GAME STRUCTURE ANALYSIS IN ADOLESCENT SQUASH PLAYERS

By

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ABSTRACT

This study was aimed to determine the game structure of adolescent male squash players generally, in Under-17 Age Category (U-17), Under-19 Age Category (U-19) and between these two age categories. Fifty squash games (twelve matches) recorded in four Junior National Tournaments were analyzed to obtain the data of match duration (minutes), game duration (minutes), rallies per game, shots per rally, rally length (seconds), rest time between rallies (seconds), ball in play in minutes, ball in play in percentage (%) and work-rest ratio. Results for general game structure (where both categories had taken into account) showed the means of game duration at 8.87 minutes, number of rallies per game at 20.36, number shots per rally at 10.54, rally length at 16.04 seconds, time between rallies at 10.40 seconds, ball in play at 5.46 minutes or 61.77%, work-rest ratio at 1.70 and match duration at 36.15 minutes. Results showed the number of shots per rally, ball in play in minutes, ball in play in percentage, rally length, work-rest ratio being significantly higher in U-19 than in U-17. Adolescent players in U-19 possess quite similar values for rally length, number of shots per rally, rest time between rallies and ball in play in percentage when compared with adult elite squash players. Training protocol of adolescent squash players should basically follow the game structure during match-play which had been found in the study and the differences between U-17and U-19 suggest training loads should be applied differently in the mentioned categories.

ABSTRAK

Secara amnya, kajian ini bertujuan untuk menentukan struktur permainan skuasy dalam kalangan pemain remaja lelaki. Manakala, secara spesifiknya, kajian ini bertujuan untuk menentukan struktur permainan untuk pemain dalam kategori 17 tahun ke bawah (U-17), kategori 19 tahun ke bawah (U-19) dan menentukan perbezaan antara dua kategori tersebut. Lima puluh permainan skuasy (12 perlawanan) yang direkodkan dalam empat pertandingan junior peringkat kebangsaan dianalisis untuk mendapatkan data tempoh masa perlawanan (minit), tempoh masa permainan (minit), jumlah rally (siri pukulan sebelum mendapat markah) dalam setiap permainan, jumlah pukulan untuk setiap rally, panjang rally (saat), masa antara dua rally (saat), masa permainan sebenar (minit), peratusan masa permainan sebenar (%) dan nisbah kerja-rehat. Keputusan untuk struktur permainan secara amnya (di mana kedua-dua kategori diambil kira) menunjukkan tempoh masa permainan adalah 8.87 minit, jumlah rally dalam satu permainan adalah 20.36, jumlah pukulan untuk setiap rally adalah 10.54, panjang rally adalah 16.04 saat, masa antara dua rally adalah 10.40 saat, masa permainan sebenar adalah 5.46 minit atau 61.77%, nisbah kerja-rehat adalah 1.70 dan tempoh masa perlawanan adalah 36.15 minit. Keputusan juga menunjukkan jumlah pukulan untuk setiap rally, masa permainan sebenar, peratusan masa permainan sebenar, panjang rally dan nisbah kerja-rehat adalah lebih tinggi dalam kategori U-19 daripada U-17. Apabila berbanding dengan pemain elit dewasa skuasy, pemain remaja dalam kategori U-19 menunjukkan keputusan yang hampir sama dalam panjang rally, jumlah pukulan untuk setiap rally, masa antara dua rally dan peratusan masa

permainan sebenar. Protokol latihan pemain skuasy remaja secara asanya perlu mengikuti struktur permainan semasa pertandingan seperti yang ditunjukan dalam kajian ini dan perbezaan antara kategori U-17and U-19 menunjukkan beban latihan harus berbeza antara kedua-dua kategori tersebut.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Squash has been played for over 140 years, in 185 countries, and the World Squash Federation (WSF) now has 150 National Associations in membership. Squash has grown sensationally in the last forty years and it is now poised to become one of the largest and best loved of all sports (WSF, 2012). Squash is played in various categories according to gender and age of players: Men, Women, Junior Men, Junior Women and Masters age categories. Therefore, research on match characteristics and requirements for various categories of players is important. However, studies on elite junior (adolescent) squash players on physiological characteristics as well as match structure, spatial and temporal structure are scarce.

Furthermore, the traditional English scoring system was changed to point per rally (PPR) 15 scoring system in 1988, and to PPR-11 scoring system in 2004 necessitating for more research on elite squash, especially for elite junior squash players. To the best of the author's knowledge, limited data have been reported on match characteristics of junior squash, particularly after the introduction of the new scoring system in 2004.

Notational analysis is the process of recording and analyzing the movements made by players during play and has been widely applied to racket sports, such as tennis, badminton and squash (Lees, 2003). The data collected

from notational analysis are related to the position, action, time and outcome of an event in the game. Notational analysis has helped to establish a range of game characteristics that have been useful in defining training practices and strategic aspects of play by producing feedback to coaches and scientific support staff. It has been applied for a sufficiently long time to enable evolutionary features within the racket sport (Lees, 2003). Thus, notational analysis has become a sophisticated tool for data collection in regard to game structure and squash is highly suitable for its use.

An examination of the match activity through notational analysis of the game structure and temporal structure variables of the Malaysia elite junior squash players may provide some baseline data which can then be used by coaches, sports scientists, and future investigators to improve the performance of junior squash teams in the international competitions.

1.2 Problem Statement

Most of the researches on performance analysis in squash were focused on either elite players match analysis or on the practical aspects of their game improvement. Junior (adolescent) squash players were not given adequate attention in the research and difference between the age categories (Under-17 Age Category and Under-19 Age Category) in relation to the game structure remains unclear. However, quantification of their match structure can open quite promising prospective of improving their performance through influencing certain variables of the match structure.

1.3 Significance of the Study

This study helps to provide the quantitative data on match performance structure of Malaysia adolescent squash players, in general and for different age categories, namely Under-17 Age Category and Under-19 Age Category, to the coaches and scientists. The findings of the study can be significant for practical application in training. The results can be invaluable when coaches are planning tactics and strategies on how their players might play in the upcoming matches.

1.4 Research Objective

The general objective of this study was to determine game structure of adolescent male squash players.

The specific objectives:

1) To determine the game structure of adolescent squash players in Under-17 Age Category.
2) To determine the game structure of adolescent squash players in Under-19 Age Category.
3) To determine difference in the game structure between two age categories of adolescent squash players if any.

1.5 Research Hypothesis

Null hypothesis (Ho): There would be no significant difference in the game structure between two different age categories of adolescent squash players.

Alternative hypothesis (Ha): There would be a significant difference in the game structure between two different age categories of adolescent squash players.

CHAPTER 2

LITERATURE REVIEW

2.1 Requirements and Demands of the Game

The physiological demand of racket sports is determined largely by the surface, equipment, missile characteristics, extent to which the game is contested and by environmental factors such as temperature and humidity (Lees, 2003).

A major determinant of the outcome of the game is an individual's physical fitness (Lees, 2003). Essentially squash fitness calls for strength, endurance, and physical agility besides the demand of high technical skill, good match temperament and mental agility (Hawkey, 1984). Squash game puts high demands on physical fitness of a player which requires development of high forces, fast reactions and rapid changes of direction (Steininger & Wodick, 1987). Components of health related fitness such as cardiovascular, strength and flexibility are the most important qualities for squash since they are the foundation for the development of all others (Wollstein & Ellis, 1995). In addition, cardiovascular endurance, local muscular endurance, speed and speed endurance are collectively referred to as energy system demands so critical to sport such as squash (Wollstein & Ellis, 1995). It can be concluded that factors that contribute to success in squash are tactical, technical and physical fitness that consists of health related fitness and skill related fitness.

Squash is an indoor game that is primarily aerobic in nature at elite level, with intermittent bursts of activity being supplied from anaerobic energy sources (Gillam et al., 1990; Sharp, 1988). Players can modify the physiological demand by controlling the rest intervals between rallies and between games and sets (Lees, 2003). Furthermore, since the intensity of effort is greatest during a rally, the rally length is important to the energy systems utilized. The length of rallies has been classified into three categories by Sharp (1998): those that last less than 5 seconds, those that last 6–20 seconds and those that last for more than 20 seconds. These time classifications relate to the aerobic and anaerobic energy sources available to the player.

Most studies have shown that aerobic fitness is important in squash players of various standards (Sharp, 1998; Locke et al., 1997; Todd et al., 1995; Mellor et al., 1995). It was shown that HRmax in squash players was close to the age-related maximum (Lees, 2003). The mean intensity of 86% and 92% of maximal oxygen uptake (VO_2max) and maximal heart rate (HRmax), respectively sustained during squash game suggest a predominant contribution of aerobic metabolism to energy requirements (Girard et al., 2007). Nevertheless, it was suggested that endurance-type training has to be limited because it might induce an increase in the magnitude of the fast-to-slow shift in muscle myosin heavy chain phenotype, thus reducing strength, speed, and explosiveness (Mero et al., 1991).

Although aerobic metabolism is the predominant contribution to energy demand, the high-intensity periods in squash were long enough to cause relatively high blood lactate concentration ([LA]) levels (Girard et al., 2007). On the whole, the long durations of time spent near VO_2max and the concomitant

high [LA] indicate that squash at elite level is an anaerobic-aerobic activity that requires a wide range of metabolic and technical qualities. Players need good aerobic fitness because the duration of the game is relatively long, but also good anaerobic fitness because of the short periods of high-intensity plays (Lees, 2003).

Girard et al. (2007) has reported relatively high ([LA]) values (up to 8 $mmol.L^{-1}$) during squash game which is 2-3 times as high as in tennis. [LA] dropped from 9.2 $mmol.L^{-1}$ (during fourth game) to 5.7 $mmol.L^{-1}$ when a player was observed to slow the pace to give him a chance to recover in the final game (Sharp, 1998). This reduction of [LA] indicated the physiological success of the strategy. Hence, Sharp (1998) commented on the adage that one should not be merciful to a tiring opponent who may recover given time, with lower blood lactate and renewed vigor and confidence.

Several studies (Lees, 2003; Mellor et al., 1995; Reilly & Halsall., 1995) have revealed that low-skill players respond in a different way than higher skilled players, mainly because of processes of adaptation within the cardiovascular system. For example, Reilly and Halsall (1995) have reported that heart rate and rating of perceived exertion (RPE) responses to squash match play were 12–20% higher in recreational players than regular competitors. Furthermore, Brown et al. (1998) studied the transition from elite junior to elite senior squash. They reported that elite junior players had a 7–9% lesser capacity to consume oxygen than elite senior players, suggesting that physiological factors, technical and tactical differences that affect the transition.

