

A Prospective Epidemiological Study of Injuries in Japanese National Tournament-Level Badminton Players From Junior High School to University

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Background: Injury prevention programs have recently been created for various sports. However, a longitudinal study on badminton injuries, as assessed by a team's dedicated medical staff, at the gymnasium has not been performed.

Objectives: We aimed to perform the first such study to measure the injury incidence, severity and type as the first step in creating a badminton injury prevention program.

Patients and Methods: A prospective, longitudinal survey was conducted between April 2012 and March 2013 with 133 national tournament-level badminton players from junior high school to university in Japan with the teams' physical therapists at the gymnasium. Injury incidence was measured as the injury rate (IR) for every 1,000 hour (1000 hour) and IR for every 1,000 athlete exposures (1000 AE). Severity was classified in 5 levels by the number of days the athlete was absent from practice or matches. Injury types were categorized as trauma or overuse.

Results: Practice (IR) (1,000 hour) was significantly higher in female players than in male players; the rates increased with increasing age. IR (1,000 AE) was significantly higher in matches than in practice in both sexes of all ages, except for female junior high school students and injuries were most frequent for high school students in matches. The majority of the injuries were slight (83.8%); overuse injuries occurred approximately 3 times more than trauma.

Conclusions: This is the first study in which medical staff assessed injuries in badminton, providing value through benchmark data. Injury prevention programs are particularly necessary for female university students in practice and high school students in matches.

Keywords: Epidemiology; Incidence; Athletic Injuries; Racquet Sports

1. Background

Badminton is a very common sport worldwide. Injury prevention programs have recently been created as an initiative to address sports injuries (1-3). However, a systematic injury prevention program for badminton players has not yet been created.

According to van Mechelen et al. (4) 4 steps are necessary in the development of an injury prevention program and the first is calculating the injury incidence via a longitudinal survey. Recent definitions of sports injury incidence include injury rate (IR) per 1000 hour, with one hour defined as one hour of sports participation by one athlete (5-9), and IR per 1000 athlete-exposures (1000 AE), with one athlete-exposure defined as participation in one sports session by one athlete (10-12). Of the previous stud-

ies regarding badminton injuries (13-19), there have been few longitudinal studies of injuries using IR (1000 hour) or IR (1000 AE). In a study of 44 elite badminton players in Hong Kong, Yung et al. (13) reported an IR (1000 hour) of 5.04 from calculations based on team records. In another study of 270 elite-level badminton players and 105 recreation-level badminton players in Denmark, Jorgensen et al. (14) reported an IR (1000 hour) of 2.9 from calculations based on self-registration.

In their prospective epidemiological study in which injuries in English professional football clubs were recorded by a physical therapist (PT), Hawkins et al. (5) reported that benchmark data from prospective surveys are necessary to create injury prevention programs. Furthermore,

according to a study referring to the union of European football associations (UEFA) model of epidemiological studies of injuries, the ideal contact person to complete injury studies is a member of the club's medical staff, such as the team doctor or a PT (20); similarly, in studies of rugby injuries, each team's medical staff recorded injuries during matches (7-9). However, past surveys of badminton injuries have used only medical records and self-registration; to the best of our knowledge, there are no reports of longitudinal injury surveys by the medical staff of each team such as those conducted in football and rugby.

2. Objectives

The objective of the present study was to establish a benchmark as the first step towards creating a badminton injury prevention program. In order to achieve that objective, longitudinal injury surveys were conducted by teams' dedicated PTs with Japanese national tournament-level badminton players from junior high school to university.

3. Patients and Methods

This longitudinal survey, conducted between April 2012 and March 2013, included 133 badminton players in junior high school, high school, or university who competed at the national tournament level. All teams that were surveyed appeared in that year's national tournament for their age group. All players received an explanation of the study's objectives and methods and provided written consent. The study protocol was approved by the ethics committee of Kyorin University.

