Influence of Ankle Injury on Subsequent Ankle, Knee, and Shoulder Injuries in Competitive Badminton Players Younger Than 13 Years

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Background: In recent years, there has been a trend in badminton toward more specialized training at an earlier age. Accompanying this trend is the increased frequency of injuries in young players. Ankle injury is the most common injury in pediatric sports; however, its influence on subsequent injuries is rarely considered.

Purposes: To evaluate the incidence of ankle, knee, and shoulder injuries in youth badminton and to investigate the influence of ankle injuries on subsequent ankle, knee, and shoulder injuries.

Study Design: Descriptive epidemiology study; Level of evidence, 3.

Methods: A custom-designed questionnaire was used to survey Japanese players 7 to 12 years of age who attended national elementary school–level badminton tournaments between May and September 2019. Information including the players' characteristics, training history, injuries in the previous 12 months, and ankle injury histories were collected. Logistic regression was used for analysis.

Results: A total of 478 players were included in the study, with 71 ankle injuries, 74 knee injuries, and 48 shoulder injuries reported. The injury incidence rates (per 1000 hours of play) were 0.23 (95% CI, 0.18-0.29) for the ankle, 0.24 (95% CI, 0.19-0.30) for the knee, and 0.16 (95% CI, 0.11-0.20) for the shoulder; 90.1% of ankle injuries, 25.7% of knee injuries, and 33.3% of shoulder injuries were acute. Previous ankle injury was significantly associated with subsequent ankle injury (adjusted Odds Ratio (OR), 3.05; 95% CI, 1.54-6.07; $P < .05$), knee injury (adjusted OR, 2.03; 95% CI, 1.12-3.69; $P < .05$), and shoulder injury (adjusted OR, 2.46; 95% CI, 1.26-4.83; $P < .05$).

Conclusion: The study results indicated that previous injury to the ankle significantly increased the occurrence of subsequent ankle, knee, and shoulder injuries. Emphasizing protection and prevention of ankle injuries may help lower future injury risk in young badminton players.

Keywords: ankle injury; knee injury; shoulder injury; badminton; pediatric sports

Pediatric sports have changed dramatically in the past few decades, with trends toward early specialization and intensive training.[33] A Malaysian study showed that a majority of elite badminton players began specialization or received supervised training at an average age of 9.0 years.[32] According to the Nippon Badminton Association, there were 23,288 primary school–aged children (age, 7-12 years) playing badminton competitively in Japan in 2019.[37] Accompanying the rising number of early-entry players is the growing concern of injuries, as they can create physical and mental barriers that produce long-term effects on a player's performance, limit their future potential, or even end their sports career. Younger players, who are physically and physiologically different from adults, are considered to be at higher risk in sports because of their immature musculoskeletal system and cognitive functions.[12,23]

Ankle injury is the most commonly seen sports-related injury in school-aged children,[3,46] yet its occurrence and consequence in badminton-specific populations remain unclear. In competitive badminton, players are required to perform rapid lunges and jumps in multiple directions in response to the opponent's action and immediately return to the central position to prepare for the next movement,[14,39] making the ankle one of the sites that is most prone to injuries.[20,24,29] Most ankle injuries are sprains[22] and put players at risk of long-term consequences, including reinjury, instability, and prolonged

The Orthopaedic Journal of Sports Medicine, 10(5), 23259671221097438
DOI: 10.1177/23259671221097438

symptoms.[4,9,28,36] Although a number of studies have investigated the short-term and long-term outcomes related to ankle injuries, most of them have focused on the significant recurrent risk.[35,48] Only a few studies have explored the relationship between previous ankle injury histories and subsequent knee injury.[6,30] Also, the results from different studies are contradictory. For example, Kramer and colleagues[30] reported increased anterior cruciate ligament injury in female athletes with previous ankle injury history, whereas in a similar study conducted by Brand et al,[6] a positive relationship was not established.

The term "kinetic chain" is used to describe how the body performs a movement and transfers energy. Each movement is a chain of events that are interrelated, in which a deficit in one component of the chain can affect another. Previous studies have demonstrated that ankle instability, which is a common problem after an ankle injury, is associated with a series of kinetic dysfunctions[15,44,47]; therefore, since the ankle joint acts as a terminal segment of the kinetic chain, it is reasonable to assume that injuries to the ankle are predisposing factors for injuries in other joints in both the lower and upper extremities.

In the current study, we aimed to evaluate the incidence of ankle, knee, and shoulder injuries in youth badminton and to investigate the influence of ankle injury on subsequent ankle, knee, and shoulder injuries. We chose these 3 locations because they are where the majority of pathologies occur and knowing their correlations with previous ankle injury histories can be instructive in the future development of injury prevention programs.

