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# Survey of Epidemiology and Mechanisms of Badminton Injury Using Medical Check-Up and Questionnaire of School Age Badminton Players

Xiao Zhou, Kazuhiro Imai, Xiaoxuan Liu



***Abstract*****—**Badminton is one type of racket sports that requires repetitive overhead motion, with the shoulder in abduction/external rotation and requires players to perform jumps, lunges, and quick directional changes. These characteristics could be stressful for body regions that may cause badminton injuries. Regarding racket players including badminton players, there have not been any studies that have utilized medical check-up to evaluate epidemiology and mechanism of injuries. In addition, epidemiology of badminton injury in school age badminton players is unknown. The first purpose of this study was to investigate the badminton injuries, physical fitness parameters, and intensity of shoulder pain using medical check-up so that the mechanisms of shoulder injuries might be revealed. The second purpose of this study was to survey the distribution of badminton injuries in elementary school age players so that injury prevention can be implemented as early as possible. The results of this study revealed that shoulder pain occurred in all players, and present shoulder pain players had smaller weight, greater shoulder external rotation (ER) gain, significantly thinner circumference of upper limbs and greater trunk extension. Identifying players with specific of these factors may enhance the prevention of badminton injury. This study also shows that there are high incidences of knee, ankle, plantar, and shoulder injury or pain in elementary school age badminton players. Injury prevention program might be implemented for elementary school age players.

***Keywords*****—**Badminton injury, epidemiology, medical check-up, school age players.

## I. Introduction

BADMINTON is a non-contact racket sport requiring rapid arm movements from a wide variety of postural positions, with the shoulder in abduction/ER [1] and requires players to perform jumps, lunges, and quick directional changes [2]. In badminton match, overhead is the most important stroke that is approximately 44.6% (17% clear, 13.8% smash and 13.8% drop), followed by 23.4% lob, 18.1% net and 13.9% others in men’s singles [3] and approximately 57% (24.7% clear, 8.6% smash and 23.7% drop) followed by 15.1% lob, 15.1% net and 12.8% others in women’s singles [4]. Due to these characteristics of badminton, injuries are occasionally caused. In badminton injuries, 74% of injuries are overuse, and 26% of injuries are trauma including strain (12%), sprain (11%) and fracture (1.5%) [5]. Trauma injuries often occur in lower extremity (63%), followed by upper extremity (18.1%), and back and waist (16.6%). Regarding trauma injuries in lower extremity, knee (37.1%), ankle (28.3%), thigh (13.2%) and heel (11.2%) are recognized as the common sites.

Upper limb badminton injuries most often occur in shoulder (36.9%), and elbow ranked the second [2]. The study regarding shoulder pain in tournament level and amateur badminton players revealed that the intensities of shoulder pain assessed by visual analog scale (VAS) were 50 ± 20 and 56 ± 23, respectively [6]. Relationship between shoulder laxity and pain has been reported in swimmers that a statistically significant correlation was identified between laxity score and the presence of interfering shoulder pain [7]. As for badminton, few epidemiological studies [1], [6] have used medical check-up to reveal association between intensity of shoulder pain, physical fitness parameters, and shoulder range of motion (ROM). Additionally, few previous studies [2], [5] have investigated the distribution of badminton injuries and the rate of badminton injury in school age badminton players.

The primary purpose of this study was to investigate the badminton injuries, physical fitness parameters, and intensity of shoulder pain using medical check-up, and then to describe the association among intensity of shoulder pain, shoulder ROM, and physical fitness parameters, so that the mechanisms of shoulder injuries might be revealed. The secondary purpose was to determine the distribution of badminton injuries in elementary school age players (≤ 12 years old).

