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Epidemiological characteristics of injury in 7–22-year-old badminton players by age and sex

Xiao Zhou[1,2], Kazuhiro Imai[2]✉, Xiao-Xuan Liu[2,3], Zhuo Chen[2], Eiji Watanabe[4] & Hongtao Zeng[1]

Badminton-related injury is thought to happen with increasing incidence among badminton players. Literature shown injury incidence across age is scarce. The objective was to investigate the epidemiological characteristics of badminton-related injuries among badminton players broken down by age and sex. This epidemiology study is a retrospective design in 7–22-year-old badminton players at a national competitive tournament with a questionnaire from 2018 to 2023. An injury was defined as somatic complaint with time loss and/or medical care. Badminton-related injuries were normalized to rate per 1000 training-hours calculated by Poisson distribution in the collected data according to age and gender. Among all the 711 badminton players, 60.3% (429 players) suffered from at least one badminton-related injury. Regardless of gender, the most frequently injured anatomical site was knee (male: 18.8%, female: 18.6%), followed by ankle (male: 13.4%, female: 13.4%) and lower back (male: 12.3%, female: 10.0%). In male badminton players, the shoulder (7.6%) ranked fourth as the plantar (6.7%) ranked fourth in female badminton players. The rate per 1000 training-hours of badminton-related injuries showed that male players peaked at age 15–16 years and female players peaked at age 17–18 years, with 3.24 injuries and 3.52 injuries per 1000 training-hours, respectively. In 7–22-year-old badminton players, knee, lower back, and shoulder injuries frequently occurred and were significantly associated with the incidence of badminton-related injuries. The peak incidence of badminton-related injuries was in 15–16-year-old male badminton players while the peak incidence was in 17–18-year-old female badminton players. These data have the potential to help target the most at-risk anatomical sites and the most at-risk badminton players precisely for injury prevention programs.

Keywords Athletic injuries, Racquet sports, Injury incidence, Youth players

According to the Nippon Badminton Association, there were 287,676 school–aged players aged 7–22 years playing badminton competitively in Japan in 2023[1]. Many Japanese badminton players sustain injury[2]. Injury related to badminton was estimated a 22% increase in badminton participants from 2006 to 2016[3]. About 54.8%–88.2% of badminton players experience at least one injury related to badminton[4–8]. The number of injury rate per 1000 player-hours of exposure varies from 0.9 to 5.1 injuries[2,4,6,7,9]. In terms of anatomical sites, lower limb injuries are the most common, accounting for 44.4%-82.9%. Moreover, injury related to badminton frequently occurs in lower back and upper limbs[10,11]. Some types of lower limb injuries such as Achilles tendon and anterior cruciate ligament (ACL) rupture are severe that lead to time loss of badminton participation[12–15]. For example, accounting for 37% of ACL injuries required surgically treatment, which results in severe time loss of badminton participation. The loss of badminton participation can negatively affect badminton performance, the badminton player's health later in the sports life, and, ultimately, the badminton player's long-term development.

Observational evidence has reported badminton players younger than 20 years showed the highest injury incidence[2,6,16]. However, badminton players under 20 years were grouped together, and the size of the participants was small. In addition, injury definition of the previous study is inconsistent. Although studies on badminton injury started from decades ago[4–7,10,11], there is still much that we do not know about differences in badminton injuries among school-aged children, adolescents, and adults broken down by age and sex using a consistent injury definition.

[1]School of Physical Education, Huazhong University of Science and Technology, Wuhan 430074, China. [2]Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo, 3-8-1, Komaba, Meguro-ku, Tokyo 153-8902, Japan. [3]Department of Radiology, Vancouver General Hospital, Vancouver, BC, Canada. [4]Institute of Sport, Senshu University, Kawasaki, Kanagawa 2148580, Japan. ✉email: imai@idaten.c.u-tokyo.ac.jp

Young badminton players are predisposed to badminton-related injuries that may have long-term sequelae both emotionally and physically. A thorough understanding of specific injury incidence is the first step to enhance badminton injury preventive program[17]. Therefore, the objective of this study was to investigate the epidemiological characteristics of badminton-related injuries among Japanese national competitive level badminton players aged 7–22 years broken down by age and sex.

Based on previous study which reported that injury increased with age, and peak injury incidence was noted during high school years[18], we hypothesized that there would be an increase with age in the badminton-related injury incidence in badminton players ≤ 22 years of age, and the peak incidence of badminton injury would be noted in 17–18-year-old badminton players with female badminton players showing a higher rate of increase compared with male badminton players.

Methods

Collaborated with the Japan Schoolchildren Badminton Federation, Nippon Junior High School Physical Culture Association Badminton Promotion Dept, Japan Intercollegiate Badminton Federation, Senshu University, and Waseda University, 810 badminton players at age 7 to 22 years at a national competitive level were recruited. A retrospective designed study was performed to survey 7–12-year-old badminton players attending the national badminton tournament games at 3 randomly selected locations between May and September 2019, 13–17-year-old badminton players attending the national badminton tournament games at 10 randomly selected locations between December 2022 and July 2023, and 18–22-year-old badminton players participating in the national tournaments of two universities from August 2018 to March 2019. A custom-designed questionnaire was given to players presenting at the badminton venue during the period of the competition. Pre-tournament a custom-designed "self-reported" questionnaire modified from past literature[19] was used to investigate baseline parameters and badminton-related injury of all the participants. Baseline parameters comprised of gender, age, racket side, years of badminton playing experience, hours of badminton training per day, days dedicated to badminton training per week, and warm-up and cool down practices. The time spent on physical or badminton motor skill training under the supervision of the coach were defined as badminton training hours. The time spent on the warm-up and cool-down practices was not taken into account as training-exposure time. With respect to injury survey, badminton-related injuries over the past year were specifically asked regarding 25 anatomical sites shown in a body image (consisting of head, face, neck, chest, abdomen, groin, back, lower back, hip, shoulder, scapular, upper arm, elbow, forearm, wrist, finger, quadriceps, hamstring, knee, shin, calf, Achilles tendon, ankle, toe, and plantar). Along with their guardians, minor participants completed the questionnaire.

