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Original Article

Training and injuries among world elite junior badminton players – Identifying the problems

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ABSTRACT

Background: The game of badminton has evolved since the early injury epidemiology studies. Since there is no published literature on injuries in elite junior badminton players from an international cohort, this study provides an updated reference of injuries in this population to inform future injury prevention strategies. The objective of this study was to report injury prevalence and training hours in elite junior badminton players participating at the World Junior Championships in 2018.
Methods: A questionnaire was used to collect data and was available in English, French, Spanish, Korean, Japanese or Chinese. It was designed to collect information including basic demographics, hours of training and competition, number of tournaments per year, current and previous injuries characterized by anatomical region, diagnosis, treatment and injury duration. The questions were focused on previous significant injuries lasting a minimum of 30 days and current musculoskeletal symptoms.
Results: One hundred and sixty-four of 436 players with a mean age of 17.1 years (SD ± 0.8) filled in the questionnaire. Participants represented North and South America, Europe, Asia, Africa and The Pacific's including the top 10 performing nations, providing a good overall representation of tournament participants. A total of 104 significant injuries (median duration of 90 days) with disruption of full training or competition capacity were reported. Seventy-eight (48%) players reported one or more significant injury. The most common location of significant injury was in the knee, ankle and lower back. Eleven injuries were reported as stress fractures. In 35 cases a player felt lasting limitation from a significant injury and in 37 cases a player felt lasting pain.
Conclusion: Previously in their career almost 50% of the players had sustained a significant injury with a median duration of 90 days. The lower extremities and the lower back were the predominant injured regions. In one third of the injuries a player had lasting limitations or pain. Stress fractures may be a serious underestimated problem in badminton.

1. Introduction

The Olympic sport of badminton is one of the most popular sports in the world, especially in Asia, where China estimates 100 million people participate in badminton.[1] Despite this, little attention has been paid to badminton injuries involving a world elite playing population within the scientific literature (Fahlström, Boesen, Koenig), and none looking at the overall injury location and type.[2–5] Badminton has evolved in intensity with a greater number of professional training squads and the change of scoring system influencing the style of play and subsequent physical demands.[6–9] Epidemiology studies are limited to national populations and generally of high heterogenity characterized by differences in methodology, injury registration, and populations, making comparison difficult or impossible.[10–15]

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The injury rate in badminton varies from 1 to 7/1000 h per person of playing time depending on the population.[10–14] The majority of injuries (91%) sustained by youth players are minor and do not result in absence from training.[13,14,16] In a large prospective study from Japan the risk of injury increased proportionately with age in a group of tournament players from high school and university.[13] However only 2% of the injuries led to absence from training for more than one month.

The epidemiology of injuries in badminton is not clear. Overuse injuries are reported to constitute 36–75% of all injuries.[10,13–16] Lower extremity injuries are most common with sprains, strains and tendinopathies being the most frequently cited.[14,16,17] Injuries in the shoulder and in the back are reported less frequently.[12,16] It is reported that 16–19% of elite players participate in competition with ongoing pain in the Achilles and/or patellar tendon and/or the shoulder.[2–5] However, we do not know if junior elite players experience similar conditions to adult players and if training- and tournament load and physical developmental differences during adolescence predisposes to injury or pain in adulthood.

Asian countries are the most successful on the world stage, with 89% of all Olympic badminton medals to date have been won by Asian players, and from personal communication and observations, it is known that players from Asian countries commonly have a higher training volume than non-Asian players, however this has not been investigated. Whether a high training volume among junior elite players is correlated to injuries is also not known.

2. Study objectives

This study is part of the Global Health Badminton Study conducted by the Badminton World Federation (BWF) to create a basis for future injury surveillance programs and injury preventive studies.[18] The two main objectives of the current study were: (a) to report significant injuries amongst the best junior elite badminton players in the world; (b) to determine any correlation between injuries and player demographics, anthropometrics (height, weight and playing arm dominance) and weekly training load.