## II. Materials and Methods

### A. Medical Check-Up

From August 2018 to November 2018, 12 badminton players have been investigated. All the participants were male amateur players whose dominant side was right. This study was approved by Ethical Committee of the Graduate School of Arts and Sciences, the University of Tokyo, Japan. In order to detect factors of badminton injuries, a questionnaire of medical check-up was used. The questionnaire included basic parameters (gender, age, weight, height, dominant side), duration of badminton experience, warming up time, anamnesis of past injury and shoulder pain. Additionally, a physical fitness test was operated to evaluate hand grip strength, flexibility of shoulder, straight leg raising, circumferences of upper limbs and lower limbs, balance ability, ROM of trunk, shoulder and elbow. A digital hand dynamometer (N-FORCE, Wakayama, Japan) was used to measure hand grip strength and a digital goniometer SA-5468 (Suncosmo, Tokyo, Japan) was used to measure ROM. Measuring capacity of the digital hand dynamometer is 0-90.0

Kazuhiro Imai is with The University of Tokyo, Japan (e-mail: imai@idaten.c.u-tokyo.ac.jp).

kg with sensitivity of 0.1 kg. Measuring range of the digital goniometer is 0-360.0 degree and has a sensitivity of 0.1 degree with resolution of 0.05 degree. Hand grip strengths on both sides of the participant were measured with a digital hand dynamometer.

Next, the participant stood on a yoga mat and bend forward with legs extended. When the participant could not touch the mat, the minimum distance between fingers and mat was measured and recorded as finger floor distance (FFD). Then, the participant lied prone on the mat. While the participant kept the pelvis flat, the examiner slowly flexed the participant's knee until the heel approached the buttock. The distance between the heel and the buttock was measured and recorded as heel buttock distance (HBD). Next, with the participant in supine on the mat, the examiner slowly raised the participant's leg with knee extension. The examiner kept raising the participant's leg until the participant could not continue because of pain or tightness in the posterior leg. The examiner measured the angle of start-stop point using the goniometer and recorded it as the straight leg raising (SLR). Next, the participant raised the right arm overhead on the back and the right fingers stretched down. Then left arm behind the lumber and the left fingers stretched up. The participant was asked to try to touch hands behind back with right arm up and left arm behind. If the right finger and the left finger could touch each other, the examiner recorded as 0 cm. If the right fingers and the left fingers were apart from each other, the examiner measured the minimum distance between the right finger and the left finger. Next, the participant began by standing with two feet a fist width apart and parallel with one another. Then, they squatted as deep they can. The criteria of the test included three points: 1. complete full deep squat; 2. complete full deep squat with raising heel; 3. loss of balance. Next, the participant was positioned supine on the mat, and the examiner passively flexed one hip, bringing the knee up to the chest in order to flatten the lumbar spine and stabilize the pelvis. The test was scored as intact if the opposite hip and knee remained stationary and positioned flat against the examination table. The test was scored as failure if the opposite hip flexed, and the knee lifted off the examination table [8]. Then, seven maneuvers of general joint laxity [9] were done (Fig. 1). The criteria of the positive joint laxity are: 1. shoulder: fingers overlap or grasping, 2. elbow: hyperextension > 15 degrees, 3. hand: passive opposition of the thumb to the flexor aspect of the forearm, 4. spine: trunk flexion with knee extended and both palms contacting the mat, 5. hip: toes going outwards > 180 degrees, 6. knee: hyperextension > 10 degrees, 7: ankle: dorsiflection > 45 degrees.

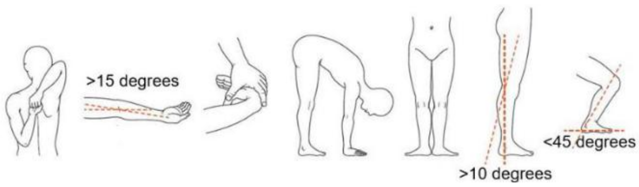


Fig. 1 General joint laxity test

Next, circumferences of thighs (5 cm, 10 cm, 15 cm above patella), the maximal circumferences of legs, upper arms, and forearms were measured respectively. The time of the balance on one leg (balance time) was measured by single leg balance. When the test started, participants stood with one leg as long as they could while lifted another thigh with flexion 90°, with closed eyes.

