CHAPTER V

DISCUSSION AND CONCLUSION

The present study examined and compared differences in kinematics of the knee joint during essential badminton movements between female and male junior badminton players. Differences between gender in the hamstrings strength, quadriceps strength, and H/Q ratio were also determined. Comparisons between genders were made because female experience more knee injuries than male in comparable sports. To our knowledge, in the current literature there have been no studies regarding the knee kinematics data during perform these badminton tasks.

1. Knee joint kinematics during badminton tasks

In the present study, significant differences in knee flexion angle at foot contact during landing and maximum varus and maximal knee internal rotation angle during net lift were found between genders.

For the landing task, female junior badminton players had an average of 10 degree greater knee flexion angle at foot contact compared to the males. This finding is in agreement with a previous study by Fagenbaum and Darling (36) who reported a 10-14 degree greater flexion angle at foot contact during single-leg landing from a jump in female college basketball athletes compared to the male athletes.

Some researchers reported similar knee flexion angles during landing and cutting among female and male collegiate athletes (39, 60, 61) and junior athletes (62). However, most previous reports are in other direction with results of the present study where female demonstrated smaller knee flexion angle during single leg landing (33,

45) and rapid direction changes tasks (side step, side jump, and shuttle-run) (37, 38) compared to their male counterparts.

Variations in kind of athletes, testing methodology and laboratory settings could largely affect the results of different studies. Most previous research investigated biomechanical of knee injury in soccer (61, 63), basketball (36, 38, 62), and volleyball (33) players. The standard tasks such as running, cutting, or landing were administered in a motion analysis laboratory. Most previous studies were not consistent in testing protocols. The knee angles reported in the literature were from different landing styles such as a drop landing from box in single leg and both legs landing, hop from box landing, forward hop landing, side jump landing, side step cutting, and shuttle-run. In the present study, badminton players performed a single leg jump landing with rapid run out after landing and lunging to return the drop shuttle cock. It was expected that the movements performed should closely simulated the actual badminton performance; therefore, the current results are more representation of the knee angles during actual sport movements.

The knee angles in other planes of movement were found to be close to a neutral position; however, statistical significant differences existed between male and female badminton players. Male badminton players had greater maximum varus and internal rotation angle compared to females. These results are not consistent with most previous research where greater knee valgus and internal rotation angles were found in female athletes (38, 60, 62, 63). The 3D knee angles can be different from study to study depending on the testing tasks, the landing height, or the training adaptation in particular sport.

Knee flexion angle of the landing task has been associated with ACL injury. Landing and cutting with a more extended knee angle decrease the ability of the hamstring muscle to prevent anterior tibia translation, thereby increasing the risk of ACL injury. This may not be the case in the present study when the H/Q is taken into account. The male junior players did not bend the knee as much as the females may be partly explained by a high H/Q ratio (0.77) of the landing leg indicating sufficient hamstring muscle force for controlling the knee in slightly flexion. Although the female H/Q ratio was well within normal range, a safe landing with knee in more flexion angle would ensure optimal hamstrings force for preventing anterior tibial translation and decreasing stress on the ACL.

Increased knee valgus has been also considered a potential factor of ACL injury in females (64). Either adding the varus, valgus, or internal rotation moment resulted in increasing the amount of strain in ACL (10, 65). Although the valgus force has been reported to be more of a risk factor to ACL injury, the increased varus force may also produce stress to the lateral collateral and cruciate ligaments of the knee joint. Attention should be paid to the junior male badminton players as the knee varus angle was over 4 degrees greater that of the female badminton players for prevention of the associated injury that may occur with repeated movements during the game.

2. Knee muscle strength of junior badminton players

2.1 Hamstrings and quadriceps strength

Male junior badminton players showed significantly greater knee muscle strength at both slow (60º/sec) and fast (180º/sec) speed when compared to females, except the left quadriceps peak torque. The results are consistent with those previous reported. Strength data at both slow and fast speeds reported in several studies are summarized in Table 10. Holmes and Alderink (44) determined the isokinetic strength of both hamstrings and quadriceps muscles in high school students (aged 15 to 18) at the same speed as the present study. The knee muscle strength of junior badminton players in this study show higher values compared to those reported in Holmes and Alderink's (44) and Gerodimos's (66) study. Differences in sport specific training and age of participants may contribute to differences in muscle strength reported. This group of junior badminton players was regularly trained (2 to 5 hours per day and 3 to 7 day per week). Male junior basketball players in the study of Gerodimos (66) were younger than badminton players in this study. There has been no report on knee muscle strength in other groups of junior badminton players for direct comparison to this study. Andersen and coworkers (67) reported the knee strength of male elite badminton athletes to be greater than our group of male junior badminton players. Differences in skill level, age, and test speed are among the reasons for differences in knee strength between studies.