3. Materials and methods

The study methods conformed to the Helsinki declaration and was approved by the Danish Data Protection Agency and was also evaluated by the Capitol Region Committee on Health Research Ethics, Denmark, where it was evaluated as not requiring formal ethical approval. Furthermore, as the study was global in nature, the BWF Legal Team evaluated, informed and approved the study design.

The study was commissioned by the BWF and participants competing in the 2018 BWF World Junior Badminton Championships, Markham, Canada (8th–17th November 2018), were invited to take part. Participants were excluded if written consent was not obtained. Due to the age limit of the Championships, no participants were over 19 years of age. Participants were recruited during the championships. If questions were not completed or answers were unclear the players were contacted by email and given until 1st May 2019 to complete the questionnaire.

3.1. Study design

A cross sectional study design according to the STROBE guidelines was adopted.[19] A questionnaire designed to collect information related to badminton playing and training history, musculoskeletal health, including basic demographic information was used. Questions regarding musculoskeletal health included in this paper consisted of two sections:

1. Significant injuries during the players badminton career defined as an injury lasting 30 days or more and causing a reduction in training capacity and/or absence from competition.
2. Current musculoskeletal symptoms defined as experiencing pain or stiffness in most of the last 30 days prior to competing at the World Junior Badminton Championships.

The musculoskeletal health questions were based on the World Olympic Association Musculoskeletal Health Global Questionnaire.[20] The questionnaires were modified for this population by the two lead authors given their specific expertise as former international badminton players, coaches and healthcare professionals (appendix). Modifications were required as the original questionnaire was aimed at retired athletes and therefore questions pertaining to long term health implications were not applicable to this junior playing population.

3.2. Data collection

Study data were collected and stored using REDCap electronic data capture tools hosted at the Capital Region of Copenhagen.[21] The questionnaire was available electronically online in English using the REDCap system and paper versions were available in English, Spanish, Indonesian, Korean, Chinese and French. The non-English questionnaires were coded making them easily convertible to the English version in REDCap. BWF approved translators converted the non-English questionnaires into English and this information was stored in REDCap.

3.3. Statistics

To evaluate potential selection bias in the study, data from the responders of the questionnaire were compared to the non-responders regarding sex, age, and representative country (Asian or non-Asian) by Wilcoxon sum rank test and chi-squared test.

Association between average hours played/week and significant injury was analysed using a logistic regression model. The model was adjusted for age since risk of injury was expected to increase with age. Models were fitted with average weekly hours played in the following categories: age< 13 years, 13–15 years and >15 years to follow the international categorization of youth players. These age categories were selected to have applied benefit to coaches and other stakeholders involved with badminton training programming through the junior age groups by informing appropriate training load selection. Similar models were also fitted for risk of ankle, shoulder, lower back and knee injury. Models were also fitted with hours played/week as a categorical variable, with categories defined as less than 10 h, 10–20 h and more than 20 h. The fit of all logistic regression models was evaluated by Hosmer-Lemeshow goodness of fit test. Comparison between groups was performed with chi squared test or, for variables with less than 5 expected frequencies, with Fishers exact test, and by *t*-test or, for non-normally distributed data, by Wilcoxon sum rank test. For each comparison group, multiple variables were tested. To reduce the potential of type I errors from multiple testing, Bonferroni correction of the p-values were used ($p < 0.0025$). All analysis was done in R 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

4. Data availability

The data associated with the paper are not publicly available but are available from the corresponding author on a reasonable request.

5. Results

5.1. Participants

In total, 164 of 436 tournament competitors (38%) completed the questionnaire. There were 93/164 males (57%) and 70/164 females (43%) and one player with unknown gender who completed the questionnaire with a mean age of 17. 1 years (SD ± 0.8) (Table 1). There were 60/200 Asian players (30%), 103/236 non-Asian players (43%) and 1 player with unknown origin who completed the questionnaire. Comparison of responders with non-responders showed that the responders were predominantly males and from a non-Asian country ($p = 0.009$ and 0.002 respectively). There were no age differences between the groups of responders and non-responders. Players from 32 countries from all continents participated, including all the top-ranked badminton nations. The mean age when starting to play badminton was 7.8 years.

