver[2], Peter O'Donoghue[2] and Richard Tong[2]

[1]Sport Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Cardiff School of Sport, University of Wales Institute Cardiff, Cyncoed Campus, Wales, CF23 6XD UK
[3]Seni Silat Malaysia, Ministry of Culture, Arts and Tourism, Malaysia

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Introduction

- Silat Olahraga is a martial art of East Asian origin that is similar to both judo and taekwondo in that it is weight-classified, unarmed and full contact (Aziz *et al.*, 2002).
- Circuit training represents a form of interval training, whereby intensity and exercises employed can be tailored to reflect the demands of the sport. This type of training could promote adaptations in both the aerobic and anaerobic systems, both of which are highly taxed during silat competition (Aziz *et al.*, 2002).
- However, this exercise pattern is unlikely to be specific to silat where exponents have a typical work to rest ratio of 16:8 s during competition (Shapie *et al.*, 2008).
- Therefore, the purpose of the current study was to determine the effect of age and maturation on 6-week of silat-specific circuit-training (SSCT).

Methods

- Thirteen (n=26) and 16 year (n=21) old boys participated in SSCT twice weekly during their normal silat lessons, while control groups (C) of 13 (n=26) and 16 year (n=14) olds continued with their normal training.
- Participants in both groups attended 2 fitness testing sessions with a minimum of 48-hours between each session in week 1 (pre-training) and week 8 (post-training) in which they completed various tests of general and silat-specific fitness.
- Descriptive statistics for each group pre- and post-training intervention are provided as means (± standard deviations). A 2 x 2 x 2 model ANOVA (age x group x time) were used to test for significant differences in performance, where age = 13 or 16 year age groups; group = C (control) or E (experimental) group & time refers to pre-to-post training fitness test data.

Results

- The main and interaction effects of age, interaction group and time on silat-specifics variables are displayed in table 1.
- While, analysis of individual group responses demonstrated differing results between C and E groups across the two age groups for some variables in figure 1, 2, 3, and 4.

Table 1. Main and interaction effects of age, interaction group and time on silat-specifics variables.

Variable	Age	Inter	Time	Age*Time	Time* Inter	Age*Time* Inter
Handgrip Strength	0.000**	0.882	0.002**	0.089	0.517	0.119
MedBall	0.000**	0.626	0.000**	0.769	0.074	0.754
Yoyo	0.000**	0.224	0.035**	0.000**	0.072	0.058
Push- ups	0.023**	0.587	0.000**	0.332	0.000**	0.735
Squat Jump	0.000**	0.418	0.733	0.078	0.391	0.138
Rebound Jump						
- jump height	0.000**	0.565	0.000**	0.031**	0.107	0.108
- CT	0.000**	0.124	0.040**	0.069	0.000**	0.244
- RSI	0.204	0.195	0.125	0.006**	0.008**	0.974
TT of 3DJ	0.000**	0.089	0.044**	0.598	0.170	0.110
TT of 3KT	0.000**	0.497	0.177	0.472	0.334	0.704

** denoting significant difference ($p < 0.05$) Age=13-year and 16-year old groups; Inter (Intervention)=control and experimental groups; Time=pre-test and post-test; MedBall=Medicine Ball throw distance; Yoyo = Yoyo Intermittent Endurance Test Leve1 1; CT=Contact Time; RSI=Reactive Strength Index (jump height / CT); TT=total time

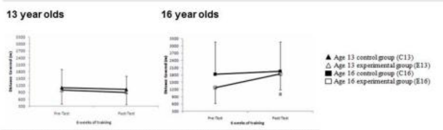

Figure 1. Results for pre- and post-training yo-yo intermittent endurance test level one performance in 13 year olds (left) and 16 year olds (right) silat performers; "a" denoting a significant change ($p < 0.05$) in the experimental group.

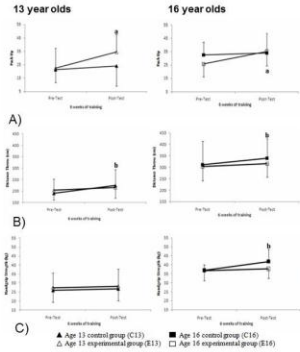

Figure 2. Results for pre- and post-training of upper body test performance of 13 year olds (left) and 16 year olds (right) silat performers. (A) push-ups performance; B) medicine ball throw performance; C) handgrip performance; "a" denoting a significant change ($p < 0.05$) in the experimental group and "b" denoting a significant change ($p < 0.05$) in the control group.

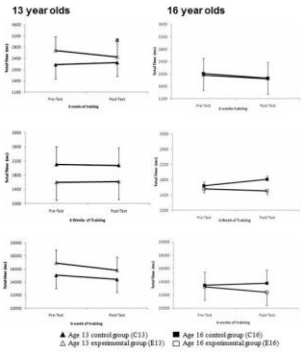

Figure 3. Results for pre- and post-training of silat-specific performance in 13 year olds (left) and 16 year olds (right) silat performers. (A) 3-directional jump; B) 3-kick test; C) 20-kick test; "a" denoting a significant change ($p < 0.05$) in the experimental group.

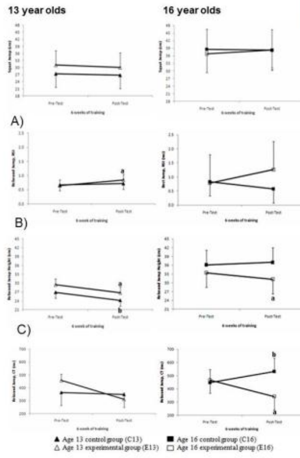

Figure 4. Results pre- and post-training of jump tests performance in 13 year olds (left) and 16 year olds (right) silat performers. (A) best squat jump; B) best jump height of rebound jump; C) best contact time (CT) of rebound jump; D) best reactive strength (RSI) of rebound jump; "a" denoting a significant change ($p < 0.05$) in the experimental group and "b" denoting a significant change ($p < 0.05$) in the control group.

Discussion

- The E16 improved endurance performance due to the exposure to the intervention training while no other group improved on this measure.
- The significant improvement in E16 may be due to increases in body size or active muscle mass (Van Praagh and Doré, 2002; Beunen, 1997; Blimkie *et al.*, 1989), which are maturation dependent. This study supports a greater sensitivity to training during this period immediately post-PHV, probably coinciding with peak weight velocity (Malina *et al.*, 2004).
- The significant improvements in E13 and E16 in push-ups following intervention suggesting that both groups are able to adapt these mechanisms with training (e.g. lactate tolerance and buffering) to a similar degree, suggesting no association between natural development and trainability.

Conclusion

- Gains in endurance and squat jump are more pronounced in more mature children and may be associated with hormonal status, while gains in jumps requiring more co-ordination suggest greater neural gains in younger children.
- Both E groups were able to improve push-ups performance, suggesting similar local muscular adaptation. Improvements following SSCT appear to be age and maturation dependent, while traditional training may be better at improving upper body strength and power.

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Contact Information: Mohamad Nizam Mohamaed Shapie iijam@um.edu.my