METHODS

This study was a collaboration among the Graduate School of Arts and Sciences at the University of Tokyo, Institute of Sport at Senshu University, and Japan School Children Badminton Federation. The study protocol received ethics committee approval, and the study was performed in compliance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all participating players and their guardians.

Participants and Injury Assessment

A descriptive cross-sectional study design was used to survey elementary school badminton players (age, 7-12 years) attending the national badminton tournament games at 3 randomly selected locations between May and September 2019. A custom-designed questionnaire was given to players presenting at the badminton venue during the period of the competition. Players answered the questionnaires with the help of their guardians. The questionnaire comprised 2 parts: in the first part, information obtained included the player's sociodemographic profile (age, sex, weight, and height) and training history (number of years involved in badminton, racket hand, training hours per day, and training days per week), and in the second part, players were asked about their injury history in the ankle, knee, and shoulder over the previous 12 months, as well as any ankle injuries before that period.

We defined an injury as any physical discomfort that occurred during practice or match play resulting in one or more of the following 3 situations: (1) having to discontinue the current training or match immediately, (2) being absent from the next scheduled training or match, and/or (3) requiring medical attention related to the injury. If a player answered yes to injury history, they were also asked to describe the injury event; gradual-onset injuries that could not be explained by a single event were categorized as overuse, and all other injuries were categorized as acute. Finally, each reported injury was reviewed and only included in the study if it was considered related to either practice or a match, with players with badminton experience of $<$12 months being excluded from the analysis. In total, 478 players qualified for analysis.

Statistical Analysis

All statistical analysis was performed using SPSS for Windows Version 26.0 (IBM Corp). The incidence rate (IR) was calculated as the number of injuries per 1000 hours of badminton exposure. Age and body mass index were treated as continuous variables and were presented as means with standard deviations. All remaining variables were categorized: sex (female or male), age-group (7-8, 9-10, or 11-12 years), badminton experience (1-2, 2-3, or $>$3 years), racket hand (left or right), training hours per day ($\leq$2 or $>$2 hours), and training days per week ($\leq$3 or $>$3 days). The chi-square test was used for group comparisons of categorical data. Multivariate logistic regression tests were used to examine the association between history of previous ankle injury and subsequent injuries via calculation of the beta coefficient and crude and adjusted Odds Ratio (ORs) with their 95% CIs. For all analyses, a P value $<$.05 was considered statistically significant.

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Final revision submitted February 10, 2022; accepted March 2, 2022.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from the Graduate School of Arts and Sciences at the University of Tokyo (reference No. 602-2).

TABLE 1
Baseline Characteristics of the Study Participants (N = 478)[a]

Variable	Value
Sex	
Male	211 (44.1)
Female	267 (55.9)
Age, y	10.4 ± 1.3
Age-group	
7-8 y	73 (15.3)
9-10 y	199 (41.6)
11-12 y	206 (43.1)
Body mass index	16.0 ± 2.6
Training per day	
≤2 h	161 (33.7)
>2 h	317 (66.3)
Training per week	
≤3 d	96 (20.1)
>3 d	382 (79.9)
Experience	
1-2 y	106 (22.2)
2-3 y	131 (27.4)
>3 y	241 (50.4)
Racket hand	
Left	56 (11.7)
Right	422 (88.3)

[a]Data are reported as n (%) or mean ± SD.

TABLE 2
Injury Profiles for the Ankle, Knee, and Shoulder by Sex and Injury Type

Location	No. of Injuries	Incidence Rate per 1000 h (95% CI)
Ankle		
Overall	71	0.23 (0.18-0.29)
Female/male	46/25	0.26 (0.19-0.34)/0.18 (0.11-0.26)
Acute/overuse	64/7	0.21 (0.16-0.26)/0.022 (0.0059-0.040)
Knee		
Overall	74	0.24 (0.19-0.30)
Female/male	42/32	0.24 (0.17-0.32)/0.24 (0.16-0.32)
Acute/overuse	19/55	0.062 (0.034-0.090)/0.18 (0.13-0.23)
Shoulder		
Overall	48	0.16 (0.11-0.20)
Female/male	32/16	0.18 (0.12-0.25)/0.11 (0.061-0.18)
Acute/overuse	16/32	0.052 (0.027-0.078)/0.11 (0.068-0.14)

RESULTS

The baseline characteristics of the 478 study participants are listed in Table 1, the average sport exposure per player was 639.5 hours per year. Injury profiles are shown in Table 2. Overall, there were 71 ankle injuries, 74 knee injuries, and 48 shoulder injuries during the previous 12 months. The injury IRs (per 1000 hours) by location were 0.23 for the ankle, 0.24 for the knee, and 0.16 for the shoulder. Female players had higher IRs than male players for the ankle (0.26 vs 0.18; $P = .013$) and the shoulder (0.18 vs 0.11; $P = .021$), whereas no difference was found for knee injuries ($P = .245$). Most ankle injuries had an acute onset (64 of 71 [90.1%]; $P < .001$) compared with 19 of 74 (25.7%) knee injuries and 16 of 48 (33.3%) shoulder injuries.