5.2. Injuries

A total of 104 significant injuries were reported. The number of significant injuries were not different between males and females ($p = 0.52$) or Asian players compared with non-Asian players ($p = 0.15$). Seventy-eight (48%) players reported one or more significant injury where the median duration of a significant injury was 90 days (55–172,5) until return to play. The minimum and maximum durations of a significant injury were 30 and 1800 days respectively. Median duration was the same for males and females. Thirty five (34%) players felt lasting limitation from a significant injury and 37 (36%) players felt lasting pain. The most common locations of a significant injury reported were in the knee ($n = 28$), ankle ($n = 19$) and lower back ($n = 10$) (Fig. 1). Sixty-eight (65%) of the injuries occurred during training and 32 (31%) of the injuries occurred during competition. In 3 cases the origin of the injury was not reported. Forty-five (43%) of the injuries occurred with gradual onset and 55 (53%) with sudden onset. Four participants did not answer this section. Fifteen (14%) of the injuries were classified as tendinopathies, 10 (10%) injuries as fractures, 10 (10%) as sprains and 11 (11%) injuries as stress fractures.

5.3. Stress fractures

Most of the stress fractures were located in the lower extremities and 3 were in the lower back and pelvis. Seven occurred among boys and 3 among girls and in one case the gender was not reported. Players from Asian countries reported a higher number of stress fractures (9/11) than players from other countries. However, the difference in number of stress fractures was not significant. There was a trend towards higher badminton training volume in those reporting a stress fracture compared to those with no stress fracture however with the Bonferroni correction this was not statistically significant (Table 2).

5.4. Current symptoms

One hundred and eight separate incidents of current symptoms of pain or stiffness were reported. The lower back ($n = 21$), the knee ($n = 17$) and the hip ($n = 13$) were the most frequent locations of current symptoms of either pain or stiffness.

5.5. Training and competitions

There was a trend towards training more per week and playing more tournaments per year with increasing age (Table 3). Ten percent of players trained more than 20 h/week of badminton when they were below 13 years of age. Forty percent of the players trained more than 20 h/week of badminton when they were above 15 years of age. Asian players reported significantly higher on-court training hours and off-court physical training hours than non-Asian players in all age groups ($p < 0.001$) (Table 4). Asian players played less tournaments across all age groups than non-Asian players ($p < 0.001$). There was no relationship between training hours per week and risk of a significant injury.

6. Discussion

6.1. A worryingly high number of significant injuries

This is the first study to report the incidence and severity of injuries amongst world elite junior badminton players aged 15–19 years. The results are in concurrence with previous studies suggesting that the lower extremities are the body region most affected by injury.[10,12–16] The study demonstrated a worryingly high number of significant injuries (48% of participants) with a median duration of 90 days in a representative global cohort of elite junior badminton players. We are aware that this is the prevalence of injury rather than incidence, however with this study design it is not possible to provide a precise injury incidence due to the self-reported retrospective nature of training and competition hours provided. This apparently high prevalence of injury could be due to participation bias, whereby those who volunteered were more likely to have had a notable injury history and therefore saw relevance in the study. The number of significant injuries is much higher than a previous study, where only 2% of injuries lasted more than 28 days, however differences in the level of play as well as a shorter observation time in the Japanese study may explain this difference.[13] Conversely, players who suffered serious injuries and stopped their career or who had not recovered sufficiently to qualify for the World Championships may have been excluded from the current study, suggesting the problem with serious injuries among junior elite badminton players may be underestimated in this cohort.

Table 1
Participant demographics and basic anthropometrics.