Injury recognition was based on the definition of Haggglund et al. (6), in which an injury is defined as an event that occurs during badminton and causes the player to drop out of practice or the match. Injuries were those that required medical attention (21) from the team's dedicated PT, who performed evaluations and kept records. When examination by a doctor was required, the player was quickly taken to a medical facility. The history of previous injuries includes those from 6 month prior to the academic year of this study, and injuries that occurred during the previous academic year and continued into the academic year of the survey were excluded from the analysis. The injury records included day of injury, injury type (trauma or overuse) and number of days that passed between the injury and the player's return to practice or matches. Further, each team's PTs recorded the day, time and number of players at each practice as well as the day, tournament name, and number of players at each match.

IR (1000 hour, with 1 hour defined as 1 hour of participation in the sport by 1 player) and IR (1000 AE, with 1 AE defined as participation in 1 sports session by 1 player) were used to measure injury incidence.

Injury severity and type were based on the classifications of Haggglund et al. (6). Severity was classified by how many days of practice or matches the player missed: slight injury, the player dropped out of practice or the match owing to the injury but did not require more rest; minimal injury, rested 1 - 3 days; mild injury, rested 4 - 7 days; moderate injury, rested 8 - 28 days and severe injury, rested > 28 days.

Acute injuries with a clear cause were classified as trauma, while chronic injuries with no clear trauma were defined as overuse.

The injury incidence during practice was calculated as IR (1000 hour) and IR (1000 AE). The injury incidence during matches was calculated as IR (1000 AE). Further, the frequency of injuries at each severity level was calculated against the total number of injuries. The proportion of injuries from minimal to severe was added together to obtain the proportion of injuries that required rest from practice or matches. For injury type, the proportion was also calculated for trauma and overuse against total injuries.

In the statistical analysis of injury incidence, an analysis of variance of the differences in the rates (22) was first conducted for practice IR (1000 hour), based on age and sex. For practice and match IRs (1000 AE), analyses of variance of the differences in the rates were conducted based on age, sex and matches/practice.

In the analysis of severity, Chi-squared tests were used to determine differences in sex, age, injury type and match/practice for injury type (slight injuries vs. injuries that required rest from practice or matches).

In the statistical analysis of injury type, analyses of variance of the differences in the rates were conducted for trauma and overuse based on trauma/overuse and matches/practice.

4. Results

The participant characteristics are provided in Table 1. There were 94 male students and 39 female students. University students accounted for the highest number of boys/men and the fewest number of girls/women.

The number of injuries, total practice time and AE in practice and matches are shown in Table 2, according to age and sex. Practice IR (1000 hour) was higher in girls/women than in boys/men and increased with age. In the analysis of variance of the differences in the rates for practice IR (1000 hour), the main effects (both age and sex, $P < 0.001$), and the interaction between age and sex ($P = 0.03$) were statistically significant (Table 3).

Further, match and practice IRs (1000 AE) were higher in matches than in practice in both sexes of all ages, except for female junior high school students and injuries were most frequent for high school students in matches (Table 2). In the analysis of variance of the differences in IR (1000 AE), the main effects were significant (both age, $P = 0.001$ and matches/practice, $P < 0.001$) (Table 3).

Table 1. Participant Characteristics ^a

Gender	Number of Players	Age, Y	Height, cm	Weight, kg
Male				
Junior high school	18	13.4 ± 0.7	161.7 ± 7.9	49.5 ± 7.6
High school	26	16.2 ± 0.5	169.1 ± 5.2	58.0 ± 5.6
University	50	20.0 ± 1.2	172.5 ± 6.4	65.7 ± 6.6
Female				
Junior high school	16	13.8 ± 0.8	159.4 ± 6.1	49.9 ± 6.8
High school	16	16.1 ± 0.7	162.3 ± 5.7	54.7 ± 5.0
University	7	20.7 ± 1.1	163.4 ± 3.1	59.6 ± 5.3

^a Values are reported as number or mean ± standard deviation.