Injury definition

To keep consistent in definitions and allow data across other research to be compared, the judgment criteria of this study for badminton-related injury were established which were in accordance with the International Olympic Committee[19,20]. An injury was defined as any somatic complaint that resulted in one or more of the following three situations: (1) unable to continue the current badminton match or training session; (2) unable to attend from the next match or training session; and/or (3) the requirement for medical care regardless of the likelihood of absenting from a match or training session. Participants were selected as follows: (1) playing badminton at a national level competition; (2) training weekly regularly; (3) participants that had completed a questionnaire and an informed consent form. Exclusion criteria were as follows: (1) years of badminton playing experience less than 1 year; (2) the questionnaire had not been completed; (3) age is not in the range of 7–22 years. The screening flow is shown in Fig. 1. According to the inclusion and exclusion criteria, 711 elite badminton players included 394 females, 317 males were involved in this study. All the participants were categorized into subgroups for data analysis according to age and sex as shown in Fig. 1.

The protocol of this research was reviewed and approved by the Graduate School of Arts and Sciences, the University of Tokyo, Japan (Notification Number 602–2 26 July 2018). This approval was obtained in compliance with the Declaration of Helsinki statement. Written informed consent forms from all the participants and guardians of the minors have been obtained.

Equity, diversity and inclusion

Our study included children, adolescents, and adults inclusive of both male and female badminton players from different socioeconomic levels. The author group comprised of two women and four men, a mix of early, middle and late career researchers from the disciplines of sports science, and sports medicine and medicine. Four authors were Chinese, and two Japanese.

Statistical analysis

We used the Shapiro–Wilk test to analyze the normality of basic parameters. All the data of age, years of badminton playing experiences, hours of badminton training per day, days dedicated to badminton training per week, badminton training hours per week, and yearly badminton training hours over the past year, presented non-normal distribution. Non-parameter statistical analysis of the eight groups was analysed by Kruskal–Wallis ANOVA. The injury rate per 1000 training-hours of exposure was calculated by Poisson distribution for comparing the injury incidences among the eight groups. The 95% confidence interval (CI) of the injury rate per 1000 training-hours of exposure was also calculated.

All the male and female players were divided into eight groups broken down by age, that is 7–8-year-old group, 9–10-year-old group, 11–12-year-old group, 13–14-year-old group, 15–16-year-old group, 17–18-year-old group, 19–20-year-old group, and 21–22-year-old group.

For further data analysis, logistic regression models were used to examine the association between the occurrence of badminton-related injuries and injuries to the anatomical sites. Model 1 adjusted variables included

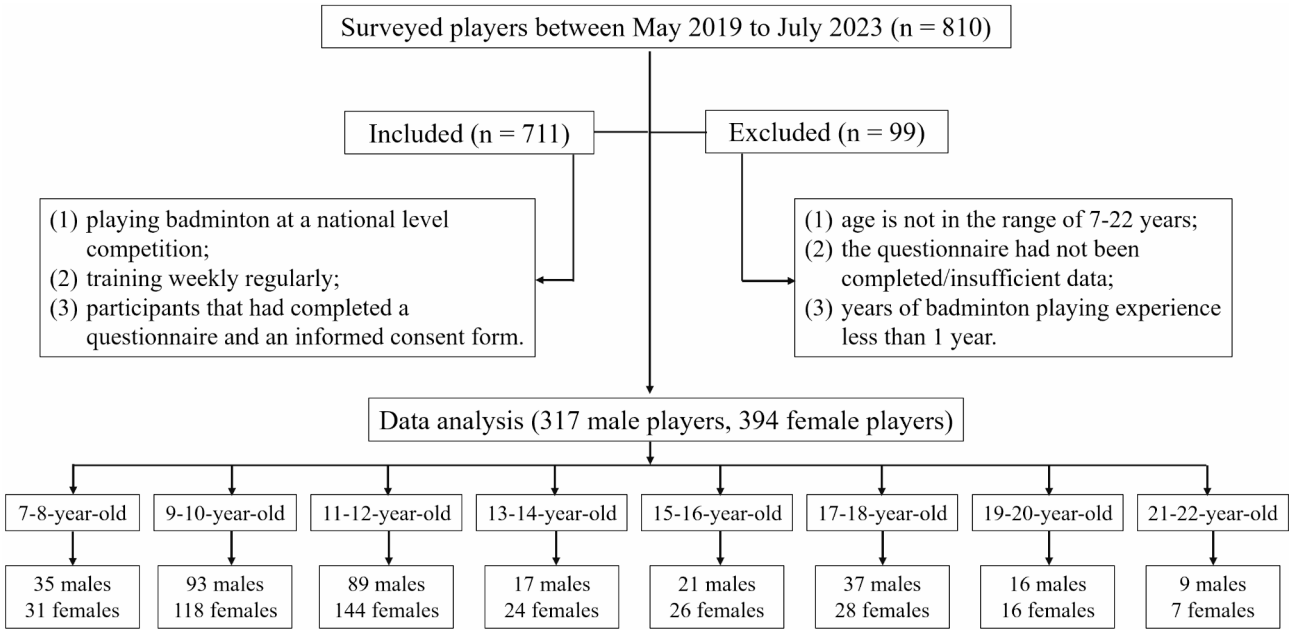

Fig. 1. Screening flow.