	Males	Females	Unknown	Total
Participants, n (%)	93 (56.7%)	70 (42.7%)	1 (0.6%)	164
Mean Age (years ± SD[a])	17.1 ± 0.8	17.1 ± 0.8	–	17.1 ± 0.8
Mean Weight (kg ± SD[a])	70.8 ± 6.5	60.4 ± 5.6	–	66.3 ± 8.1
Mean Height (cm ± SD[a])	179.3 ± 7.3	166.5 ± 5.8	–	173.8 ± 9.2
Mean Badminton Start (years ± SD[a])	7.7 ± 2.20	7.8 ± 2.0	–	7.3 ± 2.0
Right-handed Players, n (%)	84 (90.3%)	62 (88.6%)	–	146
Left-handed Players, n (%)	9 (8.6%)	8 (11.4%)	–	17
Unknown Hand Dominance, n (%)			–	1

[a] Standard Deviation.

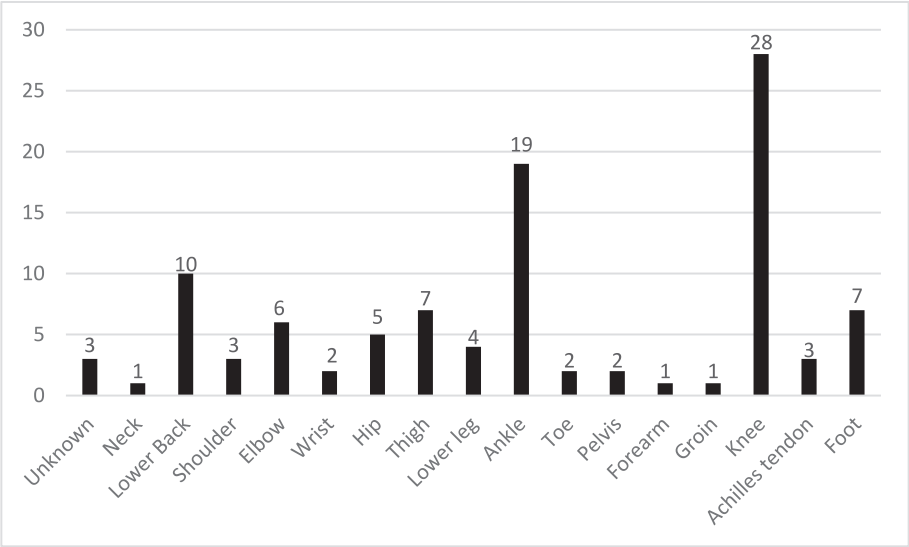

Fig. 1. Location of significant injuries.

Table 2
A comparison of mean hours of training per week in players with and without a stress fracture throughout their junior career.

Players (n = 164)		Stress fracture n = 11	No stress fracture n = 153	p-value*
Age < 13 years	Badminton training hours/week ± SD[a]	16.2 ± 6.0	11.4 ± 8.1	0.17
Age < 13 years	Physical training hours/week ± SD[a]	5.4 ± 5.4	4.7 ± 6.0	0.07
Age 13-15	Badminton training hours/week ± SD[a]	21.0 ± 6.1	14.7 ± 8.1	0.009
Age 13-15	Physical training hours/week ± SD[a]	7.9 ± 7.2	6.0 ± 6.1	0.37
Age >15 years	Badminton training hours/week ± SD[a]	27.7 ± 8.2	19.0 ± 9.4	0.007
Age > 15 years	Physical training hours/week ± SD[a]	10.1 ± 7.7	7.8 ± 8.7	0.49

* Significant level is 0.0025 due to the Bonferroni correction.
[a] Standard Deviation.

Table 3
Title: The development of training and competition attendance for all participants (n = 164) throughout their junior career.