In shoulder ROM assessment, internal rotation (IR) and ER of the 2nd position on both of dominant side and nondominant side were measured. The participants were in supine position on a standard examining table, with straight leg, 90 degrees of shoulder abduction, 90 degrees of elbow flexion and the forearm in the neutral position. The examiner stabilized the scapula and pushed the forearm anteriorly (IR) and posteriorly (ER) while rotating the humerus in the glenohumeral joint to produce maximum passive IR and ER. The angles of IR and ER (Fig. 2), which changed from the neutral position to the point of tightness in which no more glenohumeral motion would occur without movement of the scapular, were measured by the second examiner.


Fig. 2 Measurement of shoulder ROM

Next, elbow flection and extension, trunk ROM of flection, extension, side bend, and rotation were assessed. Finally, badminton forehand overhead clear test was adopted to check forehand overhead stroke skill of the participants, and then shoulder and elbow pains were assessed using VAS, where no pain was scored as 0 and the worst imaginable pain was scored as 100. The participants were also asked to mark the locations of the pains of their shoulders and elbows.

### *B. School Age Badminton Players Questionnaire*

This study was approved by Ethical Committee of the Graduate School of Arts and Sciences, the University of Tokyo, Japan and collaborated with Nippon Badminton Association. 338 elementary school age badminton players, consented by their guardian, consisting of 148 boys and 190 girls, have been investigated. A questionnaire to investigate time loss (sports incapacity) badminton injury/pain was used in this study. The questionnaire included basic parameters (gender, age, dominant side), badminton experience, warm-up time, cool down time, time loss injury/pain associated with badminton. Participants were assigned into three groups (7-8 year old group, 9-10 year old group and 11-12 year old group).

### C. Statistic Methods

SPSS was adopted for statistical analysis. We used Shapiro-Wilk test to examine normality. If data were normal, paired t-test and independent test were used for statistical analysis on paired analysis, and one way analysis of variance (ANOVA) test was used for groups (7-8 year old, 9-10 year old and 11-12 year old group) analysis. If data were abnormal, Wilcoxon's rank-sum test was used for paired data. Spearman's rank correlation coefficients were used to examine the relationship between intensity of shoulder pain, shoulder ROM, and body parameter, respectively. The multiple regression was used to analyze the effect of shoulder pain related factors on shoulder pain intensity. Logistic regression was used to detect the association between badminton injuries and factors. The level of significance was set as below 0.05.

## III. Results

### A. Medical Check-Up

Characteristics of the participants are shown in Table I. All 12 participants have experienced shoulder pain. They were divided into two groups due to present shoulder pain status. 3 participants reported present shoulder pain and they were classified as present pain group. The rest of the 9 participants reported previous shoulder pain and did not have any present shoulder pain: they were classified as previous pain group. Weight and BMI of present pain group were significantly weaker ($p < 0.01$) compared with previous pain group. There were no differences of age, height, duration of badminton experience, weekly playing time, warm-up time between present pain group and previous pain group.

Data on physical characteristics of the participants are shown in Table II. Compared with present pain group, participants in previous pain group showed significantly weaker of the maximal circumferences of upper arm (dominant side: 27.8 vs 33.4, $p < 0.05$; nondominant side: 26.4 vs 32.3, $p < 0.05$) and the maximal circumferences of forearm (dominant side: 24.2 vs 26.2, $p < 0.05$; nondominant side: 22.3 vs 24.8, $p < 0.05$) on both sides. In previous pain group, the maximal circumferences of upper arm and maximal circumferences of forearm on dominant side were significantly greater compared with nondominant side ($p < 0.05$, $p < 0.01$, respectively) while in present pain group, there were no significant differences between dominant and nondominant sides. There were no differences of hand grip strength and balance between both sides in either group. There were also no differences of hand grip strength, balance on both sides, FFD, general joint laxity and VAS scores between present pain group and previous pain group.