2.2 Game Structure Analysis of Squash

Squash matches are played over three to five games. Games are divided into rallies of varying length, where each rally begins with a service and, after a variable number of alternating shots, ends when the ball goes out of court or is not retrieved before bouncing twice (Kingsley et al., 2006). Hence, squash is an intermittent activity that is characterized by sustained movement incorporating frequent bursts of near maximal activity in a range of directions with regular short recovery periods (Kingsley et al., 2006; Girard et al., 2007).

Besides understanding the contribution of different energy pathways and physiological requirements (as discussed in section 2.1), it is also important to know the game structure and the match activities, temporal structure and work rate in which relevant information and requirements can be provided to coaches and scientific support staff so that training prescription can be improved.

Squash game imposes a non-rhythmical pattern of activity on players, similar in principle to the other racket games for example tennis and badminton (Reilly, 1990). However, the motion of the squash players is specific to squash, due to closed and small space in which the game is played and the bouncing of the squash ball from the all four walls of the court (Vuckovic et al., 2005). For example, the use of the walls helps to sustain activity for longer than other racquet sports and a mistimed shot may not be so costly an error since the ball might still stay in play within the walled court (Reilly, 1990). The motion of squash is comprised from different stops and poses, changes of motion direction, turns, jumps, lunges and side-steps (Vuckovic et al., 2005).

From the point of view of coaches, the dynamics of competition (Torres-Luque et al., 2011) and temporal structure variables of squash game (Girard et al., 2007) is of vital importance in daily practice and training. The temporal structure of racquet sports sees alternations in periods of work and rest, which result in a high number of plays and game actions representative of the competitive load both quantitatively and qualitatively (Torres-Luque et al., 2011). Notational analysis is used to identify patterns of player movement and activities during elite squash match-play (Hughes & Franks, 1994; Hughes & Robertson, 1998). Hughes and Bartlett (2002) had designed the performance indicators which were used to assess the changes in performance of squash game. The main performance indicators were the amount of attacking and defensive shots, shot distribution, shot selection, rally length, work-rest ratio, winners and errors. Coaches should be aware of the total play time, real play time, resting time, the number of exchanges, etc., since it is recommended to train based on individual characteristics and not on those of elite players, especially when development of junior players is not yet completed (Torres-Luque et al., 2011). Coaches should design more efficient training plan according to characteristic of the sport to improve training process and development of players (Vuckovic et al., 2005).

2.2.1 Match duration

The duration of a match in racket sports can vary from as little as 6 minutes in squash (Sharp, 1998) to 5 hours or more in tennis (McCarthy-Davey, 2000), although durations of 20–90 minutes are more common across all racket sports (Lees, 2003).

Match duration of squash is depending on whether games are played to three or five sets. The average score of an elite squash match is 3-1 (Hughes, 2005). The average duration of a match was reported as 53 minutes by Hughes et al. (2006). However, there were no recent findings for match duration in adolescent squash players.

2.2.2 Game duration

Game duration is the total playing time in a game. The mean duration of a game for adolescent squash players was reported as 10 minutes by Kingsley et al. (2006). This was in line with durations recorded during World-standard competitions (e.g., World Championship 2004 in Doha, Qatar, December 2004; official results from PSA) ranging between 5 and 15 minutes. A more recent finding revealed by Sport Science and Coaching within English Squash Elite Programme SSCESEP (2010) showed that the mean of game duration for adults elite squash players was 14.36 minutes, which is higher than junior players.

Vuckovic et al. (2005) studied the motion structure of the international and national rank squash players. These researches noted that games played

by international players were on average 414 seconds longer than the games played on the national level.

2.2.3 Real play time

Real play time is one of the temporal variables of the squash game and is the time of actual game play or the total rally time in a game. It is comprised of each and every single rally in a game. Different terms had been used for this variable. Real play time is also known as ball in play, effective playing time or actual playing time. In previous researches, this variable had always been reported in minutes or percentage.

In a recent study by Girard et al. (2007), mean of ball in play in minute was reported as 17.5 and ball in play in percentage was 69.7 in a total of 21 squash games. According to SSCESEP (2010), however average of ball in play in minute and percentage was largely lower, reported as 9.02 minutes and 62% respectively for 400 squash games. This finding agreed with Vuckovic et al. (2005) research in which ball in play was stated as 9.12 minutes for international level squash players. While, there was no recent findings for real playing time in adolescent squash players.

Reilly (1990) concluded that players are engaged in actual play for proportionately longer in squash than in the other racquet sports. In a previous study by Docherty (1982), real playing time in 30 minutes of play was compared for the different skill levels (highly skilled, medium skilled and low skilled) and sports (squash, tennis and badminton). In this study, players were divided into

groups based on their previous experience and success in playing. Analysis of time spent in actual play revealed that squash players were involved in play for 15 of the 30 minutes of game play, compared to 5 and 10 minutes respectively for tennis and badminton. Girard et al. (2007) reported that energy expenditure in squash players is largely higher than in tennis. Difference of real playing time was used to explain this phenomenon. These researchers suggested that one possible explanation could be the higher real playing time in squash (50–70% (Montpetit, 1990); 70 ±5% (Girard et al., 2007)) than in tennis (20–30% (Smekel et al., 2001)).

When comparing the different skill levels, the real playing time was consistent for the skill level groups within each tennis and badminton, with the notable exception of the squash players (Docherty, 1982). Players in the low skilled squash group played for 12 minutes during the 30 minutes game, which was significantly less than the respective playing times of 16 minutes and 17 minutes recorded for the medium and highly skilled groups. According to this researcher, skill level within each sport was only a significant factor in predicting length of play for squash players in which the medium and highly skilled groups played significantly longer than those of a lower level of skill. Besides, a similar trend was noted by Mercier et al. (1987) in which the ball was in play for 61% of the time in matches between 'high-skilled' players, compared to 42% when games were played between 'average skilled' players.

The differences in the real playing time reflects both the nature of the physical boundaries in which the three racquet sports are played and the degree of skill complexity. Wall court is one of the unique characteristics of squash. According to Docherty (1982), as squash is played within a walled court,

the participant has a greater margin of error whilst keeping the ball in play. In squash, a ball that is over hit, or played off center, may not be so costly an error, will still remain in play (Reilly, 1990). In this regard, similar error in badminton or tennis would results in the shuttle or ball passing out of the court (Docherty, 1982). In badminton, however, minimal time is spent between the retrieval of the shuttle and subsequent resumption of play. More physical demands, such as speed and strength, are imposed in tennis due to the court size and therefore the fitness level can be limiting. Different from squash, tennis is an "open court" game which reduces the margin of error. When an error is made, the court dimensions and lack of a walled constraint result in considerable time being spent on retrieving the ball (Docherty, 1982). Hence effective playing time in percentage is reduced when resting time increased by time spending on retrieving the ball. Besides, the serve in tennis is a difficult skill to master for players at low skill levels and results in rallies frequently not being started. Therefore the serve in tennis may also be a contributing factor in reducing the actual playing time. On the other hand, the serve from players with higher skill levels can be so effective that it eliminates the possibility of a return volley (Docherty, 1982).

2.2.4 Rally length

Rally length is the duration of a rally. It is also known as the period of time of a point. SSCESEP (2010) reported that average rally length was 20 seconds in 100 elite squash matches.

Previous research by Sharp (1998) indicated that the mean rally length of squash was 5–20 seconds. Different from squash, an average of 6-10 seconds has been found for elite tennis game (Morante et al., 2005; Fernandez et al., 2006; Kovacs, 2007; Hornery et al., 2007). For adolescent tennis players, mean duration of a rally was reported as 9.08 seconds according to a study by Kingsley et al. (2006). However, there were no recent findings for rally length in adolescent squash game-play.

In a recent study by Girard et al. (2007), the frequency distribution showed that no rally duration occurred more often than any other emphasizing the high degree of uncertainty in the course of squash game. For example, the research findings revealed that with 34.6% of the time, the ball was in play 10 seconds or less, and 32.6% of rallies were more than 21 seconds in duration. This findings were very different from badminton matches between highly skilled players, in which the 3–6-second interval represented 40% of the total moves and the time intervals more than 10 seconds and more than 21 seconds were 80 and 1%, respectively (Manrique & González-Badillo et al., 2003).

On top of that, the findings reported by Girard et al. (2007) also not in line with the previous research by Montpetil (1990) who indicated that 80% of rallies last less than 20 seconds and 49% last less than 10 seconds in professional and grade A players. A possible explanation by Girard et al. (2007) for the

relatively long rally length recorded in their study could be the higher standard of the players.

Reilly (1990) concluded finding from the previous research that at low standards of squash game, rally length may be short but duration of rally increased appreciably at higher standards of squash game. For example, Docherty (1982) found that highly skilled players played longer than those with lower level. This researcher revealed that the mean rally length of 4.4(±0.8) s, 8.4(±1.7) s and 8.8(±1.0) s for low, medium and highly skilled Canadian squash games. Besides, rally length of squash game may be much longer at international level than at county standard (Hughes, 1985).

Despite playing for significantly less time the low skilled squash players had a shorter mean rally length than the medium and highly skilled players. Same as in explaining real playing time in squash game, skill level was also a significant factor only in predicting the duration of rallies for squash players in that the medium and highly skilled groups played significantly longer than the low skilled group (Docherty, 1982).

An inter-sport comparison showed that, with the exception of the lower skilled players, medium and highly skilled squash players were involved in rallying for a longer period than the badminton and tennis players. On top of that, the badminton and low skilled squash players rallied significant longer than the lower, medium and higher skilled tennis players.

Furthermore, in previous researches a statistically significant difference between types of plays had been determined. Findings noted that offensive

plays last less than defensive plays in tennis (Bernardini et al., 1998; Smekal et al., 2001).

Study by Girard et al. (2007) observed decrease in duration of rallies from game 1 and game 2 to game 3. These researches suggested that this phenomenon might be caused by development of fatigue in the process of the match. Mean heart rate of players were increased from game 1 and game 2 to game 3. A possible explanation for this increase could be caused by hypovolemia induced by progressive dehydration because the players were not allowed to drink during inter-game recovery periods (Girard et al., 2007). In this context, fluid losses reaching 2.4 L per hour have been reported in England national-level players (Brown et al., 1998). Kay and Marino (2000) found that fatigue develops as the duration and intensity of physical exertion increase during racket play and is affected by environmental temperature and hydration status.

Besides, it had been indicated by Girard et al. (2007) that the range of rally duration of squash is quite large. Hence, these researchers suggested that the players need to sustain longer work intervals in training which is up to 3 minutes to improve the relative endurance.