Players (n = 164)	Age < 13 years n = 164	Age 13–15 years n = 164	Age > 15 years n = 164
Badminton training hours/week ± SD[a]	11.7 ± 7.9	15.3 ± 8.1	19.8 ± 9.4
Physical training hours/week ± SD[a]	4.8 ± 5.9	6.2 ± 6.2	8.0 ± 8.6
Rest days/week ±SD[a]	2.3 ± 1.3	1.7 ± 0.9	1.2 ± 0.6
Badminton training >10 h per week	41.1% (n = 68)	61% (n = 100)	85% (n = 139)
Badminton training > 20 h per week	13% (n = 22)	24% (n = 40)	38% (n = 62)
Tournaments/year ±SD[a]	9.8 ± 5.9	12.5 ± 7.9	13.6 ± 8.4

[a] Standard Deviation.

Table 4
A comparison of the training and competition history in players from Asian countries with players from non-Asians countries throughout their junior career.

Players (n = 164) 1 unknown origin	Age <13 years: Asians n = 60	Age <13 years: Non-Asians n = 103	Age 13–15 years: Asians n = 60	Age 13–15 years: Non-Asians n = 103	Age >15 years: Asians n = 60	Age >15 years: Non-Asians n = 103
Badminton training hours/week ± SD[a]	18.0 ± 7.1	8.2 ± 6.0	22.5 ± 6.3	11.3 ± 6.1	28.2 7.5	15.1 ± 6.5
Physical training hours/ week ± SD[a]	8.9 ± 7.5	2.4 ± 2.4	11.0 ± 7.5	3.5 ± 2.5	13.4 ± 11.8	4.9 ± 2.6
Rest days/week ± SD[a]	1.6 ± 1.1	2.7 ± 1.3	1.2 ± 0.5	2.0 ± 1.0	1.1 ± 0.5	1.3 ± 0.6
Tournaments/year ± SD[a]	9.1 ± 7.0	10.2 ± 5.2	11.8 ± 10.3	13.0 ± 5.9	13.7 ± 11.2	13.6 ± 6.1

p < 0.001 when comparing Asians with Non-Asians in all age groups.
[a] Standard deviation.

6.2. Stress fractures unevenly distributed

Of concern is that a notable portion of the significant injuries were stress fractures (n = 11). A stress fracture is a true overuse injury, perhaps the most serious, and especially warrants attention in a junior population. In a Japanese study of female high school athletes from different sports, 16.8% (n = 66) reported a stress fracture.[22] In our study, there is a higher incidence of stress

fractures reported amongst players from Asian countries and the players with stress fractures reported higher training volume though not statistically significant. This tendency definitely warrants further investigation. However, there may be a selection bias towards more Asian players with stress fractures answering the questionnaire, given the skewed distribution of Asian players with questionnaire data. There does not seem to be any correlation between other injuries and weekly hours of training and the risk of injury does not appear to rise with an increase in hours played. This suggests that a high training volume does not necessarily lead to a high risk of significant injury apart from stress fractures. In other sports there seems to be a correlation between rapid changes in training volume and injuries.[23–26] It would be reasonable to consider that strictly controlled planning of changes in training volume, intensity and tournament activity in badminton could reduce the risk of overuse injuries, although this needs more investigation to draw any further conclusions.

6.3. Lower back and shoulder injuries

Although the lower extremities had the highest number of injuries reported, the lower back accounted for the third highest number of significant injuries and was the most frequent location of current pain or stiffness. This may be a result of high load and the demand of flexibility in the lower back during badminton. Only 3(2.9%) significant shoulder injuries were reported in the current study. In comparison 16% of the players at a senior world championship played with some kind of pain in the shoulder.[2] In this study, only 4 (2.4%) players reported pain in the shoulder for most days during the month leading up to the tournament. It is important to investigate what causes this apparent rise in shoulder problems when the players progress from junior to senior level. From personal communications with elite coaches we know that the training load and technical drills loading the shoulder rises when junior players progress to senior players. The combination of a higher training load with repetitive high load strokes and the improvement in strength through weight training may cause an overload of the shoulder girdle.