TABLE I
CHARACTERISTICS OF PRESENT AND PREVIOUS PAIN GROUPS

| | Present pain (n = 3) | Previous pain (n = 9) |
|---|---|---|
| Age (years) | 24.0 ± 1.7 | 29.8 ± 13.0 |
| Height (cm) | 171.3 ± 4.6 | 176.4 ± 5.8 |
| Weight (kg) | 56.3 ± 2.1** | 78.2 ± 13.7 |
| BMI | 19.4 ± 0.3** | 24.3 ± 4.0 |
| Experience (years) | 12.7 ± 5.5 | 8.7 ± 7.1 |
| Weekly playing (min) | 290.0 ± 141.8 | 246.0 ± 148.3 |
| Warm-up (min) | 6.7 ± 2.9 | 8.9 ± 4.9 |

Values are mean ± SD
**Significant difference ($p < 0.01$) (Mann-Whitney U-test)

The results of shoulder, trunk and elbow ROM are shown in Table III. In pain group, IR on dominant side was significantly weaker than nondominant side while no other differences were found between dominant and nondominant sides. In present pain group, there was no difference on IR, ER, TROM, GIRD, ER gain, trunk rotation, elbow flexion and elbow extension between dominant side and non-dominant side. There were significant differences on trunk extension (43.17 vs 30.01, $p <$ 001) between the pain group and no pain group while no differences of trunk flexion were found between the two groups. TROM loss was defined as the difference in total ROM between the dominant extremity and the nondominant extremity within the same participant. ER gain was defined as the difference between total ER in the dominant extremity and total ER in the nondominant extremity in a single badminton athlete.

TABLE II
A COMPARISON OF PHYSICAL FITNESS BETWEEN PRESENT AND PREVIOUS PAIN GROUPS

| Variables | Present pain (n = 3) | | Previous pain (n = 9) | |
|---|---|---|---|---|
| | Dominant | Nondominant | Dominant | Nondominant |
| Hand grip (kg) | 44.8 ± 3.7 | 37.5 ± 0.6 | 40.5 ± 6.0 | 36.5 ± 6.8 |
| FFD | 11.3 ± 5.8 ($p$ = 0.064) | | 3.4 ± 5.6 | |
| HBD | 0.0 | 0.0 | 2.1 ± 3.9 | 2.6 ± 3.0 |
| SLR | 70.6 ± 2.8 | 63.0 ± 8.6 | 71.8 ± 13.2 | 74.4 ± 11.4 |
| Shoulder flexibility (cm) | 2.9 ±5.0 | 6.2 ± 10.8 | 0.9 ± 2.8 | 3.8 ± 6.1 |
| General joint laxity | 0.50 ± 0.50 | | 0.78±0.94 | |
| Upper arm circumferences (cm) | 27.8 ± 2.3* | 26.4 ± 2.4* | 33.4 ± 4.2† | 32.3 ± 4.4 |
| Forearm circumferences (cm) | 24.2 ± 0.5* | 22.3 ± 0.2* | 26.2 ± 1.5†† | 24.8 ± 1.4 |
| Balance (s) | 54.9 ± 57.5 | 65.5 ± 59.5 | 10.1 ± 7.4 | 15.0 ± 23.3 |
| VAS (mm) | 68.6 ± 44.8 | | 41.2 ± 31.0 | |

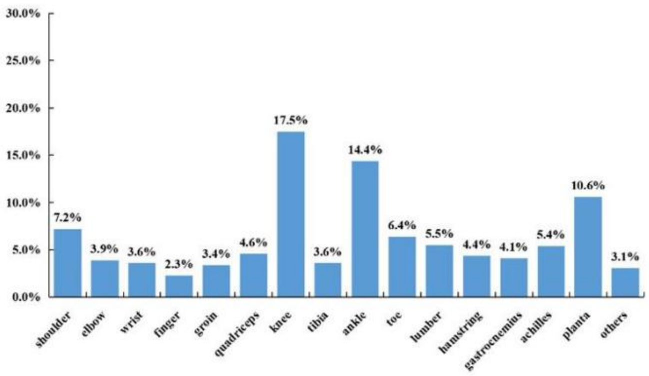
Values are mean ± SD
*Significant difference ($p < 0.05$) compared with previous pain group †Significant difference ($p < 0.05$) compared with nondominant side ††Significant difference ($p < 0.01$) compared with nondominant side
Data between dominant side and nondominant side, present pain group and previous pain group analyzed by Wilcoxon's rank-sum test, Mann-Whitney U-test, respectively.