Variable	7/8 yrs (n = 35)	9/10 yrs (n = 93)	11/12 yrs (n = 89)	13/14 yrs (n = 17)	15/16 yrs (n = 21)	17/18 yrs (n = 37)	19/20 yrs (n = 16)	21/22 yrs (n = 9)
Age	7.60 ± 0.50*	9.61 ± 0.49*	11.19 ± 0.40*	14.31 ± 0.35*	15.83 ± 0.67*	17.90 ± 0.49*	19.49 ± 0.48*	21.11 ± 0.33*
Years, experience	2.17 ± 0.98*	2.84 ± 1.27*	3.24 ± 1.44*	7.96 ± 1.22*	8.88 ± 2.27*	10.71 ± 2.56*	11.11 ± 2.75*	10.89 ± 3.59*
Hours, training	2.81 ± 1.23*	2.83 ± 0.79*	2.73 ± 0.91*	2.71 ± 0.59*	3.12 ± 0.68*	3.89 ± 0.70*	3.39 ± 0.52*	3.07 ± 0.15*
Training times, weekly	4.33 ± 1.26*	4.42 ± 1.24*	4.74 ± 1.10*	6.47 ± 0.62*	6.57 ± 0.51*	6.43 ± 0.73*	5.25 ± 0.86*	5.44 ± 0.68*
Total hours, weekly	11.84 ± 4.61*	12.48 ± 4.98*	13.11 ± 5.81*	17.65 ± 4.72*	20.56 ± 5.06*	25.05 ± 5.53*	17.86 ± 4.40*	16.70 ± 1.90*
Total hours, year	473.71 ± 184.25*	499.14 ± 199.06*	524.49 ± 232.28*	705.88 ± 188.65*	822.54 ± 202.28*	1002.16 ± 221.34*	714.58 ± 176.10*	668.15 ± 76.07*

Table 1. Basic parameters of male badminton players broken down by age. Values are mean ± standard deviation. *P value < 0.001 among the eight age groups in male players.

Variable	7/8 yrs (n = 31)	9/10 yrs (n = 118)	11/12 yrs (n = 144)	13/14 yrs (n = 24)	15/16 yrs (n = 26)	17/18 yrs (n = 28)	19/20 yrs (n = 16)	21/22 yrs (n = 7)
Age	7.87 ± 0.34*	9.56 ± 0.50*	11.15 ± 0.35*	14.11 ± 0.45*	15.94 ± 0.60*	17.95 ± 0.46*	19.41 ± 0.49*	21.29 ± 0.49*
Years, experience	2.06 ± 0.84*	2.67 ± 1.16*	3.30 ± 1.35*	7.03 ± 1.30*	8.48 ± 1.91*	10.88 ± 2.20*	11.35 ± 1.60*	13.57 ± 1.62*
Hours, training	2.45 ± 0.72*	2.78 ± 0.77*	2.72 ± 0.83*	3.38 ± 0.67*	3.15 ± 0.59*	3.54 ± 0.51*	3.28 ± 0.52*	3.36 ± 0.63*
Training times, weekly	4.77 ± 1.40*	4.44 ± 1.27*	4.58 ± 1.21*	6.29 ± 0.69*	7.08 ± 3.97*	6.18 ± 0.86*	5.50 ± 0.82*	5.43 ± 0.53*
Total hours, weekly	11.85 ± 5.01*	12.33 ± 4.78*	12.63 ± 5.78*	21.45 ± 5.56*	22.47 ± 12.60*	21.79 ± 4.01*	18.00 ± 3.71*	18.00 ± 2.24*
Total hours, year	473.87 ± 200.41*	493.22 ± 191.09*	505.35 ± 231.29*	858.06 ± 222.37*	898.72 ± 504.08*	871.67 ± 160.58*	720.00 ± 148.13*	720.00 ± 89.44*

Table 2. Basic parameters of female badminton players broken down by age. Values are mean ± standard deviation. *P value < 0.001 among the eight age groups in female players.

gender and age; Model 2 adjusted variables included gender, age, years of badminton playing experiences, hours of badminton training per day, days dedicated to badminton training per week, badminton training hours per week, and yearly badminton training hours over the past year. A *p*-vale less than 0.05 was considered statistically significant.

Results

The mean age of the 711 participants was 12.08 years, with a standard deviation of 3.57 years. Tables 1 and 2 show the basic parameters of male and female players broken down by age. In male players, there were significant differences in age ($p < 0.001$), years of badminton playing experiences ($p < 0.001$), daily training hours ($p < 0.001$), weekly training days ($p < 0.001$), weekly training hours ($p < 0.001$), and yearly training hours ($p < 0.001$) among the eight groups of male players. As male players, there were significant differences in age ($p < 0.001$), years of

badminton playing experiences ($p < 0.001$), daily training hours ($p < 0.001$), weekly training days ($p < 0.001$), weekly training hours ($p < 0.001$), and yearly training hours ($p < 0.001$) among the eight groups in female players. Among all the 711 badminton players, 60.3% (429 players) suffered from at least one badminton-related injury.

Distribution of badminton-related injury

All the injury incidences in the head, face, scapular, chest, and forearm constituted less than 1% of the total; therefore, we grouped these five sites together in the category "others". The distribution of injuries related to badminton in anatomical sites is shown in Fig. 2. Totally, the most common badminton-related injury localized in the knee, accounting for 18.7% of all the surveyed injuries, the ankle ranked the second (13.4%), followed by lower back (10.9%), shoulder (6.5%), and plantar (6.1%). Regardless of sex, the most common injury related to badminton localized in the knee (male: 18.8%, female: 18.6%), followed by ankle (male: 13.4%, female: 13.4%) and lower back (male: 12.3%, female: 10.0%). In the male players, the shoulder ranked fourth (7.6%) while plantar ranked fourth (6.7%) in the female players.

