



Original Article

Longitudinal study on locations of injury among junior high school, high school, and university badminton athletes at Japanese national-level competitions

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Abstract. [Purpose] The aim of study was to examine incidence of injury according to location of injury to develop an injury prevention program for elite badminton players of junior high school, high school, and university. [Participants and Methods] We conducted a prospective longitudinal study, between April 2012 and March 2013, on 133 national-level badminton players attending junior high school, high school, and university. Injury rates in athletes per 1,000 exposures were calculated based on gender and school age for the five most common injury locations, in addition, severity, type and circumstance were investigated. [Results] Injury rates in athletes per 1,000 exposures were the highest in the racket-side (RS) shoulder/clavicle among the female university students (4.35), RS thigh of high school females (2.21), and lumbar spine/lower back of males of all school ages and junior high school females (1.83–1.25). Significantly higher injury rates were noted for the overuse of the lumbar spine/lower back and RS shoulder/clavicle, trauma of the RS thigh and ankle, and injury, when compared with slight injury of the RS ankle. [Conclusion] Injury prevention programs should be developed for RS shoulder/clavicle overuse in university females, RS thigh trauma in high school females, and lumbar spine/lower back in males of all school ages and junior high school females.

Key words: Badminton, Injury prevention program, Epidemiological study

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INTRODUCTION

Badminton is popular worldwide, and the 2020 Tokyo Olympics included five badminton events: men's singles and doubles, women's singles and doubles, and mixed doubles. In the recent years, studies of injuries in badminton players have been published to develop injury prevention programs^{1–5)}. Recently, we have also published a longitudinal study on elite badminton players in Japan that included junior high school, high school, and university players, which was performed at a gymnasium by physical therapists; that study reported injury rates (IR) per 1,000 athlete exposures (AEs) and IR per 1,000 hours by gender, school age, and circumstances of play (match play/training)⁶⁾.

Mechelen et al.⁷⁾ noted that the creation of an injury prevention program involves the following steps: Step 1: Establishing the extent of the sports injury problem (incidence and severity), Step 2: Establishing the etiology and mechanisms of injury,

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Step 3: Introduce preventive measures, and Step 4: Assessing their effectiveness by repeating Step 1. Further Bahr et al.⁸⁾ also noted that the critical step in the sequence needs information on the risk factors and mechanisms, which are influenced by anatomy, gender, school age, and skill level. In the first study⁶⁾, we reported and clarified incidence and severity by gender, school age, and competition level using the first and second steps only to be able to formulate an injury prevention program. Furthermore, this second study examined the injury location as a factor of anatomy and investigated a specific injury prevention program for elite badminton players. Since badminton necessitates different movements on the side of the body that holds the racket (racket side [RS]) and does not hold the racket (non-racket side [N-RS]), these injury locations must be investigated. Based on the longitudinal study conducted at the gymnasium during training and match play, it was also useful to determine the incidence of injury location to examine IR per 1,000 AEs and IR per 1,000 hours. Ogiuchi et al.⁹⁾ reported that badminton injuries commonly occurred in the RS knee, N-RS ankle, N-RS foot, lumbar spine/lower back, and RS shoulder/clavicle; however, their findings were not obtained from the longitudinal study. Meanwhile, Goh et al.⁵⁾ conducted a longitudinal study and reported that the lower extremities, particularly the knee, was a common location of injury; however, they did not differentiate between RS and N-RS. Yung et al.⁴⁾ reported that the most common injury location in terms of IR per 1,000 hours was the back, followed by the shoulder/clavicle, thigh, knee, and ankle. However, their findings were not based on a longitudinal study and they did not differentiate RS and N-RS. Other investigations on injury location¹⁰⁻¹⁶⁾ also failed to report findings according to RS and N-RS in terms of IR per 1,000 AEs or IR per 1,000 hours based on longitudinal studies conducted at the gymnasium during training and match play.