2.2.5 Rallies per game

In elite squash game for adolescent players, the number of rally per game was reported as 28 according to a study by Kingsley et al. (2006). However for adults, rallies per game were reported as 18 in elite squash game (Hughes et al., 2006) and 27 according to SSCESEP (2010).

When comparing the different skill levels, despite significantly lower real playing time and shorter rally length the low skilled squash players had greater number of rally per game than the medium and highly skilled players (Docherty, 1982).

2.2.6 Number of shots

According to a study by Kingsley et al. (2006), in elite squash game for adolescent players, the number of shots per game and number of shots per rally were reported as 160 and 5.71 respectively. However for adults, Hughes et al. (2006) reported that shots per rally averaged 12.99. Besides, SSCESEP (2010) revealed that shots per rally were 14.41.

When comparing with adolescent tennis game, study by Torres-Luque et al. (2011) showed that junior male and female tennis players had an average 5.45 ± 0.22 and 5.93 ± 0.12 shots per rally respectively. For elite tennis games, number of strokes per rally has been cited at around 3-5 strokes per rally on average (Girard & Millet, 2004; O'Donoghue & Ingram, 2001; Smekal et al., 2001). More recent research has reported that the number of strokes per rally is

tending to decrease in tennis, revealing the evolution of this sport (Fernandez-Fernandez et al., 2007, 2008; Mendez-Villanueva et al., 2007).

Hughes (1998) noted that the models defined for elite men's squash have changed over time as players have become fitter and the equipment has improved. He reported that over a period of 15 years, the number of shots per rally has decreased from 20 to 14.

Number of shots per rally is directly affected by rally length (Torres-Luque et al., 2011). In tennis, this variable also depends on the type of ball, the game surface, the gender of players and tactical strategy that they use (Fernández et al., 2006).

2.2.7 Rest time between rallies

Rest time between rallies is the period of rest interval between rallies or points. In elite adult squash game, the rest time between rallies have a mean of 12.71 seconds (Hughes et al., 2006). More recent finding reported by SSCESEP (2010) showed similar results with Hughes et al. (2006) which is 13 seconds. On the other hand, for elite junior squash, study by Kingsley et al. (2006) reported that the rest times between rallies during match-play were 8 seconds. Surprisingly, Girard et al. (2007) revealed that rest time between rallies for adult squash players as 8 seconds in which exactly the same as the findings for adolescent players by Kingsley et al. (2006).

Like squash, tennis is an intermittent sport, with repetitive short actions of moderate and high intensity (Kovacs, 2007). When comparing with junior tennis

players, study by Torres-Luque et al. (2011), showed that they had the resting time per rally of 20.56 seconds which is longer than junior squash players. These researchers also noted that male junior tennis players (21.18 seconds) have longer resting time than female (19.12 seconds). Finding showed that they had resting time of 65.86% of the total time (Torres-Luque et al., 2011).

2.2.8 Work to rest ratio

Work to rest ratio also referred to as work-rest ratio or exercise to rest ratio. Information of analysis of movement has been reported in earlier researches in terms of work times and work to rest ratio in tennis, squash and badminton (Lees, 2003). The work to rest ratio determines the demand of the game and quantify physiological requirements of the activity (Duthie et al., 2003; Reilly, 1990) These have been reported to be around 0.5, but with some variation between the racquet sports and between standards of play (Reilly, 1990).

Elite or professional squash has a high uncertainty in the course of match play which consists of repeated, short, high-intensity, intermittent bouts. Rallies of squash have duration of 5-20 seconds interspersed by shorter resting periods of about 7–8 seconds (Locker et al., 2007; Sharp, 1998; Montpetil, 1990). According to a study by Girard et al. (2007) work to rest ratio was reported as 2.4 for elite squash game. However, there are no relevant findings for work to rest ratio in junior squash game.

Players are engaged in greater work-rest ratio in squash than in the other racket sports. In general, the work-to-rest ratio of tennis game is approximately 1:2 – 1:4 (Elliott et al., 1985; Christmass et al., 1998; Kovacs, 2007; O'Donoghue & Ingram, 2001; Reilly & Palmer, 1995; Smekal et al., 2001). Besides, more extreme ratios of between 1:3 and 1:5 can be found (Kovacs, 2007; Kovacs et al., 2004). Whereas, the work-to-rest ratio in the junior elite players as a whole evaluated in the study by Torres-Luque et al. (2011), since there was no difference between the sexes, was approximately 1:2.7.

On top of that, the mean of rest time between rallies was shorter than the mean of rally duration for elite squash (Girard et al., 2007). This is very different from badminton and tennis. Liddle and O'Donoghue (1998) investigated rally and rest times for each discipline of badminton (apart from mixed doubles). They found mean rest durations to be longer than mean rally durations for all forms of the game. In men's singles, mean rally length was found to be 9.15 ±0.43s, whilst the mean rest time was 13.84 ±1.16s. These figures differ greatly from those found by Coad et al. (1979) and Docherty (1982). They found rally length to be around five seconds with five to ten seconds of recovery in between.

2.2.9 Influence of Real Play Time and Resting Time to Anaerobic Component

The relatively high blood lactate concentration ([LA]) values (up to 8 mmol.L^{-1}) during squash game indicate that, during the frequent periods of high intensity, muscular energy is derived from anaerobic glycolysis. The strong correlation found between [LA] and time spent >90% of maximal oxygen uptake (VO_2max) tends to confirm this statement (Girard et al., 2007). Study by Sharp (1998) also supported this observation, showing that during intense competition and particularly toward the end of the match, [LA] can exceed 10 mmol.L^{-1}.

From previous research, there is evidence that [LA] can reach generally higher values in squash (5–8 mmol.L^{-1} [Mercier et al., 1987; Van Ransburg et al., 1982]) than in tennis (3–6 mmol.L^{-1} [Christmass et al., 1998; Bergeron et al., 1990]), in which the longer rest intervals provide ample opportunities for oxidative metabolism to predominate. This showed again that the ball in play in percentage is a key difference between these two activities and their metabolic responses (Girard et al., 2007).

Ferrauti et al. (2001) provided substantial data supporting this statement. Their study assessed the effect of the recovery duration in intermittent training drills on metabolism and coordination in sport games. This study noted that running speed and stroke quality during intermittent tennis drills are highly dependent on the duration of recovery time. These researches reported that a 5-second shorter recovery duration between repeated sprints and drills in tennis players resulted in less complete restoration of phosphocreatine, leading to

increased demands on anaerobic glycolysis to maintain the rate of energy production and therefore higher [LA] values.

CHAPTER 3

METHODOLOGY

In this study, fifty squash games which had been recorded in video clips were analyzed using Elite Sport Analysis-FOCUS-X2 PRO software to obtain the data of selected variables.

3.1 Sample

Data were collected from 50 recorded games (12 matches) in four Junior National Tournaments. The tournaments included CIMB National Junior Circuit Penang 2011, CIMB National Junior Circuit KL 2011, KL Open Local Event 2011 and Milo All Star 2011.

The games were divided into two groups according to age: Under-17 Age Category and Under-19 Age Category. From the 50 recorded games, 28 games (7 matches) were played in Under-17 Age Category and 22 games (5 matches) were played in Under-19 Age Category. The study was delimited to only male adolescent squash players from 16 to 19 years old.

3.1.1 Video clips

The matches were analysed post-event using videos; this was due to the speed of live match play being too fast to gather all relevant details.Video clips

of the tournaments were provided by MOHE Sport Excellence Research Grant, 2010 awarded in 2010. Permission of video usage was given by the principle investigator of the said research grant for this study. The video of matches were recorded with Panasonic-SDR-H80S Camcorder. All the matches were recorded from rear side view.

3.1.2 The matches

All recorded matches were played according to the point per rally (PPR) 11 scoring system in which a point was scored at the end of every rally regardless of whether the winner held serve or not. In accordance with the rules applied in professional men tournaments since 2004, the first player accounting for 11 points was declared the winner.

3.2 Procedure

Analysis of all games was done using Elite Sport Analysis-FOCUS-X2 PRO software in post-match mode. The software allows the user to view video of a performance and then enter the 'events' (actions) that they are interested in using the Category Set facility in Focus.

For every game, a new 'project' was created using the software.Then 'Event Buttons' were created in the 'category' using the 'Category Set' facility. This was then followed by adding the video clip of the game to the 'project'. The actions in the game were coded using the 'Event Buttons'. Five actions were coded or notated: game start, game end, rally start, rally end and shot start. After coding, the time of every action would be recorded. Therefore, the software provided the time of every game start, game end, rally start, rally end and shot start for each game-play.

After that the data of the actions were extracted from the matrix and exported to spreadsheet (Microsoft Excel) eventually followed by the calculation of the game structure variables for each game and match.

3.2.1 Game structure variables

There were nine game structure variables selected for this study including match duration (minutes), game duration (minutes), rallies per game, shots per rally, rally length (seconds), rest time between rallies (seconds), ball in play in minutes, ball in play in percentage (%) and work-rest ratio.

Since one game represents the enclosed unit of the play and is not related to other games in the match neither by duration nor by results (Vickovic et al., 2005), all variables were studied on the game level except match duration.

Hence, game duration, rallies per game, shots per rally, rally length, rest time between rallies, ball in play in minutes, ball in play in percentage and work-rest ratio were game-wise (per game data/ collected from each game), whereas match duration was match-wise (per match data/ collected from each match). Description of the variables has been shown in Table 3.1.

Table 3.1 Description and definitions of game structure variables

Variables	**Description**
Match duration (minutes)	The total duration of every single game in a match. The resting time between games was not taken into consideration for analysis. Match duration depends on number of games which can vary from three to five games in a match.
Game duration (minutes)	The duration from the beginning of the game when the first player serves until the last point end in a game.
Rallies per game	Number of rallies in a game.
Shots per rally	Number of strokes in a rally.