When analyzing the association between history of ankle injury and subsequent injuries, we discovered that 21.1% of players reinjured their ankle, 28.4% of players with previous ankle injury subsequently developed knee injury, and 37.5% of players with previous ankle injury subsequently developed shoulder injury (Table 3). A previous ankle injury tripled a player's reinjury risk (crude OR, 2.83; $P < .05$; adjusted OR, 3.05; $P < .05$), and previous ankle injury was also significantly associated with subsequent knee injury (crude OR, 2.11; $P < .05$; adjusted OR, 2.03; $P < .05$) and subsequent shoulder injury (crude OR, 3.31; $P < .001$; adjusted OR, 2.46; $P < .05$) (Table 3).

DISCUSSION

Injuries in Youth Badminton

The injury incidences per 1000 hours of badminton were 0.23, 0.24, and 0.16 in the ankle, the knee, and the shoulder, respectively. When compared with previous studies in adult players, Jørgensen and Winge[28] reported IRs of 0.23 (ankle), 0.28 (knee), and 0.23 (shoulder) per 1000 hours, and Yung et al[50] reported IRs of 0.26 (ankle), 0.30 (knee), and 0.30 (shoulder) per 1000 hours. Unlike these studies, our study found a lower prevalence of shoulder injuries compared with ankle or knee injuries. The reason for this is likely because most shoulder injuries are due to overuse and thus tend to happen more frequently in older players who generally have more years of exposure.

Of the limited research focusing on sports injuries in players aged <13 years, we discovered 1 study of soccer players with the same age range (7-12 years) and similar definition for injury as used in our study. Based on coaches' reports and telephone interviews, Rössler et al[41] found the IR per 1000 hours to be 0.22 for the ankle, 0.17 for the knee, and 0.025 for the shoulder. The injury incidences were lower compared with those reported in our study, despite soccer being one of the children's sports with the highest injury incidence.[13] The difference can be explained if the sports exposure for each player in the 2 studies is taken into account. In our study, the average exposure for 1 player was 639.5 hours per year, 9.8 times more than the approximately 65.5 hours per year in the study of Rössler et al,[41] implying that Japanese children train more frequently than do soccer players of the same age in the Czech Republic and Switzerland, where that study took place.

We found that 90.1% of the ankle, 25.7% of the knee, and 33.3% of the shoulder injuries were acute injuries. These findings are inconsistent with the findings of a previous study involving adult badminton players, in which acute injuries accounted for 66.7%, 12.0%, and 5.0% of total injuries in the ankle, the knee, and the shoulder, respectively.[28] Regardless, the majority of knee and shoulder injuries were caused by overuse in pediatric players. In recent years, there has been a significant increase in overuse injuries

TABLE 3
Association of Previous Ankle Injury With Subsequent Injuries

		Crude			Adjusted[a]		
	n (%)	β	OR (95% CI)	*P*	β	OR (95% CI)	*P*
Subsequent ankle injury	15 (21.1)	1.04	2.83 (1.48-5.41)	<.05	1.12	3.05 (1.54-6.07)	<.05
Subsequent knee injury	21 (28.4)	0.74	2.11 (1.19-3.73)	<.05	0.71	2.03 (1.12-3.69)	<.05
Subsequent shoulder injury	18 (37.5)	1.20	3.31 (1.74-6.28)	<.001	0.90	2.46 (1.26-4.83)	<.05

[a]Adjusted for sex (female or male), age (7-8, 9-10, or 11-12 years), badminton experience (1-2, 2-3, or >3 years), racket hand (left or right), training hours per day (≤2 or >2 hours), and training days per week (≤3 or >3 days). OR, odds ratio.

in children, primarily attributed to early specialization and intensive training.[16,49] Although many overuse injuries are self-limited, they can increase hospital visits and have the potential to develop into chronic pain. It is estimated that up to 70% of children drop out of organized sports by the age of 13,[7] and it is likely that pain or feeling burnout can contribute to this. Hence, it is important to limit training hours and loads in pediatric players. Major League Baseball and USA Baseball have developed recommended pitch-count limits to prevent injuries[34]; however, such guidelines are lacking for young badminton players.

The study results indicated that girls were 1.6 times ($P = .013$) more prone to injuries in the shoulder and 1.4 times ($P = .021$) more prone to injuries in the ankle; interestingly, no significant sex-based difference ($P = .245$) was found in the knee, in opposition to what was generally agreed, that female players who play sports involving jumping and sidestep cutting maneuvers are at higher risk of knee injury.[26] Tagesson et al[45] suggested that children might demonstrate no differences in knee stabilization capability between sexes, as opposed to adults; thus, the sex discrepancy of knee injury in children is worth further investigation in future studies.