To establish a benchmark for steps one and two in developing an injury prevention program for elite badminton players, we conducted a prospective longitudinal study at a gymnasium by physical therapists. Among the results, we reported in the previous study⁶⁾ that the IR per 1,000 hours during practice was higher in females than in males and that this IR increased with school age. Further, the IR per 1,000 AEs during match play was the highest in both male and female high school players. Following the first part, the present study (conducted as a second part) aimed to determine the IR per 1,000 AEs for injury locations based on RS/N-RS according to gender and school age. We also investigated and reported findings on injury severity, injury type, and circumstances of injury in terms of location.

PARTICIPANTS AND METHODS

This prospective longitudinal study began in April 2012 with the recruitment and follow-up of 133 junior high school, high school, and university badminton players who competed in national-level tournaments; injuries that occurred during the one-year academic period ending in March 2013 were examined descriptively (Table 1). This study was approved by the Ethics Committee of Kyorin University (23-14), and informed consent was obtained from all athletes.

The definitions of injury, injury severity, injury type, and circumstances of injury were followed in accordance to the report of Hagglund et al.¹⁷⁾. An injury was defined as a physical complaint that occurred during play, caused abstinence from subsequent training or match play, and required medical attention from a team physical therapist at the scene¹⁸⁾. Physical complaints were classified by severity as follows: (1) slight injury if the athlete must stop immediate training or match play, as advised by the medical team, but did not abstain from further training or match play; and (2) injury if the athlete abstained from one or more days of subsequent training or match play. Injuries were also classified into the following two types: (1) trauma, if the injury occurred suddenly due to a specific event, and (2) overuse, if the injury developed chronically over time with no specific traumatic causes. If medical attention or examination by a physician was required, athletes were promptly examined at a medical facility. Physical therapists also examined pre-existing conditions that were present within 6 months before the start of the study and injuries that occurred from the previous academic year until the current academic year of the study; these injuries were excluded from analysis.

Injury location was classified based on the injury surveillance locations reported by Junge et al.¹⁹⁾: five locations in the head and trunk (head, neck/cervical spine, thoracic spine/upper back, lumbar spine/lower back, and abdomen), six locations in the upper extremities (shoulder/clavicle, upper arm, elbow, forearm, wrist, and hand), and six locations in the lower extremities (hip, thigh, knee, lower leg, ankle, and foot/toe). Injury locations in the upper and lower extremities were also

Table 1. Participant characteristics

Gender	School age	Number of players	Age (years)	Height (cm)	Weight (kg)	AEs
Male	Junior high school	18	13.4 ± 0.7	161.7 ± 7.9	49.5 ± 7.6	5,062
	High school	26	16.2 ± 0.5	169.1 ± 5.2	58.0 ± 5.6	6,983
	University	50	20.0 ± 1.2	172.5 ± 6.4	65.7 ± 6.6	10,362
Female	Junior high school	16	13.8 ± 0.8	159.4 ± 6.1	49.9 ± 6.8	4,916
	High school	16	16.1 ± 0.7	162.3 ± 5.7	54.7 ± 5.0	4,527
	University	7	20.7 ± 1.1	163.4 ± 3.1	59.6 ± 5.3	1,379

Values are presented as numbers or mean ± standard deviation.

Athlete exposures (AEs)=∑number of participants.

differentiated based on whether they occurred on the racket-holding side of the body (RS) or the opposite side (non-racket side [N-RS]).

Circumstances of injury were classified as injuries that occurred during training under coach supervision and during a match of the athlete's team.

Calculations and statistical analysis were performed based on gender and school age. First, the total number of AEs was calculated, wherein a single athlete exposure was defined as one participation in training or match play by an athlete. Then, the total number of injured athletes was calculated by location; this included multiple injuries at the same location for one athlete.