In the present study, concentric peak torque relative to body mass of both hamstrings and quadriceps muscles decreased as speed of contraction increased. Several studies in adolescents (44, 66) and adults (67) reported the similar results. The mechanism can be described by the moment (force) – velocity relationship with the decrease of tension related to a combination of the number of cross bridge breaking and reforming and fluid viscosity in both contractile element and connective tissue (46).

Table 10. Concentric hamstring and quadriceps muscle strength of various population at slow and fast speeds for dominant leg

	Age (years)	Speed (°/sec)	Females (Nm/kg)	Males (Nm/kg)
Hamstrings torque at slow velocity				
Elite badminton players [a]	23.5 ± 0.6	30	N/A	1.86
Collegiate athletes [b]	18 to 23	60	1.14	1.32
High school students [c]	15 to 18	60	0.99	1.23
Junior basketball players [d]	12 to 17	60	N/A	1.31 to 1.84
Junior badminton players (present study)	14 to 18	60	1.32	1.65
Hamstrings torque at fast velocity				
Elite badminton players [a]	23.5 ± 0.6	240	N/A	1.30
High school students [c]	15 to 18	180	0.69	0.88
Junior basketball players [d]	12 to 17	180	N/A	0.98 to 1.39
Junior badminton players (present study)	14 to 18	180	0.98	1.35
Quadriceps torque at slow velocity				
Elite badminton players [a]	23.5 ± 0.6	30	N/A	3.69
Collegiate athletes [b]	18 to 23	60	2.23	2.72
High school students [c]	15 to 18	60	1.79	2.17
Junior basketball players [d]	12 to 17	60	N/A	2.09 to 2.76
Junior badminton players (present study)	14 to 18	60	2.10	2.46
Quadriceps torque at fast velocity				
Elite badminton players [a]	23.5 ± 0.6	240	N/A	2.15
High school students [c]	15 to 18	180	1.01	1.27
Junior basketball players [d]	12 to 17	180	N/A	1.53 to 1.99
Junior badminton players (present study)	14 to 18	180	1.55	1.91

[a]Andersen et al (67), [b] Lephart et al (45), [c] Holmes and Alderink (44), [d]Gerodimos et al (66).

2.2 Hamstrings to quadriceps ratio

Deficit of the knee muscle strength has been related to increased risk of knee injury. With imbalance of the knee muscles, improper knee motion are more likely to occur during the game (43, 48). H/Q ratio has been widely used both clinically and in research as an indicator of the balance of the knee muscle strength (43, 46, 47). A low H/Q ratio has been suggested to be a contributing factor to knee injuries such as ACL tears (43), and overuse conditions (48). In present study, the ratio of peak concentric hamstrings torque to peak concentric quadriceps torque was reported in the same way to previous studies (44, 47, 48, 66-68).

The H/Q ratios reported in the current study (0.63 – 0.77) are comparable to those reported in other junior athletes, such as junior male basketball players (0.62 – 0.71) (66) and high school student (0.55 – 0.70) (44) as shown in Table 11. Hewett et al (69) reported the mean H/Q ratios of uninjured subjects from twenty-two previous studies across all velocities to be 0.52 for females and 0.61 for males. Therefore, a group of badminton players of the current study had H/Q ratio range that is above the values previously reported.