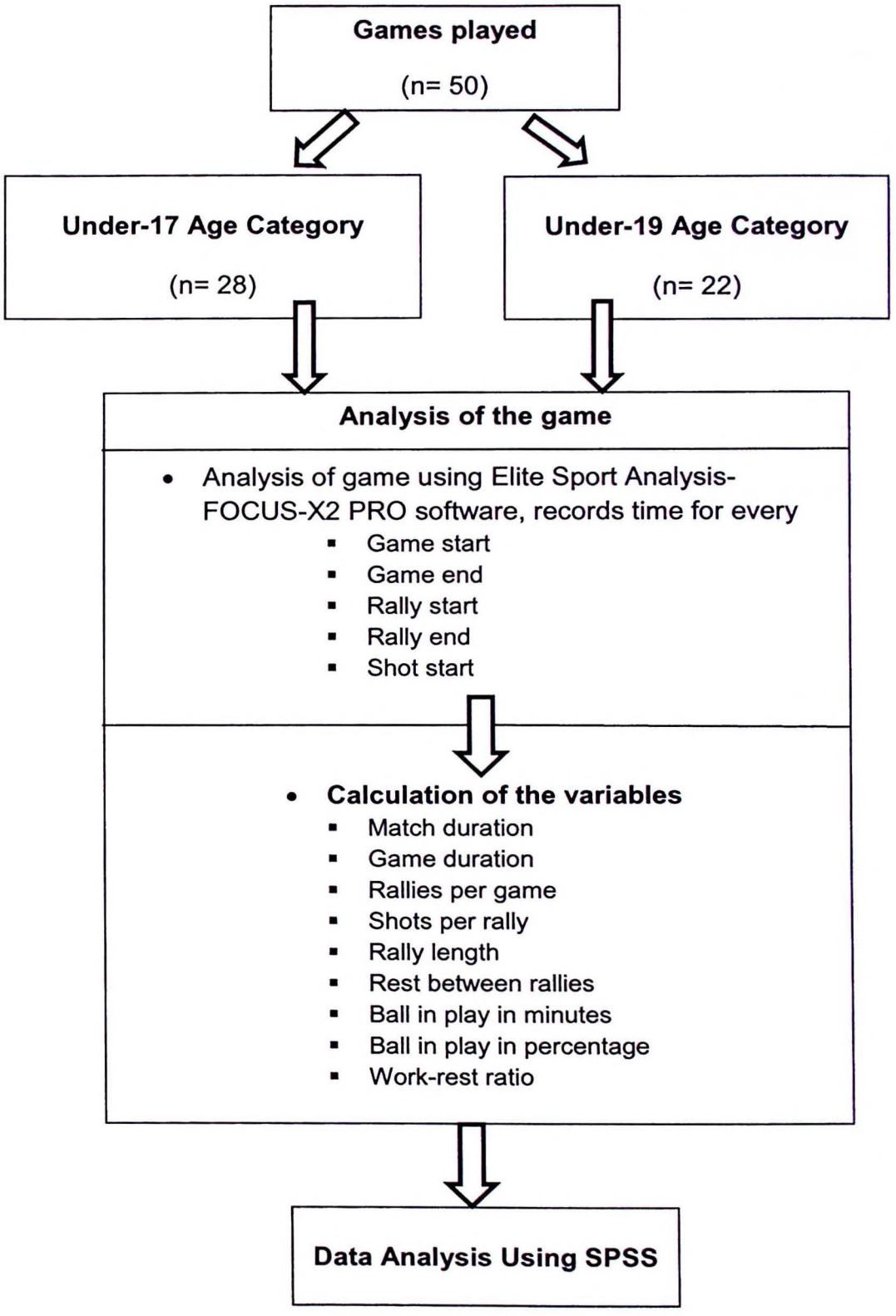
Rally length (seconds)	Duration of rally, from the beginning of the rally when the player serves until the rally end.
Rest between rallies (seconds)	Resting time between rallies, from the end of the point/rally until the player begins the next serve.
Ball in play in minutes	Real playing time in a game presented in minutes. It is the total or cumulative time of rallies in a game.
Ball in play in percentage	Real playing time in a game presented in percentage. It is the ratio of total time of rallies per game to game duration in percentage. Ball in play in percentage = $\frac{\text{Total rallies time per game}}{\text{Game duration}} \times 100\%$
Work-rest ratio	Ratio of playing time to resting time in a game. The inter-game recovery periods were not taken into consideration for analysis. Work-rest ratio= $\frac{\text{Total rallies time per game}}{\text{Total rest time per game}}$

3.3 Statistical analysis

SPSS version 20.0 statistical program was used to analyze the data collected in this study. The results of variables for each match and game were exported from spreadsheet (Microsoft Excel) to SPSS for analysis.

Descriptive statistics was reported in mean and standard deviation for each variable. Then, descriptive statistics was reported in mean and standard deviation for each variable for Under-17 Age Category and Under-19 Age Category respectively. Comparison of variables between different groups was done using Independent Sample T-Test to determine if there were any significant differences between Under-17 Age Category and Under-19 Age Category. A level of significance of $p \leq 0.05$ was used for all of the statistical analyses.

Figure 3.1 Flow chart of study design



CHAPTER 4

RESULTS

The general objective of this study was to determine the game structure in adolescent male squash players. Data were generated from 50 pre-recorded games (12 matches). The games related statistics were divided into two age categories: Under-17 Age Category and Under-19 Age Category. From the 50 recorded games, 28 games (7 matches) were played in Under-17 Age Category (U1-7) and 22 games (5 matches) were played in Under-19 Age Category (U-19).

Nine performance variables were identified for this study and included match duration (minutes), game duration (minutes), rallies per game, shots per rally, rally length (seconds), time between rallies (seconds), ball in play in minutes (minutes), ball in play in percentage (%) and work-rest ratio. All variables were studied on the game level except match duration. Thus, from the nine performance variables, game duration, rallies per game, shots per rally, rally length, time between rallies, ball in play in minutes, ball in play in percentage and work-rest ratio were game-origin (per game data), whereas match duration was match-origin (per match data).

Descriptive statistics was reported in mean, standard deviation, minimum and maximum. Comparison of variables between different age categories was done using Independent Sample T-Test to determine if there were any significant differences between Under-17 Age Category and Under-19 Age

Category. A level of significance of $p \leq 0.05$ was used for all of the statistical analyses.

4.1 General Game Structure

Descriptive statistics was reported in mean, standard deviation, minimum and maximum for each variable. The results presented in table 4.1 show the means for game duration at 8.87 minutes, rallies per game at 20.36, shots per rally at 10.54, rally length at 16.04 seconds, time between rallies at 10.40 seconds, ball in play at 5.46 minutes or 61.77%, work-rest ratio at 1.70 and match duration at 36.15 minutes as a whole evaluated in the present study.

Table 4.1 *Variables for games (n=50) and matches (n=12) played*

Variables	Mean	*SD*	Minimum	Maximum
Game duration (minutes)	8.87	3.36	4.02	21.27
Rallies per game	20.36	5.05	12.00	33.00
Shots per rally	10.54	3.51	6.21	24.06
Ball in play in minutes	5.46	2.31	2.16	14.75
Ball in play in percentage (%)	61.77	7.15	45.39	74.10
Rally length (seconds)	16.04	5.48	9.24	33.35
Rest between rallies (seconds)	10.40	3.47	5.78	21.38
Work-rest ratio	1.70	0.51	0.83	2.85
Match duration (minutes)	36.15	13.48	16.08	59.37

4.2 Game Structure for Under-17 Age Category (U-17)

Descriptive Statistics was reported in mean, standard deviation, minimum and maximum for each variable. A total of 28 games and 7 matches were played in Under-17 Age Category. The results presented in table 4.2 show the means for game duration (8.07 minutes), rallies per game (20.79), shots per rally (8.85), rally length (13.24 seconds), rest time between rallies (9.99 seconds), ball in play in minutes (4.65 minutes), ball in play in percentage (58.56 %), work-rest ratio (1.47) and match duration (30.32) in this category (Table 4.2).

Table 4.2 *Variables for Under-17 Age Category (n= 28)*

VARIABLES	MEAN	*SD*	Minimum	Maximum
Game duration (minutes)	8.07	2.83	4.02	14.42
Rallies per game	20.79	5.57	12.00	33.00
Shots per rally	8.85	1.54	6.21	11.71
Ball in play in minutes	4.65	1.69	2.16	8.14
Ball in play in percentage (%)	58.56	6.46	45.39	71.90
Rally length (seconds)	13.24	2.38	9.24	18.09
Rest between rallies (seconds)	9.99	2.68	6.70	15.85
Work-rest ratio	1.47	0.40	0.83	2.57
Match duration (minutes) (n=7)	30.32	11.29	16.08	46.83

4.3 Game Structure for Under-19 Age Category (U-19)

Descriptive Statistics was reported in mean, standard deviation, minimum and maximum for each variable. A total of 22 games and 5 matches were played in Under-19 Age Category. The results presented in table 4.3 show the means for game duration (9.88 minutes), rallies per game (19.82), shots per rally (12.69), rally length (19.62 seconds), rest time between rallies (10.93 seconds), ball in play in minutes (6.49 minutes), ball in play in percentage (65.84%), work-rest ratio (2.00) and match duration (44.32 minutes) in this category (Table 4.3).

Table 4.3 *Variables for Under-19 Age Category (n= 22)*

VARIABLES	MEAN	*SD*	Minimum	Maximum
Game duration (minutes)	9.88	3.75	4.57	21.27
Rallies per game	19.82	4.38	13.00	28.00
Shots per rally	12.69	4.14	7.96	24.06
Ball in play in minutes	6.49	2.60	3.26	14.75
Ball in play in percentage (%)	65.84	5.88	55.48	74.10
Rally length (seconds)	19.62	6.23	12.29	33.35
Rest between rallies (seconds)	10.93	4.28	5.78	21.38
Work-rest ratio	2.00	0.49	1.25	2.85
Match duration (minutes) (n=5)	44.32	12.86	28.10	59.37

4.4 Comparison of Game Structure between Under-17 Age Category (U-17) and Under-19 Age Category (U-19)

Comparison of variables between different age categories was done using Independent Sample T-Test to determine if there were any significant differences between Under-17 Age Category (U-17) and Under-19 Age Category (U-19). A level of significance of $p<0.05$ was used for all of the statistical analyses.

The results presented in table 4.4 show the mean and standard deviation for game duration, rallies per game, shots per rally, rally length, time between rallies, ball in play in minutes, ball in play in percentage, work-rest ratio and match duration in U-17 and U-19 categories respectively. There was a significant difference in mean of number of shots per rally, ball in play in minutes, ball in play in percentage, rally length and work-rest ratio between U-17 and U-19 ($p<0.05$). The means for these variables were significantly higher in U-19 category than in U-17 category (Table 4.4).

Table 4.4 *Variables of squash game by age category.*

VARIABLES	AGE CATEGORY				INDEPENDENT T-TEST
	U-17		U-19		P-value
	MEAN	*SD*	MEAN	*SD*	
Game duration (minutes)	8.07	2.83	9.88	3.75	0.057
Rallies per game	20.79	5.57	19.82	4.38	0.507
Shots per rally	8.85	1.54	12.69	4.14	<0.001*
Ball in play in minutes	4.65	1.69	6.49	2.60	0.004*
Ball in play in percentage	58.56	6.46	65.84	5.88	<0.001*
Rally length (seconds)	13.24	2.38	19.62	6.23	<0.001*
Rest between rallies (seconds)	9.99	2.68	10.93	4.28	0.375
Work-rest ratio	1.47	0.40	2.00	0.49	<0.001*
Match duration (minutes)	30.32	11.29	44.32	12.86	0.73

*significant difference ($p<0.05$) between U-17 and U-19

4.4.1 Comparison of Game Duration between U-17 and U-19

The mean difference between game duration of U-17 and U-19 was not statistically significant (p=0.057, p>0.05), although the value was very close to being significant (Table 4.5)

Table 4.5 *Comparison of game duration (minutes) between U-17 and U-19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Game duration (minutes)	8.07 (2.83)	9.88 (3.75)	-1.81 (-3.685, 0.057)	-1.95 (48)	0.057

Bar chart 4.1 shows the difference graphically with U-19 category having longer game duration.