Table 2. Number of Injuries, Total Practice Time, Athlete Exposure and Injury Rate

Gender	Male			Female			
	School age	Junior high school	High School	University	Junior high school	High school	University
Number of injuries							
Match		3	8	11	1	7	5
Practice		19	54	68	26	47	21
Total practice time, h ^a		20495.5	35678.5	35653.5	19263.5	19793	4133
Athlete exposure (AE) ^b							
Match		215	205	677	198	204	185
Practice		4849	6968	9621	4718	4323	1194
Injury rate per 1000, h ^c							
Practice		0.9	1.5	2.5	1.3	2.4	5.1
Injury rate per 1000 athlete exposure ^d							
Match		14.0	39.0	16.1	5.1	34.3	27.0
Practice		3.9	8.0	8.9	5.5	10.9	17.6

^a Total practice time = Σ (number of participants × hours of practice).

^b Athlete exposure = Σ number of participants.

^c Injury rate per 1000 hour = $[\Sigma(\text{No. of injuries}) / \Sigma\{(\text{No. of participants}) \times (\text{hours of practice})\}] \times 1,000$

^d Injury rate per 1000 athlete exposure = $\Sigma(\text{No. of injuries}) / \Sigma(\text{No. of participants}) \times 1,000$.

Table 3. Analysis of Variance Results for the Differences in Injury Rate (IR) 1000 Hours, IR 1000 Athlete Exposures (AE) or Proportions

Factor	SS	DF	SS/δ ² W	P Values
IR (1000 h) based on age and gender in practice				
Main effect				
Age	1.89	2	30.7	0.000
Gender	1.05	1	17.1	0.000
Interaction				
Age × Gender	0.43	2	7.0	0.030
IR (1000 AE) based on age, gender and matches/practice				
Main effect				
Age	28.0	2	14.6	0.001
Geder	0.77	1	0.4	0.527
Matches/practice	27.9	1	14.5	0.000
Interaction				
Age × Geder	6.4	2	3.3	0.191
Age × Matches/practice	9.1	2	4.7	0.095
Geder × Matches/practice	2.6	1	1.4	0.242
Frequency of trauma/overuse based on trauma/overuse and matches/practice				
Main effect				
Trauma/overuse	1006.5	1	74.6	0.000
Matches/practice	0.0	1	0.0	1.000
Interaction				
Trauma/overuse × Matches/practice	1.3	1	0.1	0.754

In all injuries, the proportions of the injuries in each of the injury severity levels were as follows: slight injury, 83.8%; minimal injury, 4.1%; mild injury, 3.4%; moderate injury, 6.8% and severe injury, 1.9%. The proportion of the injuries that required rest from practice or matches was 16.2%. Statistically significant differences were observed based on age ($P = 0.019$) and injury type ($P < 0.001$) (Chi-squared test; Table 4). The age group with the highest percentage of injuries requiring rest from practice or matches was university students, followed by junior high school students and high school students. As for injury type, overuse was more frequent than trauma.

The proportion of overuse was about 3 times that of trauma for both matches and practice (Figure 1). Further, the analysis of variance of the differences in the rates for the proportion of trauma and overuse resulted in a significant main effect of trauma/overuse ($P < 0.001$) (Table 3).

Table 4. Differences in Injury Severity, Based on Chi-Squared Tests^a

Severity	Slight Injuries	Other Injuries ^b	Total	P Values
Gender				
Male	131 (81.9)	29 (18.1)	160 (100)	0.286
Female	92 (86.8)	14 (13.2)	106 (100)	
School Age				
Junior high school	43 (87.8)	6 (12.2)	49 (100)	0.019
High school	101 (89.4)	12 (10.6)	113 (100)	
University	79 (76.0)	25 (24.0)	104 (100)	
Injury Type				
Trauma	39 (59.1)	27 (40.9)	66 (100)	0.000
Overuse	184 (92.0)	16 (8.0)	200 (100)	
Situation				
Match	34 (85.0)	6 (15.0)	40 (100)	0.811
Practice	187 (83.5)	37 (16.5)	224 (100)	

^a Values are presented as No. (%).