Due to the limited sample sizes of 19–20-year-old and 21–22-year-old groups, we combined them together for the injury incidence analysis. Table 3 shows the injury incidences of the anatomical regions in male players broken down by age. The knee was the most common injured anatomical site in the 7–8-year-old group, the 9–10-year-old group, the 11–12-year-old group, and the 15–16-year-old group while the most common injured anatomical site in the 17–18-year-old group and 19–22-year-old group was the lower back. In the 13–14-year-old group, the most common injured site was the ankle.

The injury incidences of the anatomical regions in female players broken down by age are shown in Table 4. The knee was the most common injured anatomical site in the 7–8-year-old group, the 9–10-year-old group, the 11–12-year-old group, the 13–14-year-old, and the 15–16-year-old group while the lower back was the most common injured anatomical site in the 17–18-year-old group. In 19–22-year-old group, the knee and the ankle showed the same injury incidences, ranking the first.

Injury rate per 1000 training-hours of badminton-related injury

The injury rate per 1000 training-hours of badminton-related injury by age overall is shown in Fig. 3. Totally, in badminton players at age 7 to 22 years, the incidence rate of injury related to badminton tended to increase with age, and the peak injury incidence occurred at age 17–18 years with an incidence of 2.91 injuries (95% CI: 2.48–3.34) per 1000 training-hours. The incidence of injury related to badminton showed an upward trend with increasing age in male players as well as in female players. Male players peaked at age 15–16 years with an incidence of 3.24 injuries (95% CI: 2.39–4.09) per 1000 training-hours while female players peaked at age 17–18 years with an incidence of 3.52 injuries (95% CI: 2.78–4.26) per 1000 training-hours.

The injury rate per 1000 training-hours of badminton-related injury by anatomical site overall is shown in Fig. 4. Regardless of sex, knee injury showed the highest injury rate per 1000 training-hours (male: 0.37, 95% CI = 0.29–0.46; female: 0.46, 95% CI = 0.37–0.55; total: 0.42, 95% CI = 0.36–0.48), followed by ankle (male: 0.26,

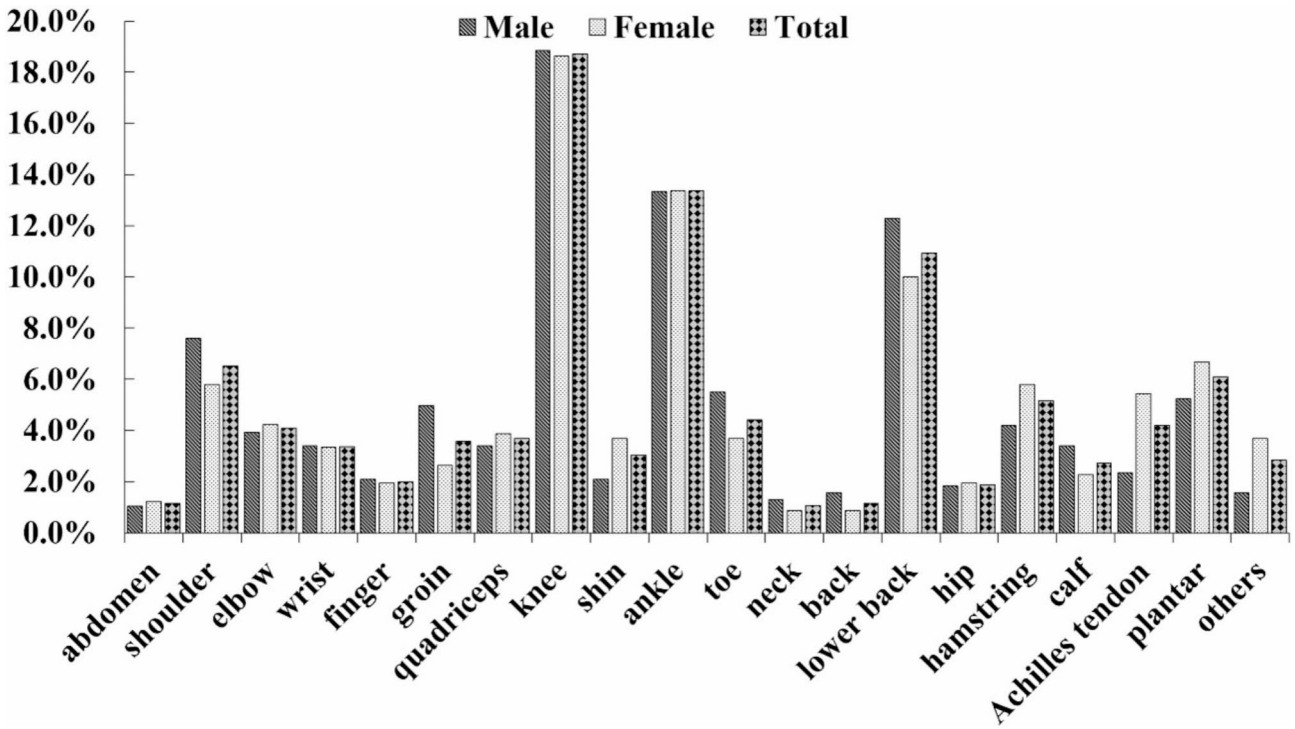

Fig. 2. Injury incidence of anatomical sites in badminton players.