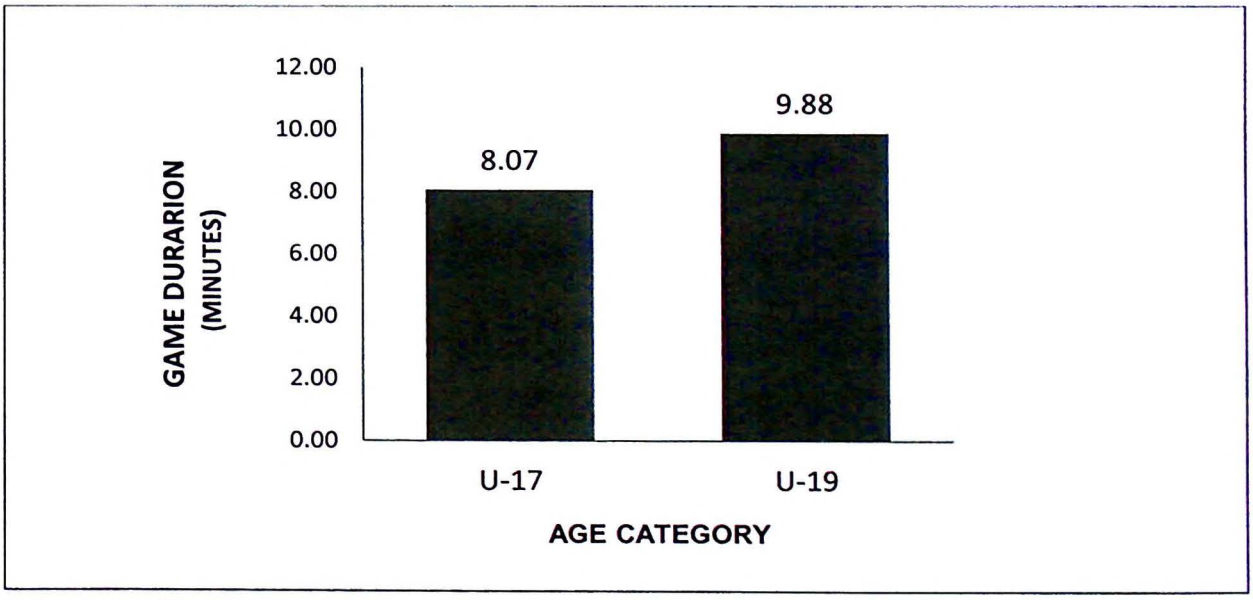


Figure 4.1 Mean of game duration (minutes) between U-17 and U-19

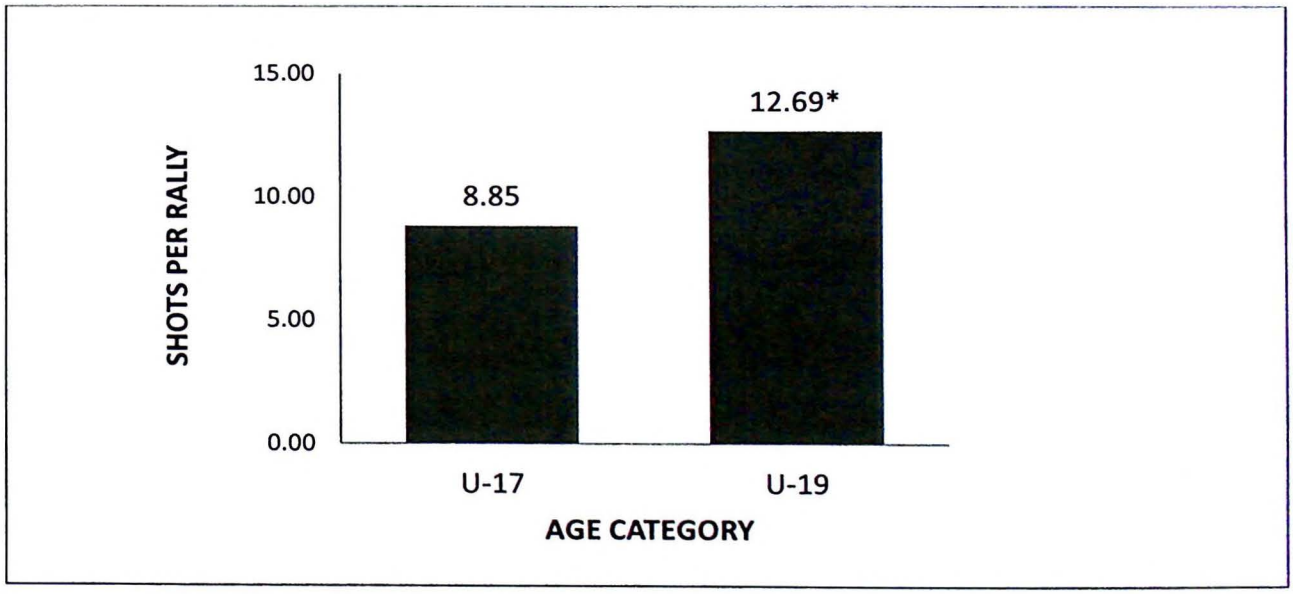
4.4.2 Comparison of Shots per Rally between U-17 and U-19

The mean difference between shots per rally of U-17 and U-19 was statistically significant ($p<0.001$). The mean of U-19 (12.69) was higher than U-17 (8.85) (Table 4.6).

Table 4.6 *Comparison of shots per rally between U17 and U19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Shots per rally	8.85 (1.54)	12.69 (4.14)	-3.84 (-5.752, -1.931)	-4.14 (25.6)	<0.001

Bar chart 4.2 shows obviously higher number of shots per rally in U-19 category.



* Significantly different

Figure 4.2 Mean of shots per rally for U-17 and U-19.

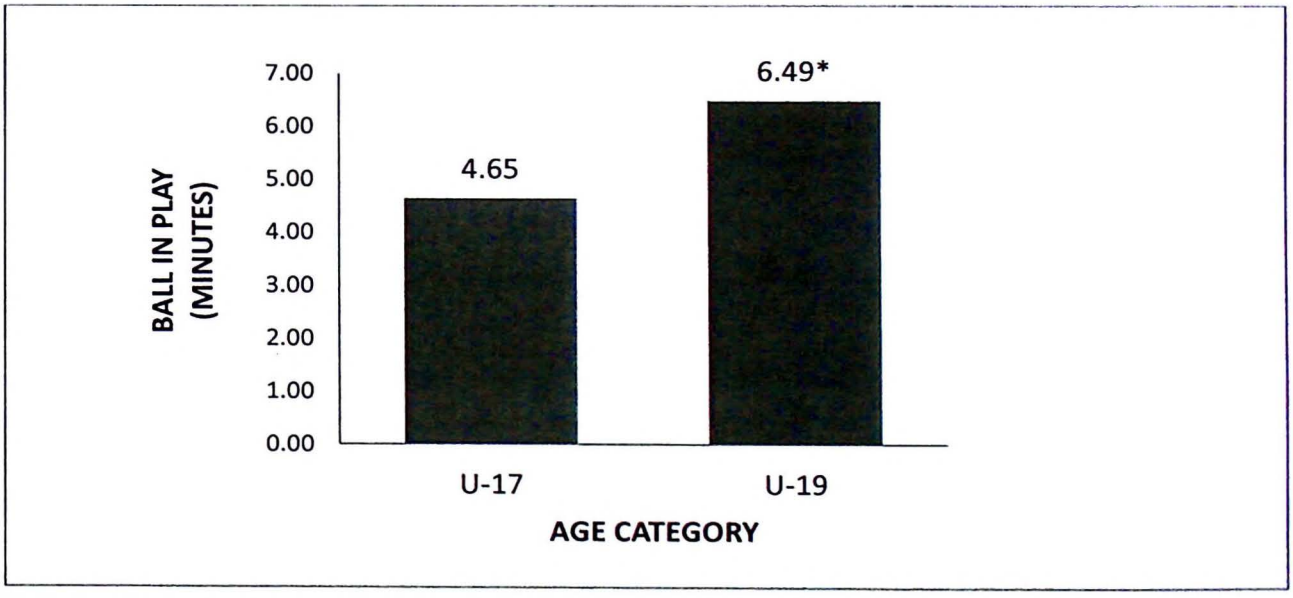
4.4.3 Comparison of Ball in Play in Minutes between U-17 and U-19

The mean difference between ball in play in minutes of U-17 and U-19 was statistically significant (p=0.004, p<0.05). The mean of U-19 (6.49 minutes) was higher than U-17 (4.65 minutes) (Table 4.7).

Table 4.7 *Comparison of ball in play in minutes between U-17 and U-19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Ball in play in minutes	4.65 (1.69)	6.49 (2.60)	-1.84 (-3.064, -0.619)	-3.03 (48)	0.004

Bar chart 4.3 clearly shows the advantage of U-19 category in minutes of ball in play.



* Significantly different

Figure 4.3 Mean of ball in play in minutes for U-17 and U-19.