^b Injuries that required rest from practice or matches.

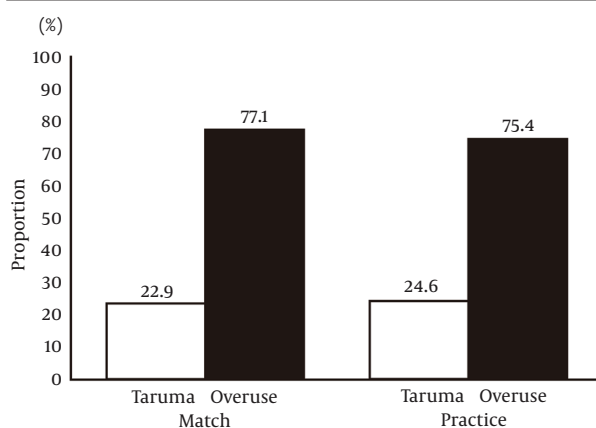


Figure 1. Proportion of Injury Type by Match and Practice

5. Discussion

The IR (1000 hour) in this sample of badminton players competing at the national tournament level ranged from 0.9 to 5.1, with higher rates in female players and with increasing age. Moreover, we noted that the IR (1000 AE) differed by age and match/practice, and a number of players were affected by slight and overuse injuries.

To the best of our knowledge, there are no previously reported badminton injury surveys conducted by the team's medical staff in the gymnasium. IRs (1000 hour) of 3.5, 0 - 4.6 and 2.0 have been reported in studies conducted by the medical personnel of English football clubs (5), at the Under-21 football European championships (6) and with the English professional rugby union (8), respectively. The benchmark for IR (1000 hours) in badminton practice was determined as 0.9 - 5.1 in our study.

Regarding age and sex differences in IR (1000 hour), age differences during practice have been reported previously in 44 elite badminton players in Hong Kong, based on medical and team records: 2.56 in elite senior players (≥ 21 year old), 2.84 in elite junior players (< 21 year old), and 1.70 in potential players (< 15 year old) (13). Sex differences were reported in 270 elite-level badminton players and 105 recreation-level badminton players in Denmark, based on self-registration, with IRs of 3.0 in men and 2.8 in women (14). Although direct comparisons are not possible between the present study and these previous studies owing to differences in subject criteria and survey methods, the present study also found differences in IRs based on age and sex. There was a significant increase in IR with age and significantly higher IRs in female players than in male players in all age groups. The mechanical load during matches increases with the level of competition, which increases with age; this might explain the age-associated increase in IR. The differences in IR by sex may partially be explained by differences in basic physical strength. In addition, the higher IR in girls could be the result of the observed trend towards poorer basic training in the girls' teams than in the boys' teams in the present study. There was also a significant interaction between age and sex in the IR (1000 hour) in practice; while the IR in the girls was 1.4 times higher than in boys in junior high school and 1.6 times higher in high school, the IR in girls was 2.0 times higher than in boys in university.

Because badminton matches last for three sets of 21 points each, with no set match duration, the present study used IR (1000 AE) and a significant difference was observed between matches and practice; university and high school students (aged ≥ 15 year) demonstrated a higher IR in matches than in practice. Similarly, although with IR (1000 hour), Yung et al. (13) reported higher IRs in matches than in training for elite seniors (3.78) and elite juniors (5.94), but not potential players (0). The higher level of competition in university and high school results in a large mechanical load during play and greater mechanical load is applied in matches than in practice,

potentially resulting in the greater IRs. Furthermore, in Japanese tournaments, a team may play as many as six matches in one day, resulting in a greater exercise load than in practice.