Thereafter, the IR per 1,000 AEs^{20–22} was calculated by gender and school age for the five most common injury locations. Analysis of variance was also performed on the IR per 1,000 AEs to determine the difference in the ratios of three factors: gender, school age, and location²³. Injuries at each location were also presented by proportion based on injury severity, injury type, and circumstances of injury. Chi-square test or Fisher's exact test was performed on the relationship between these factors and injury location, and an adjusted standardized residual analysis was also performed. A p value less than 0.05 was considered statistically significant.

RESULTS

Table 1 shows the number of athletes, age, height, weight, and AEs in the studied year by gender and school age. The number of AEs was higher in males of all school ages, and its highest number was 10,362 of university males.

The five most common injury locations according to number of athletes were the lumbar spine/lower back (35 athletes), RS knee (26 athletes), RS thigh (25 athletes), RS ankle (23 athletes), and RS shoulder/clavicle (19 athletes). Injuries according to the number of athletes were more common on the RS for all locations in the lower extremities, and injuries only occurred on the RS in the upper extremities. The five most common locations in terms of total injuries were the lumbar spine/lower back (49 injuries), RS knee (33 injuries), RS thigh (32 injuries), RS ankle (29 injuries), and RS shoulder/clavicle (29 injuries), which showed the same pattern as the most common injury locations according to the number of athletes.

Table 2 shows the number of injuries and the IR per 1,000 AEs by gender and school age for the five most common injury locations. The highest IR per 1,000 AEs was 4.35 in the RS shoulder/clavicle of university females, followed by 2.90 and 2.21 in the lumbar spine/lower back of university females and RS thigh of high school females, respectively. The IR per 1,000 AEs was the highest in the lumbar spine/lower back in males of all school ages and junior high school females (1.83–1.25). Statistical analyses results revealed that school age was the main contributory factor ($p < 0.05$) and that the interaction among gender, school age, and injury location was significant ($p < 0.01$) (Table 3).

Table 4 shows the injury severity, injury type, and circumstances of injury by location for the five most common injury locations. With this, a significant relationship was found between injury location with respect to both injury severity ($p < 0.01$) and injury type ($p < 0.001$). Additionally, adjusted residuals indicated significantly higher rates of overuse in the lumbar spine/lower back (4.24) and RS shoulder/clavicle (2.19); trauma in the RS thigh (1.97) and RS ankle (6.09); and injury as opposed to slight injury in the RS ankle (3.64). The adjusted residuals revealed no significant bias in terms of injury severity, injury type, or circumstances of injury for the RS knee.

DISCUSSION

In badminton players, we first performed a prospective longitudinal study on their injury at a gymnasium by physical therapists, and presented the incidence of injury at each injury location by gender and school age. The previous study⁶ on the IR per 1,000 hours during practice showed higher rates with increasing school age, with females showing higher rates

Table 2. Number of injuries and injury rates (IR) per 1,000 athlete exposures in five most common injury locations

Gender	School age	No. of injuries (IR per 1,000 AEs)				
		Lumbar spine/ lower back	Shoulder/clavicle	Thigh	Knee	Ankle
Male	Junior high school	8 (1.58)	3 (0.59)	3 (0.59)	2 (0.40)	2 (0.40)
	High school	12 (1.72)	9 (1.29)	5 (0.72)	9 (1.29)	9 (1.29)
	University	13 (1.25)	4 (0.39)	9 (0.87)	12 (1.16)	8 (0.77)
Female	Junior high school	9 (1.83)	3 (0.61)	4 (0.81)	2 (0.41)	1 (0.20)
	High school	3 (0.66)	4 (0.88)	10 (2.21)	7 (1.55)	8 (1.77)
	University	4 (2.90)	6 (4.35)	1 (0.73)	1 (0.73)	1 (0.73)
Total		49 (1.47)	29 (0.87)	32 (0.96)	33 (0.99)	29 (0.87)

Injury rates (IR) per 1,000 athlete exposures (AEs) = $\{\sum(\text{No. of injuries})/\sum(\text{No. of participants})\} \times 1,000$.