TABLE III
A COMPARISON OF ROM BETWEEN PRESENT AND PREVIOUS PAIN GROUPS

| Variable | Present pain (n = 3) | | Previous pain (n = 9) | |
|---|---|---|---|---|
| | Dominant | Nondominant | Dominant | Nondominant |
| IR (º) | 71.2 ± 5.5 | 75.3 ± 11.2 | 69.4 ± 8.6† | 76.6 ± 9.8 |
| ER (º) | 103.7±12.5 | 91.3 ± 3.2 | 108.0 ± 11.7 | 102.1 ± 13.5 |
| TROM (º) | 174.8 ± 20.3 | 166.3 ± 8.2 | 177.5 ± 12.5 | 178.6 ± 14.9 |
| TROM loss (º) | 8.2 ± 23.2 | | -1.2 ± 5.7 | |
| GIRD (º) | 4.2 ± 13.3 | | 7.2 ± 6.7 | |
| ER gain (º) | 12.4 ± 11.1 | | 5.9 ± 8.5 | |
| Trunk Flexion (º) | 53.2 ± 7.0 | | 69.9 ± 21.8 | |
| Trunk extension (º) | 43.2 ± 3.5* * | | 30.0 ± 5.3 | |
| Trunk rotation (º) | 52.7 ± 7.7 | 52.8 ± 4.5 | 59.5 ± 17.2 | 54.3 ±15.1 |
| Elbow flexion (º) | 148.0 ± 4.4 | 147.4 ± 4.7 | 146.3 ± 2.7 | 147.2 ± 2.5 |
| Elbow extension (º) | 10.4 ± 3.0 | 8.5 ± 3.8 | 1.4 ± 9.4 | 5.9 ± 5.3 |

Values are mean ± SD; TROM: total range of motion; GIRD: glenohumeral IR deficit.
**Significant difference ($p < 0.01$) compared with previous pain group
†Significant difference ($p < 0.05$) compared with nondominant side
Data between dominant side and non-dominant side, present pain group and previous pain group analyzed by Wilcoxon's rank-sum test, Mann-Whitney U-test, respectively.

TABLE IV
CHARACTERISTICS OF BOYS AND GIRLS BROKEN DOWN BY AGE, RESPECTIVELY




| | 9-10 year old | | 11-12 year old | |
|---|---|---|---|---|
| | Boy | Girl | Boy | Girl |
| | ı = 60) | (n = 79) | (n = 59) | (n = 82) |
| | 5 ± 1.5 | 2.8 ± 1.5 | 3.1 ± 1.8 | 3.3 ± 1.7 |
| | 0 ± 0.8 | 2.9 ± 0.9 | 2.9 ± 1.1 | 2.8 ± 1.0 |
| | 5 ± 1.2 | 4.7 ± 1.3 | 4.7 ± 1.1 | 4.7 ± 1.2 |
| | .4 ± 5.0 | 13.4 ± 5.1 | 13.8 ± 6.7 | 13.3 ± 6.4 |
| | 8 ± 14.3 | 28.6 ± 18.6 | 22.6 ± 13.1** | 33.6 ± 21.7 |
| | 7 ± 7.2 | 11.0 ± 6.9 | 9.0 ± 5.3 | 10.0 ± 8.6 |
| | (61.7%) | 47 (59.5% ) | 44 (74.6%) | 71 (86.6%) |

roup ** $p < 0.01$ (Mann-Whitney U-test), between boys and girls in 11-12 year old

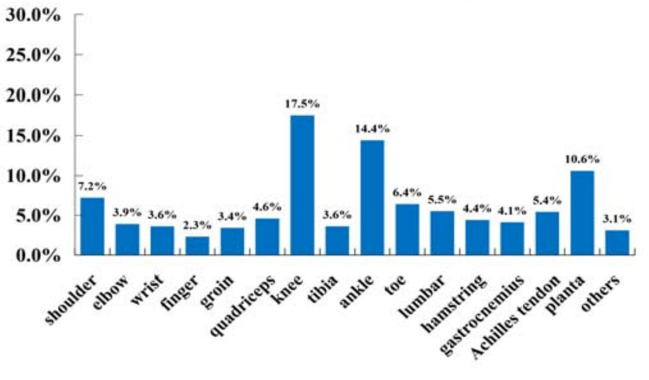



Fig. 3 Epidemiology of time loss badminton injury/pain in school age badminton players