Hoy et al. (16) reported that, of 89 badminton players who visited a hospital, 3 (3%) were absent from sports < 1 week, 25 (28%) were absent 1 - 4 weeks and 44 (49%) were absent > 4 week. Comparatively, we found a higher frequency of slight injuries; in addition, the proportion of injuries decreased as severity increased. These differences may have been related to the presence of a dedicated PT in all teams as well as the study setting: hospital vs. gymnasium.

Significant differences in injury severity were observed for both age and injury type, with university players and players with trauma experiencing more severe injuries. Similar to the IR, this difference based on age might be related to the increased mechanical stress experienced during competition by university players, which increases the risk of more severe injuries. Meanwhile, overuse symptoms can be addressed by a PT while symptoms are mild, but trauma tends to result in more severe symptoms because it occurs suddenly.

Similar to the findings of the present study, Jorgensen et al. (14) reported that > 74% of badminton injuries are overuse injuries and Ogiuchi et al. (23) found 32 cases of trauma (28.8%) and 79 cases of overuse (71%) in a cross-sectional injury survey of players designated for Olympic badminton training. Therefore, overuse is approximately 3 times more common than trauma in badminton.

In the present study, IR in practice increased with age, was higher in girls than in boys and was highest in female university students. Also, IR in matches was higher than in practice and highest in high school students, followed by university and junior high school students, for both girls and boys. Therefore, injury prevention programs are particularly necessary for female university students in practice and for all high school students in matches.

Slight injuries were the most frequent and overuse injuries were approximately three times more frequent than trauma injuries, both in matches and in practice. Regarding the IR by injury location, the rates for the lumbar spine, knee joint and shoulder joint of the dominant side were higher (results not shown). In these locations, there was also a trend for more frequent overuse injuries than trauma injuries. Therefore, creating a systematic injury prevention program that combines stretching, strength training and other aspects to address overuse injuries, particularly for the lumbar spine, knee joint and shoulder joint of the dominant side, could reduce the number of badminton injuries.

Because the subjects in the present study were Japanese national tournament-level badminton players from junior high school to university, the results may not apply to players who play recreational badminton or to older adults or elderly individuals. Also, because each team in the present study had a dedicated PTs, training and con-

ditioning in matches were conducted by the PT. Consequently, IR and severity may have been low compared to teams that do not have PTs or other medical staff. However, owing to the lack of dedicated medical staff for some teams and the inability to easily abstain from practice and matches, high-level players require injury prevention programs and the present study provides benchmarks with which an injury prevention program for national tournament-level badminton players from junior high school to university can be created. We did not perform any comparisons between players with or without additional fitness training; we could acknowledge this as a limitation of the present study, but that this is part of future work because it represents the third and fourth steps to creating an injury prevention program.

This is the first study in which medical staff assessed injuries in badminton, providing value through benchmark data. The creation of injury prevention programs in badminton is needed. Differences were observed in the IRs of badminton players based on age, sex and match/practice. Therefore, as a first step, injury prevention programs are thought to be particularly necessary for female university students during practice and high school students during matches. In terms of severity, the majority of the injuries observed were slight, while chronic injuries were 3 times more common than trauma. To prevent badminton injuries from becoming more serious, we believe that the implementation of a systematic injury prevention program aimed particularly at chronic injuries would be beneficial.

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Authors' Contributions

Eiji Miyake contributed to all processes of this study. Mitsunobu Yatsunami contributed to conception, design, analysis, writing and editing of this manuscript. Jun Kurabayashi contributed to conception, design, analysis, writing and editing of this manuscript. Koji Teruya contributed to analysis, writing and editing of this manuscript. Yasuhiro Sekine contributed to collecting data. Tatsuaki Endo contributed to collecting data. Ryuichiro Nishida contributed to collecting data. Nao Takano contributed to collecting data. Seiko Sato contributed to collecting data. Han Jae Kyung contributed to collecting data.

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