Table 3. Analysis of variance of the differences in ratios of gender, school age, and location for the five most common injury locations

	SS	DF	SS/ δ^2_w	
Main effect				
Gender	0.46	1	2.10	
School age	1.99	2	9.17	*
Location	1.77	4	8.17	
Interaction				
Gender \times School age	0.54	2	2.47	
Gender \times Location	0.73	4	3.37	
School age \times Location	2.55	8	11.74	
Gender \times School age \times Location	3.78	8	17.40	**

Sum-of-squares (SS); degrees of freedom (DF); within-participant variance (δ^2_w).

* $p < 0.05$, ** $p < 0.01$.

Table 4. Injury location and severity, type, and circumstances of injury

		Injury severity ^{#**}		Injury type ^{b***}		Circumstances of injury [#]	
		Slight injury	Injury	Trauma	Overuse	Match play	Training
Lumbar spine/lower back	Number (%)	44 (91.7)	4 (8.3)	2 (4.1)	47 (95.9)	7 (14.3)	42 (85.7)
	Adjusted res	1.85	-1.85	-4.24	4.24	—	—
Racket side Shoulder/ clavicle	Number (%)	26 (92.9)	2 (7.1)	3 (10.3)	26 (89.7)	3 (10.3)	26 (89.7)
	Adjusted res	1.49	-1.49	-2.19	2.19	—	—
Racket side Knee	Number (%)	29 (87.9)	4 (12.1)	7 (21.2)	26 (78.8)	4 (12.1)	29 (87.9)
	Adjusted res	0.80	-0.80	-0.80	0.80	—	—
Racket side Thigh	Number (%)	24 (77.4)	7 (22.6)	13 (40.6)	19 (59.4)	8 (25.0)	24 (75.0)
	Adjusted res	-0.96	0.96	1.97	-1.97	—	—
Racket side Ankle	Number (%)	16 (59.3)	11 (40.7)	21 (72.4)	8 (27.6)	4 (13.8)	25 (86.2)
	Adjusted res	-3.64	3.64	6.09	-6.09	—	—

Adjusted standardized residual analysis (adjusted res).

Adjusted res $> |1.96|$: $p < 0.05$.

Adjusted res $> |2.56|$: $p < 0.01$.

[#]: Fisher's exact test.

^b: χ^2 test.

** $p < 0.01$, *** $p < 0.001$.

than males. The IR per 1,000 AEs during match play was higher than that during training, and this rate was the highest in high school players, followed by university and junior high school players; these were for both females and males. Therefore, injury prevention programs are particularly necessary for female university players during training and for high school players during match play. The present study showed that the IR per 1,000 AEs was the highest in the RS shoulder/clavicle of university females and the RS thigh of high school females. From these findings, an injury prevention program for elite-level badminton players is needed in particular for the RS shoulder/clavicle in university females during training and for the RS thigh in high school females during match play. Regarding the cause of injuries in the RS shoulder/clavicle, Couppe et al.²⁴⁾ noted a lower shoulder external rotator strength to body weight ratio in females. Similarly, a weaker external rotator strength potentially increased the risk of shoulder injury. Although the data were not shown, internal and external rotator strengths were measured in all athletes in this present study except for high school males, and it was shown that the external rotator strength to body weight ratio tended to be lower in university females. This may be one of the reasons for the high incidence of RS shoulder/clavicle injuries noted in university females. Additionally, the RS thigh injuries may be due to added extension stress on the hip adductors during exaggerated lunging movements and extension stress from eccentric contraction of the hamstring when stepping back.

This present study also indicated the importance of preventing injuries in the lumbar spine/lower back in males of all school ages and junior high school females. Kaneko et al.²⁵⁾ reported that growing pains in the lower back were more frequent with various sports. Similar to Kaneko et al.²⁵⁾, we also observed that low back pain was the most common injury in male and female junior high school athletes. In badminton, low back pain may occur due to repeated compression forces on the intervertebral joints associated with lumbar spine extension, lateroflexion, and rotation during overhead stroke movements. It

may also be caused by repeated elevation of intradiscal pressure associated with landing movements after jumping and trunk flexion during lunging movements.