### *B. School Age Badminton Player Questionnaire*

Out of 356 elementary school age badminton player questionnaires, 338 (94.9%) including 148 boys and 190 girls were valid. The players were divided into three groups of 7-8 year old group, 9-10 year old group and 11-12 year old group and the three groups were divided into two subgroups by gender. Data on subgroups are given in Table IV. In 7-8 year old group, the duration of badminton training of boys was significantly longer ($p < 0.05$) than girls. In 11-12 year old group, there were significant differences between in boys' warm-up time and girls' warm-up time.

The distributions of time injuries/pain in anatomical sites of all the players are shown in Fig. 3. The most common regions localized in lower extremities were 74.0% of all the time loss injuries, 17.0% in upper extremities, 5.5% in lumber. Regarding the anatomical regions, the most common region was knee (17.5%), followed by ankle (14.4%), planta (10.6%), shoulder (7.2%), toe (6.4%), and lumber (5.5%).

## IV. DISCUSSION

In medical check-up study, we focused on the shoulder overuse injury in badminton. All the participants have experienced shoulder pain, so we divided the participants into present pain group in the dominant shoulder group and previous pain group. Shoulder ROM, i.e., IR and ER was used to help us understand and discuss epidemiology and mechanisms of shoulder overuse injury. The torque and force experienced through repetitive badminton forehand overhead strokes are known to lead to changes in shoulder ROM, especially increased ER and decreased IR, which could lead to glenohumeral internal rotation deficit (GIRD) [10]. A previous paper [13] supports that overhead and throwing athletes develop adaptations to their dominant shoulders that affect their passive ROM. Multiple studies demonstrated [1], [6],

[12] that the athlete's dominant shoulder, when compared with the nondominant shoulder, develops IR, known as GIRD [11]. Some studies [1], [6] have stated the association between shoulder ROM and shoulder injury in badminton. In overhead players, total ROM was reduced on the dominant side compared with the nondominant side [12]. Another study showed a loss of horizontal or cross-body adduction in throwing shoulder compared with non-throwing shoulder [13]. Shoulder laxity was also assessed using standard clinical tests that a statistically significant correlation was identified between the shoulder laxity and the presence of interfering shoulder pain [14].

The results of this study showed that balance time in present pain group was longer without significant difference than previous pain group. In junior high school baseball players, dynamic standing balance had a reduced risk of upper limbs injury. There was also a study on the association between shoulder ROM and balance in US soldiers. Shoulder ER and balance have significantly increased after deployment compared with before deployment [15]. In this study, both of shoulder ER gain and balance in present pain group were greater than previous pain group without significant difference. Movement of glenohumeral, scapular and thoracic makes major contributions to the maximum shoulder ER [16]. The participants in present pain group may have better trunk control so that they could transfer more power from down limbs to upper limbs, which may lead more shoulder ER gain.

For FFD test, the results of this study showed that FFD in present pain group was greater than previous pain group without significant difference ($p$ = 0.064). SLR test can evaluate hamstring tightness and there was no significant difference between the two groups in this study. In a baseball study, sit-and-reach test was used to study hamstring tightness that has demonstrated a strongly correlation between hamstring tightness and dominant shoulder ER in pitchers [17], which agrees with this study that previous pain group had a greater shoulder ER.

Regarding general joint laxity test, the results showed no difference between the two groups. Using Beighton score to evaluate general joint laxity in swimmers, there were significant difference between competitive swimmers and amateur swimmers [18]. In future studies, we should adopt general joint laxity evaluation in different badminton level players to explore mechanisms of shoulder overuse injury.

The results showed circumferences of upper arms and forearms in present pain group was significantly thinner ($p < 0.05$) than previous pain group. Moreover, in previous pain group, circumferences of upper limbs and forearms on dominant side were significantly greater than nondominant side, while no significant difference in present pain group. It is speculated that one factor of shoulder pain may be thinner dominant upper limbs circumferences.