Future studies are also required to understand risk factors for the development of low back pain and lower extremity injuries in badminton players.

6.4. Ankle sprains

Badminton at a world class level is played with explosive movements, rapid changes of direction and demands high flexibility in the lower extremities, which may explain the strains and sprains which affects the lower extremities.[6] We know from other sports that the incidence of ankle sprains can be reduced with neuromuscular training and the use of orthoses or sports tape.[27] A randomised controlled trial with badminton, handball and basketball players showed reduction in lateral ankle sprains when applying a low-friction shoe patch on the outside of the shoes.[28] Since the proportion of significant injuries in this study originating from sprains is high, it would be reasonable to consider the implementation of these interventions within badminton in an effort to reduce the incidence of ankle sprains.

6.5. Difference in training volume between nationalities

A high proportion of all injuries had a gradual onset and would as such be considered overuse injuries and continued attention should be paid to this injury mechanism category. In particular, analysis on player workload is required and should be a key consideration for training program planning, especially during transition periods from junior to senior training set-ups.

In this study we found a significant difference in training volume between players from Asian and non-Asian countries with players from Asian countries training more hours per week on average. This may be due to the popularity of badminton in Asia which has resulted in an elite training culture in junior badminton players. Badminton is becoming increasingly globalised with more professional training set ups for junior and senior players also outside of Asia. As developing badminton countries look to further their training provision, care should be taken to increase load in a slow and progressive fashion in order to reduce the risk of having a high acute-chronic workload ratio which may increase the risk of injury.[25,26,29] Since players from Asian countries in this study reported lower incidences of significant injuries, it is not necessarily the maximum training load that is linked with increased injury risk but perhaps it is related to rapid spikes in training load as previously demonstrated in other sports.[24,29] Furthermore, it is worth considering that players from Asian countries may have a higher chronic workload thus contributing to an optimal workload ratio resulting in a better resistance to injury.[25,30]

6.6. Limitations

We acknowledge that due to the nature of the retrospective study design with the risk of bias and the response rate of 38% (164/436), the true number of injuries may be different from what this study found. Furthermore, there may be an over representation of male players and players from non-Asian countries answering the questionnaire. Players who have experienced an injury may have been more likely to volunteer to participate in the study as they perhaps felt it was of relevance to report their experience and conversely, those without injury history may not have seen relevance of the study. In addition, there may be under representation of injury in this cohort due to currently injured or recovering players not in attendance at the competition and therefore not eligible for participation in this current study. The accuracy of diagnoses may be limited due to the self-reported information on diagnoses.

Former injury surveillance studies have focussed on National cohorts and this study is the first of its kind to report on injuries from an international junior elite population making the results generalisable to elite junior players across the world. This is the first time stress fractures have been identified as a potential problem in badminton. The concerning high number of significant injuries and stress fractures in this population highlights the need for larger prospective injury surveillance studies in youth players to gain further insight into badminton injury epidemiology. The results of this study on youth badminton players can, in spite of the relatively low response rate, give valuable information to qualify the strategy of future research.

7. Conclusion

Through their career almost 50% (78/164) of the players at the World Junior Badminton Championship in 2018 had sustained a significant injury with a median duration recovery period of 90 days. The lower extremities and the lower back were the predominantly injured regions. In one third of the injuries a player had lasting limitations or pain. A concerning number of players reported stress fractures and it may be a serious underestimated problem in badminton. The study highlights the need for prospective injury surveillance and injury prevention research.

Authorship contribution

Niels Christian Kaldau and Stewart Kerr designed the study, collected data, processed data and wrote the manuscript. Steve McCaig contributed to the protocol, analysis of data, writing and reviewing the manuscript. Per Hölmich contributed to the protocol, analysis of data, writing and reviewing the manuscript. All authors read and approved the final version of the manuscript.

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Declaration of competing interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Thomas Kallemose contributed with the statistical analysis. Mark King contributed with the study design.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asmart.2021.07.003.

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