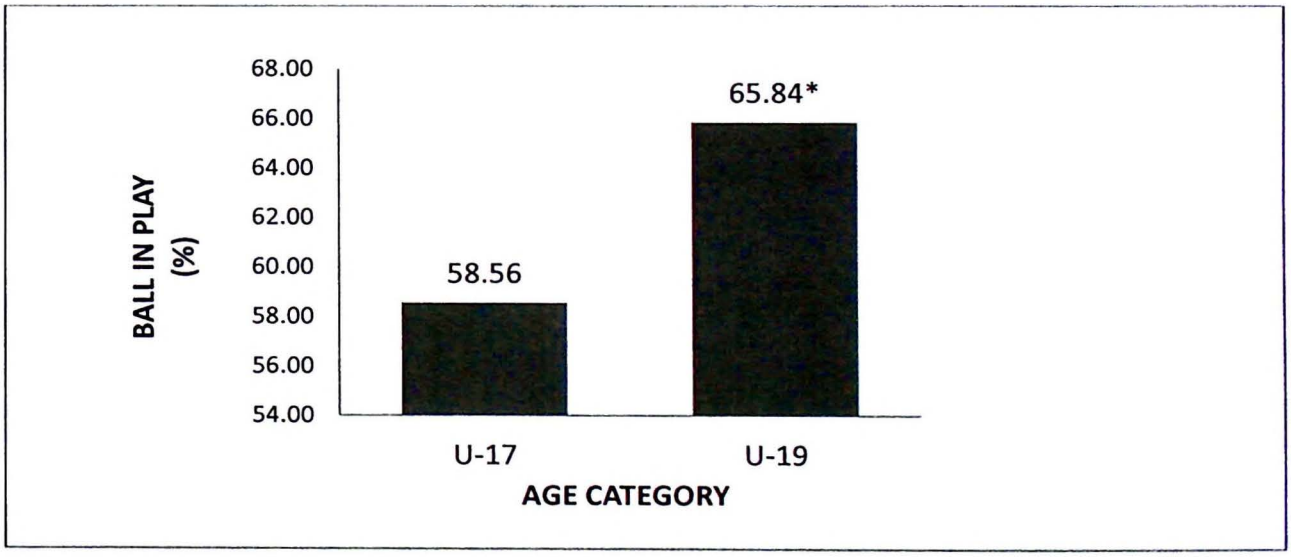
4.4.4 Comparison of Ball in Play in Percentage between U-17 and U-19

The mean difference between ball in play in percentage of U-17 and U-19 was statistically significant ($p<0.001$). The mean of U-19 (65.84%) was higher than U-17 (58.56%) (Table 4.8).

Table 4.8 *Comparison of ball in play in percentage between U-17 and U-19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Ball in play in percentage (%)	58.56 (6.46)	65.84 (5.88)	-7.28 (-10.841, -3.723)	-4.11 (48)	<0.001

Bar chart 4.4 clearly shows the advantage of U-19 category in the percentage of ball in play.



* Significantly different

Figure 4.4 Mean of ball in play in percentage for U-17 and U-19.

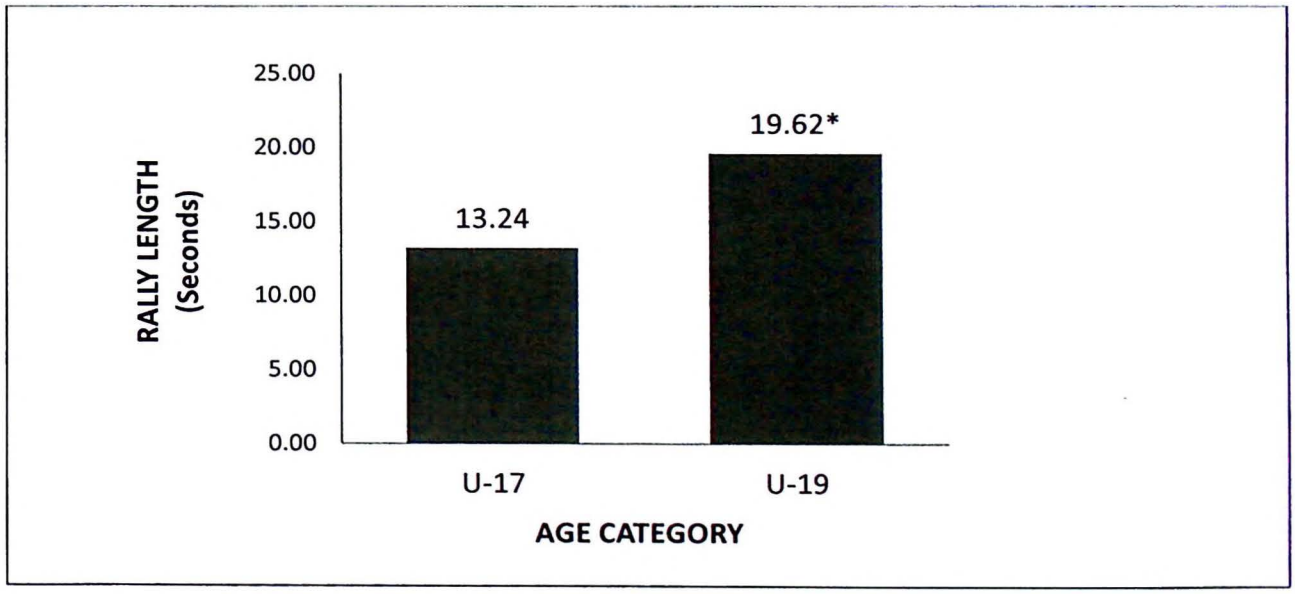
4.4.5 Comparison of Rally Length between U-17 and U-19

The mean difference between rally length of U-17 and U-19 was statistically significant ($p<0.001$). The mean of U-19 (19.62 seconds) was higher than U-17 (13.24 seconds) (Table 4.9).

Table 4.9 *Comparison of rally length (seconds) between U-17 and U-19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Rally length (sec)	13.24 (2.38)	19.62 (6.23)	-6.39 (-9.271, -3.501)	-4.55 (25.83)	<0.001

Bar chart 4.5 clearly indicates longer rally length in U-19 category.



* Significantly different

Figure 4.5 Mean of rally length (seconds) for U-17 and U-19.

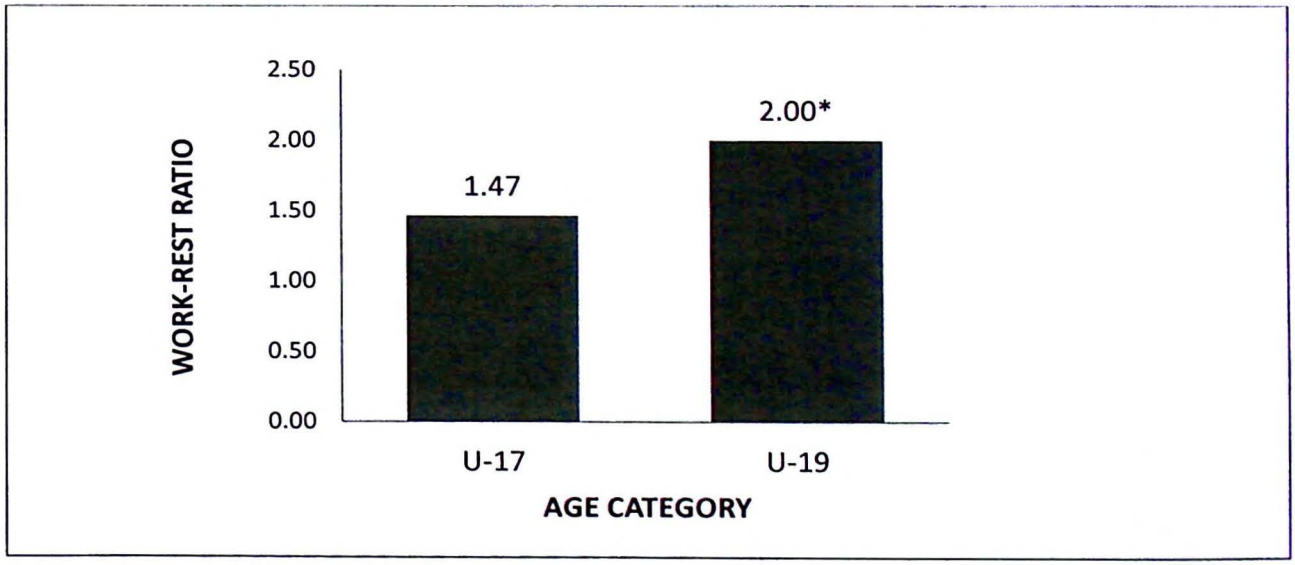
4.4.6 Comparison of Work-Rest Ratio between U-17 and U-19

The mean difference between rally length of U-17 and U-19 was statistically significant ($p<0.001$). The mean of U-19 (2.00) was higher than U-17 (1.47) (Table 4.10).

Table 4.10 *Comparison of work-rest ratio between U-17 and U-19*

Variables	U-17 (n=28)	U-19 (n=22)	Mean Difference (95%CI)	T-stats (df)	P-value
	Mean (*SD*)	Mean (*SD*)			
Work-rest ratio	1.47 (0.4)	2.00 (0.49)	-0.53 (-0.788, -0.281)	-4.25 (48)	<0.001

Bar chart 4.6 indicates differences in work-rest ratio between U-17 and U-19 age categories.



* Significantly different

Figure 4.6 Mean of work-res ratio for U-17 and U-19.

CHAPTER 5

DISCUSSION

Given few studies that examined similar variables to our study in adolescent (junior) squash players, the results of this present study will be sometimes compared with other populations, i.e. adult players. Since squash scoring system had been changed from PPR-15 to PPR-11 in 2004, findings from previous studies that had been done in 2004 and later will give a more meaningful and specific comparison with this present research than the earlier studies which had been done before 2004 and in relation to now non-existent scoring system. For example, since the points being reduced by almost a third (from 15 points to 11 points to the end the game), the number of rallies per game was reduced from 28 to 18, causing shots per game also decreasing (Hughes et al., 2006).

However, in fact, earlier studies which had been done before 2004 could also be meaningful when comparing different levels of playing standard, gender of players, etc. because principles are basically the same. Study by Kingsley et al. in 2006 will be the main basis of comparison with this present study since the mentioned study was concerning junior elite squash players which had the similar approach with the present study. However, the studied variables were not exactly the same, for example rally length, work-rest ratio, ball in play and match duration had not been reported. Thus, the variables will also be compared with the previous findings concerning adults (senior) elite players. The finding from the study by Girard et al. (2007) and the data that had been

reported by Sport Science and Coaching within English Squash Elite Programme (SSCESEP) in 2010 will be the main basis of comparison. These researches had been carried out after the introduction of the new scoring system. Comparison of sample (studied participants) in the present study with previous studies was shown in Table 5.0.

Table 5.0 *Comparison of sample of present study with previous studies*

Present study (2013)	**Kingsley et al. (2006)**	**Hughes et al. (2006)**	**SSCESEP (2010)**	**Girard et al. (2007)**
Elite juniors	Elite juniors	Elite men	Elite men	Elite men
Male	Male	Male	Male	Male

*Elite represent national and international players and juniors represent adolescent players.

5.1 Game duration

The game duration in this study was approximately 9 minutes (8.87 minutes), which is similar with the time (10 minutes), reported by Kingsley et al. (2006). However, mean difference between Under-19 Age Category (U-19) and the time reported by Kingsley et al. (2006) was even smaller. Game duration in U-19 was approximately 10 minutes (9.88 minutes), which is in accordance with the time reported by Kingsley et al. (2006). Comparison of game duration in the present study with previous studies was shown in Table 5.1.