In overhead racket sports, trunk rotation is regarded as a major segment of kinetic chain in transferring power from lower limbs to upper limbs to create larger effective ROM that contributes to more than 50% of a racket head's forward velocity [19]. Players utilize torque what is produced by the proximal trunk and shoulder joint torques to accelerate the distal upper limbs so that improve performance [20]. On the other hand, Peak angles for trunk extension and internal rotation, peak joint angular velocities for trunk rotation, trunk extension and shoulder IR that have increased significantly as proximal muscle became fatigue [21]. Previous study [22] has revealed players who had greater body weight had an increase in trunk rotation and flexion angular velocity that achieved overhead action better. In this study, participants in present pain group had significantly smaller weight, and significantly greater trunk extension than previous pain group. We speculated smaller weight participants increased trunk extension angle and shoulder angular velocity in order to improve stroking performance, which may cause shoulder pain. Regarding VAS scores, the scores of previous pain group (41.2 ± 31.0) and pain group (68.6 ± 44.8) were similar to other studies [1], [6].

The results of this study revealed that all players experienced shoulder pain, and present shoulder pain players had smaller weight, greater ER gain, significantly thinner circumference of upper limbs and greater trunk extension. In order to improve the prevention and assure injury/pain free participant in badminton, it is necessary to identify specific of weight, ER gain, circumferences of upper limbs and trunk extension of players.

In school age badminton players' questionnaire study, we were able to identify the incidence of badminton injuries separately by age and gender of elementary school age badminton players. Badminton requires weight shifting, balance and joint coordination to perform lunge motions (i.e. side stepping, crossover stepping) and running and jumps. For example, in forward lunge motion, players land the leg of the racket hand side by transferring body weight while taking the shot, and then they push off the leg of the racket hand side for recovery of the body to return the center of the court immediately in preparation for the next shot. In order to transfer body core of mass and maintain balance, a large knee movement is essential. As forward lunge motions, badminton play includes many starts and stops that may cause fatigue. Fatigue could lead to poor muscle coordination on account of many accelerations and decelerations [23] that may cause a lot of lower extremity injuries. Also, badminton players frequently change directions with different plantar loads, which may be potential risks of injuries in the lower extremities [24].

In this study, incidence of lower extremity injuries, that is knee, ankle, plantar and toe, increased with age. In addition, girls had a higher incidence of knee injuries than boys without significant difference. We used logistic regression test to analyze association between variables. Increasing age and warm up time statistically correlated with incidence of knee injury.

Gender, body mass index, level of sport and days of practice per week have a significant correlation with the prevalence of shoulder pain, and overhead sports players with shoulder pain also have been stated lower core stability and shoulder function compared to healthy players [25]. Trunk stability is suggested to minimize joint loads in all types of movements or activities with efficient biomechanical function to maximise force generation, which may contribute to injury prevention [26]. In this study, boys had a significantly higher incidence of lumber injury than girls. Considered the growth of childhood, boys are more physically aggressive and impulsive when they could not coordinate trunk rotation with extremities.

Although time loss badminton injuries have been revealed, the distribution of overuse injury and trauma is limitation of this study. In addition, we have not investigated the extrinsic factors of badminton injuries, environmental, human, racket, shuttlecock, and seasonal variation.

Through this study, epidemiology and some mechanisms of badminton injury have been revealed. We have recognized that there are high incidences of knee, ankle, plantar, and shoulder injury or pain in elementary school age badminton players. Therefore, injury prevention program focusing on knee, ankle, plantar, and shoulder might be essential for elementary school age players to enhance their safe participation.