Body site	7/8 yrs (n = 35)	9/10 yrs (n = 93)	11/12 yrs (n = 89)	13/14 yrs (n = 17)	15/16 yrs (n = 21)	17/18 yrs (n = 37)	19/22 yrs (n = 25)
Abdomen	0 (%)	0 (%)	1 (0.9%)	2 (5.1%)	0 (0.0%)	0 (0.0%)	1 (2.5%)
Shoulder	1 (10.0%)	2 (3.1%)	7 (6.1%)	2 (5.1%)	7 (13.5%)	10 (10.8%)	3 (7.5%)
Elbow	0 (%)	3 (4.6%)	5 (4.3%)	1 (2.6%)	2 (3.8%)	5 (5.4%)	1 (2.5%)
Wrist	0 (%)	3 (4.6%)	2 (1.7%)	0 (0.0%)	2 (3.8%)	5 (5.4%)	2 (5.0%)
Finger	0 (%)	2 (3.1%)	3 (2.6%)	3 (7.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Groin	0 (%)	2 (3.1%)	5 (4.3%)	2 (5.1%)	4 (7.7%)	3 (3.2%)	3 (7.5%)
Quadriceps	0 (%)	4 (6.2%)	3 (2.6%)	2 (5.1%)	1 (1.9%)	3 (3.2%)	0 (0.0%)
Knee	4 (40.0%)	17 (26.2%)	19 (16.5%)	3 (7.7%)	10 (19.2%)	18 (19.4%)	7 (17.5%)
Shin	0 (%)	2 (3.1%)	2 (1.7%)	0 (0.0%)	1 (1.9%)	3 (3.2%)	1 (2.5%)
Ankle	3 (30.0%)	10 (15.4%)	17 (14.8%)	6 (15.4%)	4 (7.7%)	9 (9.7%)	5 (12.5%)
Toe	1 (10.0%)	4 (6.2%)	6 (5.2%)	3 (7.7%)	5 (9.6%)	2 (2.2%)	3 (7.5%)
Neck	0 (%)	0 (0.0%)	2 (1.7%)	2 (5.1%)	0 (0.0%)	1 (1.1%)	0 (0.0%)
Back	0 (%)	1 (1.5%)	1 (0.9%)	1 (2.6%)	0 (0.0%)	3 (3.2%)	0 (0.0%)
Lower back	0 (%)	4 (6.2%)	12 (10.4%)	4 (10.3%)	9 (17.2%)	19 (20.4%)	9 (22.5%)
Hip	0 (%)	1 (1.5%)	1 (0.9%)	1 (2.6%)	2 (3.8%)	2 (2.2%)	1 (2.5%)
Hamstring	0 (%)	0 (%)	9 (7.8%)	1 (2.6%)	1 (1.9%)	4 (4.3%)	3 (7.5%)
Calf	0 (%)	3 (4.6%)	3 (2.6%)	1 (2.6%)	2 (3.8%)	4 (4.3%)	0 (0.0%)
Achilles tendon	1 (10.0%)	1 (1.5%)	3 (2.6%)	2 (5.1%)	0 (0.0%)	1 (1.1%)	1 (2.5%)
Plantar	0 (%)	6 (9.2%)	11 (9.6%)	1 (2.6%)	2 (2.6%)	0 (0.0%)	0 (0.0%)
Others	0 (%)	0 (%)	3 (2.6%)	2 (5.1%)	0 (0.0%)	1 (1.1%)	0 (0.0%)

Table 3. Distribution of injury related to badminton in male badminton players broken down by age.

Body site	7/8 yrs (n = 31)	9/10 yrs (n = 118)	11/12 yrs (n = 144)	13/14 yrs (n = 24)	15/16 yrs (n = 26)	17/18 yrs (n = 28)	19/22 yrs (n = 23)
Abdomen	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (4.0%)	0 (0.0%)	3 (3.5%)	2 (4.5%)
Shoulder	2 (9.5%)	3 (3.1%)	11 (6.0%)	2 (4.0%)	3 (5.4%)	5 (5.8%)	4 (9.1%)
Elbow	0 (0.0%)	6 (6.2%)	7 (3.8%)	0 (0.0%)	2 (3.6%)	6 (7.0%)	2 (4.5%)
Wrist	1 (4.8%)	2 (2.1%)	9 (4.9%)	0 (0.0%)	1 (1.8%)	3 (3.5%)	2 (4.5%)
Finger	1 (4.8%)	3 (3.1%)	3 (1.6%)	2 (4.0%)	1 (1.8%)	0 (0.0%)	1 (2.3%)
Groin	0 (0.0%)	2 (2.1%)	6 (3.3%)	1 (2.0%)	1 (1.8%)	5 (5.8%)	0 (0.0%)
Quadriceps	1 (4.8%)	4 (4.1%)	4 (2.2%)	4 (8.0%)	3 (5.4%)	5 (5.8%)	1 (2.3%)
Knee	4 (19.0%)	27 (27.8%)	32 (17.5%)	8 (16.0%)	12 (21.4%)	8 (9.3%)	9 (20.5%)
Shin	1 (4.8%)	1 (1.0%)	4 (2.2%)	3 (6.0%)	1 (1.8%)	8 (9.3%)	2 (4.5%)
Ankle	2 (9.5%)	13 (13.4%)	30 (16.4%)	5 (10.0%)	6 (10.7%)	7 (8.1%)	9 (20.5%)
Toe	0 (0.0%)	6 (6.2%)	6 (3.3%)	2 (4.0%)	1 (1.8%)	2 (2.3%)	0 (0.0%)
Neck	0 (0.0%)	1 (1.0%)	3 (1.6%)	1 (2.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Back	0 (0.0%)	0 (0.0%)	2 (1.1%)	0 (0.0%)	1 (1.8%)	2 (2.3%)	0 (0.0%)
Lower back	3 (14.3%)	4 (4.1%)	9 (4.9%)	5 (10.0%)	12 (21.4%)	11 (12.8%)	3 (6.8%)
Hip	1 (4.8%)	1 (1.0%)	2 (1.1%)	2 (4.0%)	1 (1.8%)	3 (3.5%)	0 (0.0%)
Hamstring	0 (0.0%)	2 (2.1%)	11 (6.0%)	4 (8.0%)	4 (7.1%)	5 (5.8%)	5 (11.4%)
Calf	1 (4.8%)	2 (2.1%)	4 (2.2%)	2 (4.0%)	0 (0.0%)	3 (3.5%)	1 (2.3%)
Achilles tendon	2 (9.5%)	8 (8.2%)	15 (8.2%)	3 (6.0%)	1 (1.8%)	1 (1.2%)	1 (2.3%)
Plantar	2 (9.5%)	9 (9.3%)	20 (10.9%)	2 (4.0%)	3 (5.4%)	2 (2.3%)	0 (0.0%)
Others	0 (0.0%)	3 (3.1%)	5 (2.7%)	2 (4.0%)	3 (5.4%)	7 (8.1%)	2 (4.5%)