Ogiuchi et al.⁹ reported that RS injuries were more common in the upper extremities (29 of 30 injuries) and in the thigh, knee, and lower leg (21 of 28 injuries), whereas N-RS injuries were more common in the ankle and foot (20 of 30 injuries). This present study observed the same pattern of injury in the upper extremities, thigh, knee, and lower leg; however, a different pattern was observed for injury in the ankle and foot. Badminton underwent rule changes in 2006 and adopted the rally point scoring system, which increased the use of aggressive shots, such as smashes. Shuttlecock speeds have also increased due to advances in rackets and other equipment. Therefore, the different pattern of RS ankle injury observed in this present study may be due to lunging, jumping, and landing movements that were performed quicker and more frequently by the RS lower extremity of today's badminton athletes. Nevertheless, it is noteworthy that ankle injuries were the most common N-RS lower extremity injury in this present study.

An examination of injury severity, injury type, and circumstances according to location showed that overuse injuries were significantly more common than trauma injuries in the lumbar spine/lower back. This was similar to the findings of Jørgensen et al.² who reported that 79% of injuries in the lumbar spine/lower back were overuse injuries. These findings suggest that lumbar spine/lower back injury was caused by repeated mechanical loading, indicating that badminton athletes must improve their trunk muscle strength and adopt proper form to reduce mechanical loading on intervertebral joints and discs. Overuse injuries were significantly more common than trauma injuries in the shoulder/clavicle. This may be caused by reduced strength in the external rotator muscle group due to muscle fatigue caused by frequent smashes, which indicated the importance of improving muscular endurance in the external rotator muscle group. Trauma injuries were also significantly more common than overuse injuries in the RS thigh. As mentioned earlier, avoidance of RS thigh injuries required maintenance of flexibility in the hip adductor muscle group to withstand extension stress during lunging movements. Furthermore, a significantly higher proportion of trauma injuries requiring at least one day of abstinence from play was observed in the RS ankle. Shariff et al.¹¹ reported that 85.7% of ankle injuries in badminton players were sprains. Similar to Shariff et al.¹¹, we believed that sprains accounted for a large proportion of injuries in the RS ankle in the present study. This suggested the necessity to develop a program of ankle sprain prevention to prevent athletes from withdrawing from play.

Based on these findings, we propose the following injury prevention program for badminton players of junior high school to university ages. First, for overuse injuries in the RS shoulder/clavicle in university females, targeted low-load high-frequency training would be effective, given that external rotator muscles were not strengthened by general training. Trauma injuries in the thigh of high school females required reconditioning of the hip adductor muscle group that focused on dynamic stretching and improvement of muscle flexibility before and after exercise, respectively. Overuse injuries in the lumbar spine/lower back throughout all school ages required improvement of trunk muscle strength and practice of movements that stabilize the lumbar spine. Bahr et al.⁸ also noted that shoes and other equipment were important risk factors in sports injuries. Since injuries in the RS ankle pose a high risk of withdrawal from play, it may be a good idea to select appropriate shoes and develop insoles that match the movement characteristics of badminton athletes.

This present study has some limitations. Only physicians can make the diagnosis of the injury or illness using the Japanese medical system. This study was limited to examination of injury locations because physical therapists performed at a gymnasium. However, the incidence of injury location in elite badminton players was a novel finding, and we believe it was useful in creating an injury prevention program. In addition, there might be selection bias and difficulty in applying these findings to players who are not high-level junior high school, high school, or university athletes or to players in teams without medical staff. However, since high-level players were less likely to abstain from training or match play and required injury prevention, the data obtained in this present study was useful as a benchmark. With this, further verification of the effectiveness of the developed injury prevention program was suggested in steps three and four.

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Conflict of interest

None.

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