Influence of Ankle Injury History on Subsequent Injuries

Our research demonstrated that previous ankle injury significantly affects subsequent injury among young badminton players. Previous injury is one of the most well-established factors for future injury.[2] A systemic review revealed the percentage of recurrent ankle injury as ranging from 5% to 73%.[2] Among those reinjuries, the average percentage for basketball injuries is 23%,[2] which is comparable to the 21.1% in our study. This similarity is expected as badminton and basketball are both court sports that share many similarities of injuries. The high reoccurrence is in part due to the development of chronic ankle instability (CAI), which occurs in about 30% of individuals after initial acute injury.[48] CAI manifests in 2 ways: mechanical instability, which is a lack of ligament support, and perceived instability, which is the feeling of "giving way" at the ankle joint.[2]

Over the past few decades, many underlying causes for CAI have been reported, including but not limited to proprioceptive and neuromuscular impairment, balance deficits, pathologic laxity, and altered arthrokinematics.[25] An important contributing factor to CAI may be inadequate recovery, as it is estimated that up to >70% of individuals experience prolonged morbidity after an initial ankle injury.[1] With that being said, current standard management, which includes protection, RICE (rest, ice, compression, and elevation), analgesics, and progressive weightbearing,[8] does not seem to be effective enough. An exercise-based rehabilitation program, ankle-stabilizing device, and manipulative therapy have been shown to be successful in lowering the risk of recurrent ankle injuries[5,17,42] and should be considered for incorporation into the injury prevention protocol on top of the standard management.

Previous ankle injury also increases the risk of subsequent knee injury. As previously discussed, an ankle injury has a high chance of turning into prolonged pathophysiological change in the ankle. This can cause altered biomechanics at the knee joint as these 2 joints work collectively during the kinetic chain activation.[38] For example, altered arthrokinematics of the talocrural joint is associated with limited ankle dorsiflexion,[18] and restricted dorsiflexion in the ankle reportedly lowers the knee flexion and increases the ground-reaction force, making the landing "stiff," which leads to a higher risk of injury in the knee.[21] Furthermore, the hip joint may be also involved in the knee injury mechanisms after an ankle injury. Biomechanics studies of Bullock-Saxton et al[10,11] reported reduced function of the gluteus maximus muscle in people with ankle injury history via electromyographic analysis. The gluteus maximus is part of the hip muscles and plays an important role in dynamic joint stabilization; decreased gluteus maximus activation can increase load-bearing at the knee when players land.[27]

Finally, our results indicated a significant influence of ankle injury history on shoulder injury. This is consistent with the finding of a recent Japanese study in which the authors demonstrated a link between limited ankle dorsiflexion and shoulder injury in baseball players.[43] While our research did not explore the biomechanical mechanism of why ankle injury increased subsequent shoulder injury risks, previous studies have shed some light on possible explanations: in an overhead-throwing motion, the kinetic chain works in a sequential motion,[19] in which the majority of the energy is generated from the lower extremity and the core and then transferred to the shoulder.[40] An ankle pathology can lead to "breakage" of the link, causing energy-bearing at the shoulder to increase as a way to compensate for the deficits while maintaining performance. It has been suggested that ankle sprain history was common in history-taking when examining tennis players with shoulder problems, and the authors recommended performing stability tests in the lower extremity during physical examinations of these patients.[31]

Limitations

There were some limitations to this study. It was a retrospective data analysis in which players were asked to recall injury history and thus was more prone to recall bias. The study was conducted in 3 randomly selected locations where players may demonstrate geographical bias and not best represent the national average. This study could not deduce any injury IRs for practice and matches specifically because only the average training hours were asked. Additionally, the total exposure was calculated based on the average training hours per session and the average number of training sessions per week a player reported, whereas in reality a player might be absent from training from time to time in situations such as a conflict with schoolwork or an injury. Training intensity, which is another factor that can affect injury incidence, was also missing in this research. Finally, the severity of injuries, which could help us better understand the injury characteristics in young badminton players, was not investigated in this research.

CONCLUSION

Our results identified that competitive young badminton players sustain injuries at an incidence of 0.23, 0.24, and 0.16 per 1000 hours in the ankle, in the knee, and in the shoulder, respectively, higher than soccer players of the same age. Also, ankle injury history was significantly associated with subsequent injuries in the aforementioned 3 locations. Ankle injury has the highest occurrence in pediatric sports; therefore, more emphasis should be placed on rehabilitation and return-to-sports assessment after an ankle injury in the aim of minimizing future injuries.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Japan School Children Badminton Federation for collaborating on data collection.

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