Table 4. Distribution of injury related to badminton in female badminton players broken down by age.

95% CI = 0.19–0.34; female: 0.33, 95% CI = 0.26–0.40; total: 0.30, 95% CI = 0.25–0.35), and lower back (male: 0.24, 95% CI = 0.17–0.31; female: 0.25, 95% CI = 0.18–0.31; total: 0.25, 95% CI = 0.21–0.29).

Anatomical sites and occurrence of badminton-related injuries

The most common injury sites, including the knee joint in the lower limbs, the lower back in the trunk, and the shoulder joint in the upper limbs, were selected for further statistical analysis. The results of the logistic regression analysis in Table 5 showed the higher risk of the knee injury (odds ratio (OR) = 2.11, $p < 0.001$), the lower back injury (OR = 2.26, $p < 0.001$), and the shoulder (OR = 1.82, $p < 0.001$) was significantly correlated with the total injury cases after adjusting multiple factors.

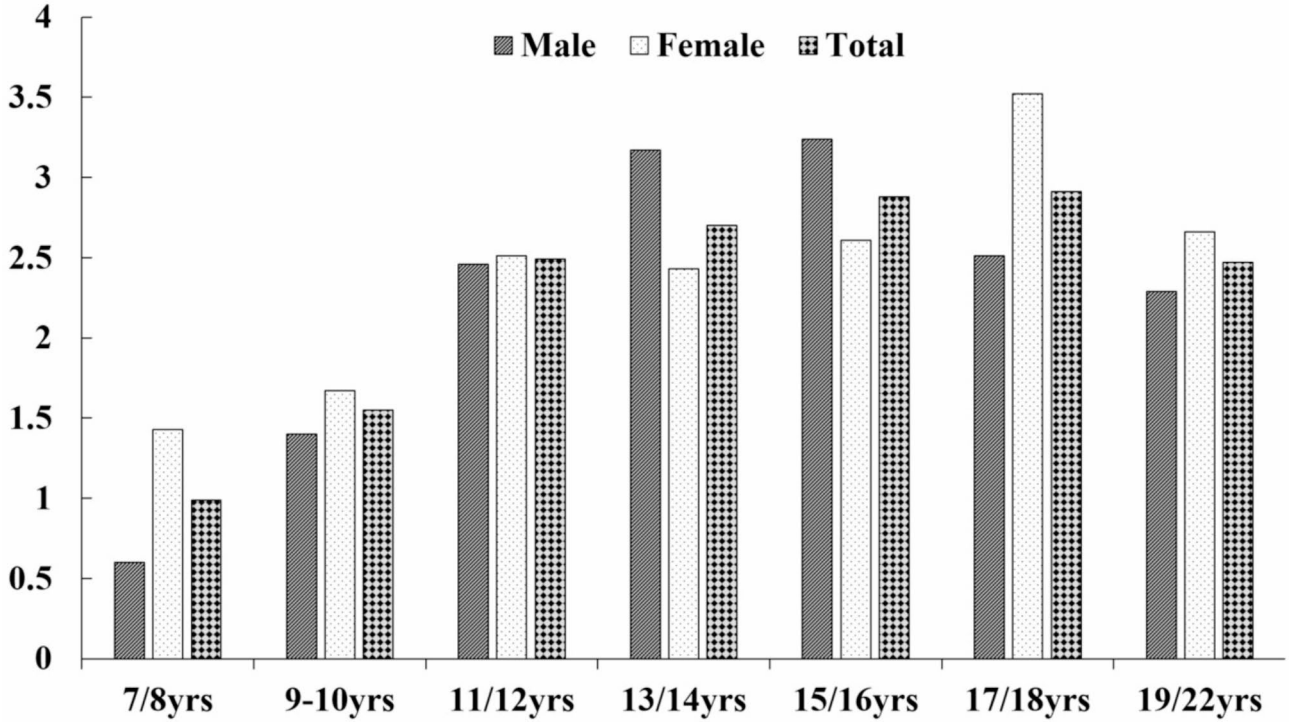

Fig. 3. Injury rate per 1000 training hours in badminton players.