There was no statistically significant difference between Under-17 Age Category (U-17) and U-19 in relation to game duration. However, the p-value was very close to 0.05 (p=0.057). Game duration in U-19 was longer than U-17, probably due to the higher skill level in U-19. Since younger, it is likely that players of U-17 less experienced and less skilled as compared to U-19.

As a whole, game duration for adolescents (junior players) is shorter as compared to adults (senior players), which counts 14.06 minutes (SSCESEP, 2010). Hence, it can be suggested that players with higher skill level have longer game duration. However, longer game duration can be also due to the longer rest time between rallies, not merely because longer real playing time.

Table 5.1 *Comparison of game duration in minutes (min) in the present study with previous studies*

Present study (2013)		**Kingsley et al. (2006)**	**SSCESEP (2010)**
General	8.87 min	10 min	14.06 min
U-17 U-19	8.07 min 9.88 min	–	–

5.2 Rallies per game

The number of rallies per game in the players as a whole evaluated in the present study (since there was no statistically significant difference between age categories), was 20.36. This is very different from previous study by Kingsley et al. (2006) in which a mean of 28 was reported for this variable (Table 5.2). A possible explanation for the relatively low number of rallies per game recorded in the present study could be the higher standard of the players.

Docherty (1982) reported that highly skilled squash players had lower number of rallies per game than the low and medium skilled players.

Although the mean difference between age categories was not statistically significant, U-17 has slightly greater number of rallies per game, probably due to the lower skill level and standard of players in U-17.

When compared with adults (Hughes et al., 2006), adolescent players in this study have slightly greater number of rallies. This again highlighted the statement that highly skilled squash players have lower number of rallies per game. However, adolescent players have largely lower number of rallies when comparing with data by SSCESEP (2010), in which 26.72 rallies per game was reported (Table 5.2). This suggests that the statement of highly skilled group having lower number of rallies per game is not exactly doubtless, thus the relation between number of rallies per game and standard of players remains unclear, thus require further investigation.

Table 5.2 *Comparison of rallies per game in the present study with previous studies*

Present study (2013)		**Kingsley et al. (2006)**	**SSCESEP (2010)**	**Hughes et al. (2006)**
General	20.36	28	26.72	18
U-17 U-19	20.79 19.82	–	–	–

5.3 Shots per rally

The number of shots per rally in this study was 10.54, fewer than adults (Table 5.3). Number of shots per rally is strongly related to average rally duration (Torres-Luque et al., 2011). Since rally length for adults is longer than adolescent players (Table 5.4), it is reasonable that they have greater number of shot than adolescents.

The number of shots per rally in this study is twice as many as the mean reported by Kingsley et al. (2006) with adolescents. This again suggests higher standard of the players in this study. In this study, players played fewer rallies per game with greater number of shots per rally, whereas in Kingsley et al. (2006), players played greater number of rallies per game with fewer shots per rally. There was statistically significant difference between age categories ($p<0.001$). The number of shots per rally in U-17 was 8.85 compared with 12.69 for U-19.

It can be suggested that it is difficult to win a rally with few shots in games at the higher standard of competition. Vuckovic et al. (2005) stated that the point is won gradually at highest international quality level, by achieving high number of shots to gather the advantage, which can be exploited in the attack to win the rally. This results in longer rally length and greater number of shots.

Since players in higher standard of competition (highly skilled) played longer rallies than lower skilled players (Docherty, 1982; Hughes, 1985; Reilly, 1990), and longer rally length generates greater number of shots per rally (Torres-Luque et al., 2011), it can be concluded that higher skilled players have greater number of shots per rally. Therefore, adolescent players who have lower

skill level possess fewer shots per rally than adults, and U-17 with lower skill level have fewer shots per rally than U-19.

Table 5.3 *Comparison of shots per rally of present study with previous studies*

Present study (2013)			**Kingsley et al. (2006)**	**SSCESEP (2010)**	**Hughes et al. (2006)**
General	10.54		5.71	14.41	12.99
U-17 U-19	8.85 12.69	p<0.001	–	–	–

5.4 Rally length

The mean rally length in U-17 was 13.24±2.38 seconds as compared with 19.62±6.23 seconds for U-19 (Table 5.4). These values are significantly different. Longer duration of rally for U-19 again highlights the differences between age groups which may be likely due to higher skill level in U-19. This is supported by Docherty (1982), who noted that skill levels was the significant factor in predicting the rally length for squash players; and also reported that medium and highly skilled groups played significant longer than the low skilled group.

The rally length in the adolescent players as a whole evaluated in the present study was 16.04 seconds. The mean rally length for adult elite players has a range of 18.6 to 20 seconds (Table 5.4). Professional adult athletes fundamentally equipped with better skills and experiences during competitive matches. Rally length of U-19 (19.62 seconds) was in the range of mean rally

length of adult elite players. This similarity might suggest that players in U-19 have quite high level of skill in progression to become professional elite level players.

An exchange of approximately 5 shots per rally was noted over an average of 7.6 seconds in adolescents (this study), compared with 6.7 seconds in adults professional players (SSCESEP, 2010; Girard et al., 2007). This suggests that although same number of shots was played by adolescent players; they take longer time to complete the shot than older, higher level players. This also has been indicated in tennis. This shows the importance of the players' evolution and development characteristics, because stroke speeds, opening angles, power, etc., are not same in elite players as in adolescent players (Torres-Luque et al., 2011). Thus, this again explains the importance of the category in relation to the studied parameters.

Furthermore, rally length also depends on tactical strategy or type of plays of the players, as defensive plays last longer than offensive plays. Tactical strategy was not evaluated in this study which could provide a better understanding of the results when comparing between age categories and between adults (seniors) and adolescences (juniors). Influence of the match pairing (stronger vs. weaker opponents) was not considered since all participating in the research players were of the similar standard.

It can be concluded that senior players have longer rally duration compared to juniors, and junior players in U-19 have longer rally duration than U-17 junior players. This finding can be significant during practical application in training.

Table 5.4 *Comparison of rally length in seconds of present study with previous studies*

Present study (2013)			SSCESEP (2010)	Girard et al. (2007)
General	16.04		20.00	18.60
U-17 U-19	13.24 19.62	p<0.001	–	–

5.5 Ball in play

There was no recent findings reported for ball in play (real play time) in adolescent squash players. Ball in play in the present study was 4.65 minutes (58.56%) for U-17 and 6.49 minutes (65.84%) for U-19 (Table 5.5). These values are significantly different ($p<0.05$). Considering the results in rally length, where high and statistically significant difference between age categories has been established, statistical significance in relation to ball in play variable was expected.

Ball in play in the adolescent players as a whole observed in the present study was 5.46 minutes. This value was in accordance with the time reported in Slovenian national senior players (5.58 minutes), probably due to similar levels of competition (national games). In this present study, analyzed video games were recorded during national junior tournaments, whereas for Slovenian national senior players, data was collected from Slovenia National Championship.

The mean of ball in play for adult elite players was approximately 9 minutes (Table 5.4), and a higher value of 17.5 minutes had been reported by

Girard et al. (2007). These values are higher as compared to adolescent players in the present study.

Such differences are probably the consequences of better technical and tactical capabilities, skills and knowledge reflected in basic and defensive play, not only in better offensive actions for senior elite players. These consequences were also indicated by Vuckovic et al. (2005) when explaining the difference in relation to real play time, distance covered and work rate between international and national elite squash players. This is supported by Docherty (1982), who noted that skill levels was the significant factor in predicting the length of play (real play time) in squash players. He reported that medium and highly skilled groups played significant longer than the low skilled group.

Table 5.5 *Comparison of ball in play of present study with previous studies*

Present study (2013)					**SSCESEP (2010)**		**Girard et al. (2007)**	
General	5.46 min		61.77 %		9.02	62%	17.5	69.7%
U-17 U-19	4.65 min 6.49 min	p=0.004	58.56 % 65.84 %	p<0.001	–		–	

5.6 Rest time between rallies

The rest time between rallies in the players as a whole (since there was no statistically significant difference between age categories) observed in the present study, was 10.4 seconds. This value is slightly higher than in the previous study (8 seconds) by Kingsley et al. (2007) (Table 5.8).

Overall, rest time between rallies in junior players is shorter than in adult elite players. However, the difference is small, approximately 2 to 3 seconds. It can be suggested that since match intensity in adults is higher than in adolescent players, longer rest time may be required to recover from fatigue. Besides, a possible explanation could be that advanced players may rest more in order to enhance lactate removal thus reducing blood lactate concentration. Kingsley et al. (2006) suggested that players were able to enhance lactate removal during match-play, probably by employing tactics during periods of play that allowed for increased recovery periods. Longer rest time between rallies provides benefit to players and Ferrauti et al. (2001) noted that running speed and stroke quality during intermittent tennis drills are highly dependent on the duration of recovery time. These researchers reported that a 5-second shorter recovery duration between repeated sprints and drills in tennis players resulted in less complete restoration of phosphocreatine, leading to increased demands on anaerobic glycolysis to maintain the rate of energy production and therefore higher blood lactate concentration.

Table 5.6 *Comparison of rest time between rallies in seconds (s) in the present study with previous studies*

Present study (2013)		**Kingsley et al. (2006)**	**Girard et al. (2007)**	**SSCESEP (2010)**	**Hughes et al. (2006)**
General	10.4 s	8 s	8 s	12.71 s	13 s
U-17 U-19	9.99 s 10.93 s	–	–	–	–

5.7 Work-rest ratio

There were no recent findings for the work-rest ratio in elite junior squash players. Work-rest ratio was 1.47 for U-17 and 2.00 for U-19 (Table 5.7). These values are significantly different ($p<0.001$). Considering the results in rally length and ball in play, where high and statistically significant differences between age categories have been established, statistical significance in relation to work-rest ratio were expected.

Work-rest ratio in the adolescent players as a whole observed in the present study was 1.7. Adult elite players showed more extreme ratio of 2.4 (Girard et al., 2007). This difference also has been shown in tennis. Junior elite tennis players showed lower ratio of 1:2.7 (Torres-Luque et al., 2011) as compared to ratios of between 1:3 and 1:5 in senior elite players (Kovacs, 2007; Kovacs et al., 2004).

Players are engaged in greater work-rest ratio in squash than in the other racket sports. Even junior elite squash players showed greater ratio than senior elite tennis and badminton players. This is fundamentally due to the mean rally length being longer than the mean rest time between rallies in the squash game. However, in tennis and badminton, the mean rally length is shorter than the mean rest time between the rallies.