## REFERENCES

[1] Fahlström M, Yeap J S, Alfredson H, et al. Shoulder pain–a common problem in world-class badminton players. Scandinavian journal of medicine & science in sports, 16: 168-173, 2006.
[2] Shariff AH, George J, Ramlan AA. Musculoskeletal injuries among Malaysian badminton players. Singapore medical journal, 50: 1095-1097, 2009.
[3] Phomsoupha M, Laffaye G. The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. Sports Med, 45: 473-495, 2015.
[4] Ming CL, Keong CC, Ghosh AK. Time motion and notational analysis of 21 point and 15 point badminton match play. S-SCI, 2: 216-222, 2008.
[5] Jørgensen U, Winge S. Epidemiology of badminton injuries. International journal of sports medicine, 8:379-382,1987.
[6] Fahlström M, Söderman K. Decreased shoulder function and pain common in recreational badminton players. Scandinavian journal of medicine & science in sports, 17: 246-251, 2007.
[7] McMaster WC, Roberts A, Stoddard T. A correlation between shoulder laxity and interfering pain in competitive swimmers. The American journal of sports medicine, 26: 83-86,1998
[8] Magee DJ. Orthopedic physical assessment. 4th ed., pp. 1-66, 607-660, vol 11. W.B. Saunders Company: Philadelphia, Pennsylvania, USA, 2002
[9] Imai K. Medical check-up. Oriental medicine in sport, pp. 40-42, Ido no Nihonsha: Yokosuka, Kanagawa, Japan, 2018. (*Japanese*)
[10] Keller RA, De Giacomo AF, Neumann JA, et al. Glenohumeral internal rotation deficit and risk of upper extremity injury in overhead athletes: a meta-analysis and systematic review. Sports health, 10: 125-132, 2018.
[11] Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med, 23:233-239, 1995.
[12] Couppe C, Thorborg K, Hansen M, et al. Shoulder rotational profiles in young healthy elite female and male badminton players. Scandinavian journal of medicine & science in sports, 24: 122-128, 2014.
[13] Borsa PA, Laudner KG, Sauers EL. Mobility and stability adaptations in the shoulder of the overhead athlete. Sports medicine, 38: 17-36, 2008.
[14] McMaster WC, Roberts A, Stoddard T. A correlation between shoulder laxity and interfering pain in competitive swimmers. Am J Sports Med, 26: 83-86, 1998.
[15] Nagai T, Abt JP, Sell TC, et al. Effects of deployment on musculoskeletal and physiological characteristics and balance. Military medicine, 181: 1050-1057, 2016.
[16] Miyashita K, Kobayashi H, Koshida S, et al. Glenohumeral, scapular, and thoracic angles at maximum shoulder external rotation in throwing. The American journal of sports medicine, 38: 363-368, 2010.
[17] Anloague PA, Spees V, Smith J, et al. Glenohumeral range of motion and lower extremity flexibility in collegiate-level baseball players. Sports health, 4: 25-30, 2012.
[18] Jansson A, Saartok T, Werner S, et al. Evaluation of general joint laxity, shoulder laxity and mobility in competitive swimmers during growth and in normal controls. Scandinavian journal of medicine & science in sports, 15: 169-176, 2005.
[19] Zhang Z, Li S, Wan B, et al. The influence of X-factor (trunk rotation) and experience on the quality of the badminton forehand smash. Journal of human kinetics, 53: 9-22, 2016.
[20] Hirashima M, Yamane K, Nakamura Y, et al. Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. Journal of biomechanics, 41: 2874-2883, 2008.
[21] Cowley JC, Gates DH. Proximal and distal muscle fatigue differentially affect movement coordination. PloS one, 12: e0172835, 2017.
[22] Wagner H, Buchecker M, Von Duvillard SP, et al. Kinematic description of elite vs. low level players in team-handball jump throw. Journal of sports science & medicine, 9: 15, 2010.
[23] Kaalund S, Lass P, Høgsaa B, Nøhr M. Achilles tendon rupture in badminton. Bri J Sports Med, 23: 102-104, 1989.
[24] Hu X, Li JX, Hong Y, Wang L. Characteristics of plantar loads in maximum forward lunge tasks in badminton. PloS one, 10: e0137558, 2015.
[25] Pogetti LS, Nakagawa TH, Conteçote GP, Camargo PR. Core stability, shoulder peak torque and function in throwing athletes with and without shoulder pain. Physical Therapy in Sport, 34: 36-42, 2018.
[26] Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports medicine, 36: 189-198, 2006.