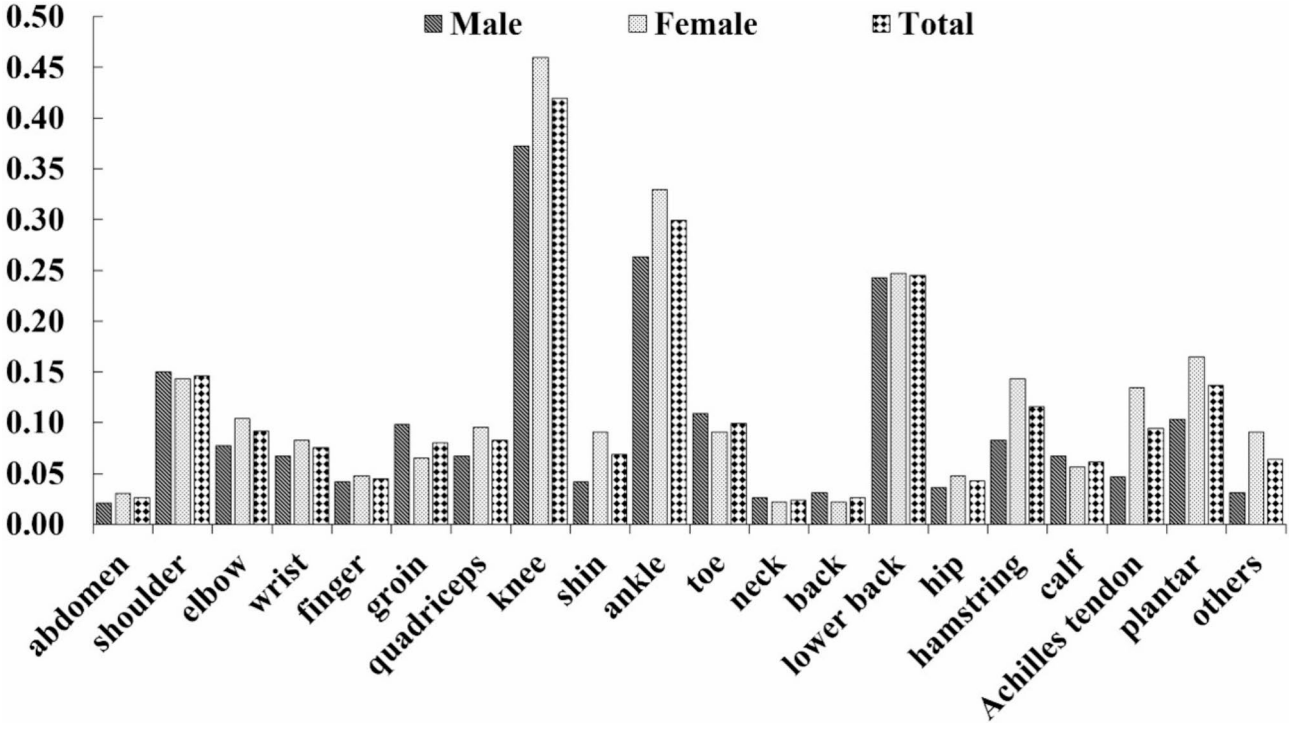

Fig. 4. Injury rate per 1000 training hours of anatomical sites in badminton players.

Discussion

In this study, we aimed to identify the epidemiological characteristics of injury related to badminton in elite badminton players at age 7–22 years participating in the national tournament. Some vital, novel, and interesting findings were found as follows: (1) the peak incidence of injury related to badminton occurred at age 15–16 years

Characteristic	Crude			Model 1			Model 2		
	OR	95%CI	*p*	OR	95%CI	*p*	OR	95%CI	*p*
Knee-Total injury	2.09	1.83–2.40	**< 0.001**	2.16	1.87–2.49	**< 0.001**	2.11	1.82–2.44	**< 0.001**
Lower back-Total injury	2.28	1.95–2.67	**< 0.001**	2.21	1.89–2.59	**< 0.001**	2.26	1.89–2.71	**< 0.001**
Shoulder-Total injury	1.86	1.62–2.15	**< 0.001**	1.82	1.58–2.11	**< 0.001**	1.82	1.56–2.12	**< 0.001**

Table 5. Logistic regression analyses of the association of the occurrence of badminton-related injuries and injuries to the knee, lower back, and shoulder. Crude was the unadjusted model; Model 1 adjusted for gender (male, female) and age (continuous variable); Model 2 include Model 1 plus years of badminton playing experiences (continuous variable), hours of badminton training per day (continuous variable), days dedicated to badminton training per week (continuous variable), badminton training hours per week (continuous variable), and yearly badminton training hours over the past year (continuous variable). OR: odds ratio; CI: confidence interval. Significant values are in [bold].

in male badminton players while the peak incidence of injury related to badminton occurred at age 17–18 years in female badminton players; (2) regardless of sex, knee injury, lower back injury, and shoulder injury were frequent, which was significantly associated with the badminton-related injury occurrence.

Peak injury incidence in badminton players

The early, timely, and precise prevention of badminton-related injury among school-aged badminton players is necessary to lower and avoid the further injury occurrence. Epidemiological surveillance is the first step to enhance sports injury prevention[17]. Recent longitudinal studies of badminton injury among 133 Japanese badminton players reported that regardless of sex, university players showed the highest injury rate (male, 2.5; female, 5.1) per 1000-training hours, followed by high school players and junior high school players during badminton training[2]. A previous study of Hong Kong elite badminton players reported that during the badminton training, the highest injury rate occurred in elite junior aged 16–21 years (2.83 injuries per 1000 training-hours), followed by elite senior aged 21–28 (2.56 injuries per 1000 training-hours)[9]. Additionally, a previous study of acute injuries in badminton from 10 to 66 years of age reported that the data of an emergency department showed the most frequently injured in patients aged 10–18 years[15]. Regarding injury related to sports in other sports, previous studies on football reported that 16-year-old players had the highest injury incidence among male youth elite football players aged 9–19 years[21]. Previous studies on elite junior and professional tennis players reported adolescent players (13–17-year-old) and adult players (≥ 18-year-old) had significantly higher injury proportions than child players, and the injury proportion of the adult players (59%) was slight high compared with the adolescent players (57%). However, more specific injury proportions broken down by age and sex are unknown[22]. In the current study, the injury incidence was identified accurately by age and sex that 15–16-year-old male players presented the highest injury rate per 1000 training hours among all the male players while 17–18-year-old female players presented the highest injury rate per 1000 training hours among all the female players which is similar to the literature that higher injury rates occur in youth sports players aged 14–17 years[23].