Table 5.7 *Comparison of work-rest ratio of present study with previous studies*

Present study (2013)			**Girard et al. (2007)**
General	1.70		2.4
U-17 U-19	1.47 2.00	p<0.001	—

5.8 Match duration

Limited recent findings on match duration could be found since introduction of the new scoring system (PPR-11) in 2004. To the best of the knowledge, in squash, the study of Hughes et al. (2006) is the only one in which match duration was indicated according to PPR-11. However, their study was concerning adult elite players and thus there was no findings for junior elite squash players in relation to match duration.

The match duration in the players as a whole evaluated in the present study (since there was no statistically significant difference between age categories) was 36.15±13.48 minutes. This value is lower as compared to 53 minutes, reported in adults (Hughes et al., 2006).

In fact, the range of match duration is quite large. In this present study, match duration ranged from 16.08 minutes to 46.83 minutes in U-17, whereas in U-19, duration ranged from 28.1 minutes to 59.37 minutes. This is because in squash, match duration is depending on whether games are played to three or five sets. In this study, 7 matches were played to five sets, 4 played to four sets and only 3 played to 3 sets. Five- set matches were more in U-19 and 3-set matches and 4-set matches were more in U-17. The average score of an elite squash match of 3-1 (4-set match) has been reported by Hughes (2005). Comparison of match duration in present study with previous study is shown in Table 5.8.

Table 5.8 *Comparison of match duration of present study with previous study*

Present study (2013)		Hughes et al. (2006)
General	36.15 minutes	53 minutes
U-17	30.32 minutes	
U-19	44.32 minutes	–

5.9 Practical applications

It is recommended that training should be based on individual characteristics and not on those of elite players, especially when development of junior players is not yet completed (Torres-Luque et al., 2011).

The game structure of adolescent elite squash players particularly the number of shots per rally, ball in play in minutes, ball in play in percentage, rally length, work-rest ratio were significantly higher in U-19 than U-17. Therefore, it can be recommended that training loads should be applied differently in those age categories.

According to Girard et al. (2007), a high percentage of training loads for elite squash players should include repetitive displacements (with stroke) of high intensity (80–90% VO_2max/ 85–90% HRmax) and moderate duration (15–20 seconds) with short recovery (8–10 seconds). Adolescent players in U-19 have quite similar rally length, number of shots per rally, rest time between rallies and ball in play in percentage with adult elite players. Therefore, it can be recommended that they can use basically the same as elite training loads.

5.9.1 Duration of repetitive displacement

For U-19, since they have similar rally length with elite adults, moderate duration (15–20 seconds) is recommended (Table 5.9). For another age category, U-17, duration of repetitive displacements could be reduced to 13-18 seconds since they have shorter rally length during match-play.

Table 5.9 Comparison between recommendations on duration of repetitive displacement of present study (adolescence) with elite adults

Study	**Rally Length (seconds)**			**Recommended duration of repetitive displacements**
	Mean	Minimum	Maximum	
Girard et al. (2007) Elite adults	**18.6**	14.1	23.5	**15-20**
Present study U-19	**19.62**	12.29	33.35	**15-20**
Present study U-17	**13.24**	9.24	18.09	**13-18**

5.9.2 Recovery period between repetitive displacements

Since adolescent players (no significant difference between U-17 and U-19) have longer rest time between rallies, longer recovery should be recommended (10-12 seconds). This is shown in Table 5.10.

Table 5.10 *Comparison between recommendations on recovery period between repetitive displacements of present study (adolescence) with elite adults*

Study	Rest between rallies (seconds)			Recommended recovery period between repetitive displacements
	Mean	Minimum	Maximum	
Girard et al. (2007) Elite adults	**8.0**	5.9	10.8	**8-10**
Present study U-19	**10.93**	5.78	21.38	**10-12**
Present study U-17	**9.99**	6.7	15.85	**10-12**

5.9.3 Intensity for repetitive displacements

Intensity of training load should be lower for adolescent players since the mean intensity of 88% HRmax during match-play was reported in adolescent squash players (Kingsley et al., 2006), which is lower than in elite players (92% HRmax) (Table 5.11). Furthermore, elite junior players had a 7–9% lesser capacity to consume oxygen than elite senior players (Brown et al., 1998). However, difference between U-17 and U-19 in relation to intensity during match-play remains unclear.

Table 5.11 *Comparison between recommendations on intensity for repetitive displacements of present study (adolescence) with elite adults*

Study	Intensity during match play	Recommended intensity for repetitive displacements
Girard et al. (2007) Elite adults	86% VO_2max 92% HRmax	80-90% VO_2max/ 85–90% HRmax
Kingsley et al. (2006) Elite junior	88% HRmax	–

It can be concluded that for U-17, a high percentage of training loads should include repetitive displacements (with stroke) of high intensity and moderate duration (13-18 seconds) with short recovery (10-12 seconds). For another age category, U-19, a high percentage of training loads should include repetitive displacements (with stroke) of high intensity and moderate duration (15-20 seconds) with short recovery (10-12 seconds).

5.10 Limitation of the study

A limitation of the present study was that the type of plays (offensive vs. defensive) was not evaluated and it could support a better understanding of the results. This is because rally length also depends on tactical strategy or type of plays of the players, as defensive plays last longer than offensive plays.

CHAPTER 6

CONCLUSIONS

6.1 Conclusion of the study

The game structure of adolescent elite squash players with regard to the number of shots per rally, ball in play in minutes, ball in play in percentage, rally length, work-rest ratio was significantly different and advanced in U-19 as compared to U-17. However, the game duration, match duration, number of rallies per game and rest time between rallies was not significantly different between age categories. Adolescent players in U-19 have quite similar rally length, number of shots per rally, rest time between rallies and ball in play in percentage with adult elite players.

6.2 Recommendations for future studies

In the future studies, the following research directions related to game structure of adolescent squash players are suggested: 1) To determine the difference in relation to time interval of rally length between U-17 and U-19 age categories, 2) To compare the types of play (offensive vs. defensive) between U-17 and U-19 age categories, 3) To compare the game structure between national and international adolescent players.

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APPENDICES

Appendix A Ethical Approval Letter

UNIVERSITI SAINS MALAYSIA

Jawatankuasa Etika Penyelidikan Manusia USM (JEPeM)
Human Research Ethics Committee USM (HREC)

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Our. Ref. : USMKK/PPP/JEPeM [260.4.(5.1)]
Date : 21st February 2013

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The Human Research Ethics Committee, Universiti Sains Malaysia (FWA Reg. No: 00007718; IRB Reg. No: 00004494) has approved in principle the study mentioned below:

Title	Match Performance Structure in Malaysian Adolescent Squash Players.		
Protocol No	-	**Principle Investigator**	Chow Xiao Wei
Date of approval Protocol received Reviewed by Committee Received Amended Protocol	21st February 2013 8th November 2012 10th January 2013 16th January 2013	**Co-Investigator(s)**	Assoc. Prof. Oleksandr Krasilshchikov
Research Center	Health Campus, Universiti Sains Malaysia.	**Date of study start**	March 2013 – February 2014
Financial Support	-	**Number of Samples**	14 samples

The following item (✓) have been received and reviewed:-

(✓) **Ethical Approval Application Form**
(✓) **Application Approval for Video Usage**

Investigator(s) are required to:
a) follow instructions, guidelines and requirements of the Human Research Ethics Committee, Universiti Sains Malaysia (JEPeM)
b) report any protocol deviations/violations to Human Research Ethics Committee (JEPeM)
c) comply with International Conference on Harmonization – Guidelines for Good Clinical Practice (ICH-GCP)
d) note that Human Research Ethics Committee (JEPeM) may audit the approved study.

PROFESSOR DR. MOHD SHUKRI OTHMAN
Chairman
Human Research Ethics Committee

UNIVERSITI SAINS MALAYSIA

Jawatankuasa Etika Penyelidikan Manusia USM (JEPeM)
Human Research Ethics Committee USM (HREC)

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Date of meeting: 30 January 2013
Venue : Bilik Mesyuarat, Pusat Inisiatif Penyelidikan Klinikal dan Sains Kesihatan USM Kampus Kesihatan.
Time : 9.00 a.m – 2.30 p.m
Meeting No : 260

Members of the Sub Committee of the Human Research Ethics Committee, Universiti Sains Malaysia who reviewed the protocol/documents are as follows:

Member (Title and Name)		Occupation (Designation)	Male/ Female (M/F)	Tick (✓) if present when above items, were reviewed
Chairperson : Professor Dr. Mohd Shukri Othman		Chairman of Human Research Ethics Committee	M	✓ (Chairperson)
Secretary I : Mrs. Mazlita Zainal Abidin		Science Officer	F	✓
Secretary II : Mr. Mohd Bazlan Hafidz Mukrim		Research Officer	M	✓
Members :				
1.	Dato' Hj. Wan Mohamed Yusoff	Ex-State Secretary of Kelantan	M	✓
2.	Professor Dr. Din Suhaimi Sidek	Lecturer, School of Health Sciences	M	✓
3.	Associate Professor Dr. Nik Hazlina Nik Hussein	Lecturer, School of Medical Sciences	F	✓
4.	Prof. Madya Dr. Nor Azwany Yaacob	Lecturer, School of Medical Sciences	F	✓
5.	Dr. Noraida Ramli	Lecturer, School of Medical Sciences	F	✓
6.	Dr. Aniza Abd. Aziz	Lecturer, School of Medical Sciences	F	✓
7.	Dr. Teguh Haryo Sasongko	Lecturer, Human Genome Centre	M	✓
8.	Tuan Hj. Ellias Zakaria	Lecturer, School of Humanities	M	✓
9.	Mrs. Zawiah Abu Bakar	Community Representative	F	✓

The Human Research Ethics Committee of Universiti Sains Malaysia is in compliance with International Conference on Harmonization–Guidelines for Good Clinical Practice (ICH-GCP) guidelines and Declaration of Helsinki.

PROFESSOR DR. MOHD SHUKRI OTHMAN
Chairman
Human Research Ethics Committee

Appendix B Application Approval for Video Usage

Application Approval for Video Usage

I, Associate Prof. Dr. Oleksandr Krasilshchikov representing MOHE Sport Excellence Research Grant 2010, give permission to this student CHOW XIAO WEI (metric no. : 106019) for video usage.

I hereby declare that the video usage by this student has been acknowledged and with my approval.

Permission of video usage from 4 tournaments is given; include CIMB National Junior Circuit Penang 2011, CIMB National Junior Circuit KL 2011, KL Open Local Event 2011 and Milo All Star 2011. Overall 12 recorded matches video clips are provided to this student for her Final Year Research purpose only.

Oleksandr Krasilshchikov, Assoc. Professor

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Date: 18/1/2013