For this study, the H/Q ratio revealed no significant differences between the female and male groups except the left leg H/Q ratio at slow speed. The left H/Q ratio strength of the male group at 60º/sec was significantly higher than the female group (0.77 ± 0.11 and 0.66 ± 0.12, respectively). At this speed the left hamstrings of the male group was significantly stronger than that of the female group while the left quadriceps strength was not different. The result was in agreement with a comprehensive review by Hewett et al (69) where isokinetic H/Q ratios of uninjured population of females and/or males were reported. They concluded that, gender difference in H/Q ratio was not observed at slow speed (30º/sec). However, at higher testing speed which more related to moderate to fast knee flexion/extension motions (60º/sec, 120º/sec, and 300º/sec) demanded during sports tasks, male showed significantly greater H/Q ratios than female. The greater quadriceps contraction increases the anterior shear force on the tibia, whereas, the greater hamstrings contraction prevents the excessive anterior translation of the tibia on the femur. Greater H/Q ratio at higher test speeds observed in males is beneficial in controlling excessive anterior tibial translation, thus high stress on ACL during sport tasks is prevented. In contrast, Yoon et al (68) reported no differences in H/Q ratio at all speed tests (30º/sec, 60º/sec, 90º/sec, 120º/sec, and 180º/sec) between genders in untrained subjects. Bowerman et al (43) found no gender difference in the H/Q ratio 60º/sec among athletes, but higher ratio was found in the athletes compared to non-athletes (0.52 and 0.48, respectively). Similar to the results of this study, no gender differences in most H/Q ratios were observed.

Table 11. Hamstring to quadriceps ratio of various populations at slow and fast velocities for dominant leg

	Age (years)	**Speed (°/sec)**	**Females (Ratio)**	**Males (Ratio)**
Elite badminton players [a]	23.5 ± 0.6	30	N/A	0.50
		240	N/A	0.60
High school students [b]	15 to 18	60	0.55	0.58
		180	0.68	0.70
Junior basketball players [c]	12 to 17	60	N/A	0.62 to 0.69
		180	N/A	0.64 to 0.71
Junior badminton players	14 to 18	60	0.63	0.67
(present study)		180	0.64	0.71
Collegiate athletes [d]	19.3 ± 1.3	60	0.50	0.51
		180	0.59	0.60
Collegiate athletes [e]	19.4 ± 1.3	60	0.62	N/A
		300	0.73	N/A
Normal untrained people [f]	21 to 35	60	0.53	0.60
		180	0.60	0.64

[a] Andersen et al (67) , [b] Holmes and Alderink (44), [c] Gerodimos et al (66), [d] Rosene et al (47), [e] Devan et al (48), [f] Yoon et al (68).

3. Limitations

Several limitations of the current study need to be considered. First, only the kinematics of the knee joint was concerned, therefore movements of the hip and ankle which could also affect the knee motions were not measured. Second, the movements during the selected badminton tasks may not be as vigorous as the movements during the actual competition. The participants might not have been forced to play at their optimal performance. Third, small number of participants and differences in skill levels might affect the results. However, variation in playing skill was somehow controlled by including only experienced badminton players who regularly practiced more than one year and were active in a tournament to participate in the study. Fourth, a skin-based marker system and its association motion artifact may not definitively predict underlying movement of the bone. However, the methods we measured the knee joint kinematics in this study are commonly used and deemed acceptable. Finally, we did not account for menstrual cycle phase of female players. Hormone fluctuations throughout the menstrual phase may have influenced knee joint laxity and muscle stiffness which may affect the variability of the kinematics results in the female group. Variability in the female group data (SD), however, was similar, and in some case smaller, than the variability in the male group data (see kinematics results in Table 2 - 7).

4. Conclusion

We found that the female group had greater knee flexion angle at foot contact during jump smash and lesser maximum varus angle and lesser maximum internal rotation angle during lunging of the net lift. Knee kinematics, knee muscle strengths and H/Q ratios of both genders were within normal range reported in athletic population. Both hamstrings and quadriceps of male junior badminton player group were stronger than those of the female group at both slow (60º/ sec) and fast (180º/ sec) speeds. Larger knee flexion angle during landing was observed in female group as the knee movement mechanism required high hamstrings force for preventing anterior tibial translation to guarantee a safe landing. Knee flexion angle during landing observed in the male group was not as high as the female group could be explained by a large H/Q ratio (0.77) of the landing leg indicating sufficient hamstring muscle force for controlling the knee in slightly flexion.

5. Future study

In future study, kinetic and electromyography (EMG) data should be added into an investigation to provide more insight about the potential knee injury mechanism in badminton sport. The kinetic data from force platform would explain more about the ground reaction force and joint torques, while the EMG data would represent activation of the muscles during performing badminton tasks. The use of unanticipated movement tasks would more closely simulate the motion of the knee during sporting tasks as there is limited time to make postural adjustments (62). In addition, the functional ratios such as the ratio of concentric flexor strength to eccentric extensor strength or the ratio of eccentric flexor strength to concentric extensor strength are more accurate in assessment of knee muscle balance. The functional H/Q ratio should be assessed for better describing the balance of the muscle contraction during functional sporting tasks.