Motor abilities and recognition are essential to understand the fundamental components of the motor skill movement pattern and appropriately coordinate trunk with the limbs for learners[24]. Moreover, people whose biological changes increased the likelihood of leading to injuries[24]. In this study, most of the badminton players were children and youth whose physical fitness (such as neuro fitness, bone, and muscle) was still developing, which means they might have been not only incapable of responding to the intensive physical demands of repetitive weight transfer through pivoting, turning, and landing but also incapable of understanding the coaches' commands. Plus, vigorous training can cause fatigue, which increases the likelihood of injury in badminton playing in turn[25]. These findings could explain why an increasing injury incidence and the peak injury incidence occurred among badminton players at age 7 to 18 years in this study.

Identifying differences between each age group

In terms of anatomical regions, the knee was the most common injured site, followed by the ankle and the lower back among all the players in this study which is in consistent with several previous studies[6,17,26]. In contrast, some previous studies reported spine/lower back was the most common injured site, knee ranked the second followed by thigh, ankle, and shoulder[27] while other previous studies reported shoulder was the most common injured site, followed by knee, thigh, back, and ankle in elite players[9]. The above-mentioned discrepancies are likely caused by differences in data collection methods, injury definition, and sample size, however, the data of the previous studies and this study verified that badminton-related injury frequently occurred in knee, ankle, lower back, and shoulder. Additionally, these findings also support the results of other sports studies that knee injuries and ankle injuries frequently occurred in sports players aged 11–21 years[23,28].

Moreover, the characteristics of injury related to badminton of anatomical regions were identified broken down by age and sex in this study. In male players, the 7–8-year-old, 9–10-year-old, 11–12-year-old, and 15–16-year-old presented the highest injury incidence of knee. The 13–14-year-old players presented the highest injury incidence of ankle. And the 17–18-year-old and 19–22-year-old players presented the highest injury incidence of lower back. In female players, the 7–8-year-old, 9–10-year-old, 11–12-year-old, and 13–14-year-old players presented the highest injury incidence of knee. In the 15–16-year-old players, the highest injured regions

were knee and lower back, accounting for 21.4% respectively. The 17–18-year-old players presented the highest injury incidence of lower back, and the 19–22-year-old players presented the highest injury incidence of knee (20.5%) and ankle (20.5%).

Badminton is a kind of overhead motion sports where necessitates rapid changes and dynamic movements frequently occur. During badminton playing, players require to start and break instantly to shift body core mass in response to hitting a shuttlecock from a various of directions using a racket. To do so, players need to frequently perform lunges, jumps, plant-and-cut, and body joint movements (such as knee extension, trunk rotation, and shoulder rotation)[10,29]. These dynamic movements place high demands on all the body joints. For hitting a shuttlecock with forehand overhead stroke motion, several simultaneous events occur including trunk rotation and body core mass shifting[30]. Trunk is a main segment of the overhead motion kinetic chain in transferring energy from lower limbs to upper limbs. More than 50% of total energy is contributed by trunk while shoulder does 13% of the work[31,32]. Meanwhile, to transfer body core mass, knee requires to frequently perform a large movement which is likely to produce more load to the lower limbs. In addition, we also found a significant association between the occurrence of badminton-related injuries and injuries to the knee, lower back, and shoulder. These findings suggest that the occurrence of injury related to badminton occurred in most body anatomical regions, particularly the knee, lower back, and shoulder, in the current study.

Limitations

Epidemiology of sports injuries in children and youth is a vital area of research that has been overlooked largely in the sport science and medical literature[33]. The findings of this study bridge several gaps of badminton relative research. Moreover, the size and variability of the sample were the strengths of this study. Specific badminton-related injury proportions were identified among badminton players aged 7–22 years broken down by age and sex. Limitations of this study include recall bias as a cross-sectional study, which is not the best to describe to injury risk per 1000 h. Based on the results of this study, prospective studies are needed in the future. Investigated data with the lack of formal medical evaluation did not consist of injury nature (such as, fracture or sprain) and type (gradual-onset or acute-onset, new or recurrent). Finally, although this study has large sample size, the sample size of badminton players aged 19–22 years was small. Large number badminton players should be recruited to verify the findings in future.

Conclusion

In 7–22-year-old badminton players, knee, lower back, and shoulder injuries frequently occurred and were significantly associated with the incidence of badminton-related injuries. The peak incidence of badminton-related injuries was in 15–16-year-old male badminton players while the peak incidence was in 17–18-year-old female badminton players. These data have the potential to help target the most at-risk anatomical sites and the most at-risk badminton players precisely for injury prevention programs.

Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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Author contributions

KI and EW planned and designed the study. XZ, KI and EW analyzed the data. XZ and KI drafted the manuscript. ZC, XL, and HZ Proofread English. All authors contributed to data acquisition and interpretation. All authors have read and agreed to the published version of the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to K.I.