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Project Report

A Retrospective Review from 2006 to 2011 of Lower Extremity Injuries in Badminton in New Zealand

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Abstract: Aim: To describe lower extremity injuries for badminton in New Zealand. Methods: Lower limb badminton injuries that resulted in claims accepted by the national insurance company Accident Compensation Corporation (ACC) in New Zealand between 2006 and 2011 were reviewed. Results: The estimated national injury incidence for badminton injuries in New Zealand from 2006 to 2011 was 0.66%. There were 1909 lower limb badminton injury claims which cost NZ$2,014,337 (NZ$ value over 2006 to 2011). The age-bands frequently injured were 10–19 (22%), 40–49 (22%), 30–39 (14%) and 50–59 (13%) years. Sixty five percent of lower limb injuries were knee ligament sprains/tears. Males sustained more cruciate ligament sprains than females (75 *vs.* 39). Movements involving turning, changing direction, shifting weight, pivoting or twisting were responsible for 34% of lower extremity injuries. Conclusion: The knee was most frequently

injured which could be due to multi-planar loading. Turning or cutting movements typically involve motion in the frontal and transverse planes that may place the knee at greater risk of injury than movement in the sagittal plane alone. Further research on badminton specific movements is warranted to better understand the mechanisms of lower extremity injuries in the sport. Sports medicine and support personnel should take into account the susceptibility of the knee to injury when designing training and injury prevention programmes given the large number of change of direction movements during badminton.

Keywords: badminton; injury; incidence; cost; body site; type; severity

1. Introduction

Badminton is a fast-paced sport involving jumps, lunges and unanticipated changes of direction and acceleration. Badminton players' ankles, knees and hips go through flexed and extended positions while maneuvering from mid-court to both court sides and forward and backwards to execute shots. Player's joints may be subject to high ground reaction forces, especially as the sport is performed on a hard surface [1].

An epidemiological review of lower limb injuries in badminton can help establish the extent of the problem of injury in the sport and highlight potential injury mechanisms, which can then inform future injury prevention measures [2]. This paper provides a descriptive epidemiology of lower extremity injuries in badminton in New Zealand over six years, from 2006 to 2011. An analysis of injury type, cause and cost (NZ$ value over 2006 to 2011) was conducted with the aim of furthering understanding possible injury mechanisms in badminton.

2. Method

Lower limb badminton injuries that resulted in claims accepted by the national insurance company Accident Compensation Corporation (ACC) in New Zealand between 2006 and 2011 were reviewed. ACC, New Zealand's national no-fault injury compensation system, supplied epidemiological records primarily of the injury event and description of injuries incurred playing badminton, together with their associated treatment costs. The ACC system uses standard international classification of diseases injury coding. The ACC taxpayer financed government organization offers a 24 h no-fault personal injury scheme that has previously been described [3]. The injury claims obtained from ACC did not allow the identification of the duration of missed competition and training time, hospitalisation duration or level of participation [4]. The national badminton organisation has no comparable database of injuries sustained. The retrospective descriptive nature of this study is considered level 2c evidence [5]. All costs are reported in New Zealand Dollars (NZ$).

Frequency and percentage of total lower limb injuries are presented by cause and injury type taking into account recommendations for defining and classifying injuries [6]. Lower limb ligament sprains typically do not require surgery or absence from play [7]. However, the more severe Grade 3 ligament injuries are usually considered serious as they involve complete disruption of the ligament. Grade 3

anterior cruciate ligament sprains often necessitate reconstruction in order for an individual to return to change of direction activities. A contusion is regarded as a soft tissue injury with a subcutaneous hemorrhage and without a break in the skin [7], commonly known as a bruise. There is no international standard for reporting badminton injuries, unlike the suggested guidelines for tennis medical conditions reporting provided by Pluim [8].

The national incidence of lower limb injury was calculated as the number of injuries divided by approximate number of players over six years multiplied by 100. Data were analyzed in Statistical Analysis System (SAS) and customized excel spreadsheets.

3. Results

3.1. Injury Incidence

The 1,909 lower limb badminton injury claims accepted by ACC over the six-year period from 2006 to 2011 cost NZ$2,014,337. The mean number of lower limb injuries was 318 ± 32 per year. The Chief Executive from Badminton New Zealand (the national governing body for badminton in New Zealand) indicated that paid registered members totaled ~8000 each year, with ~40,000 casual players participating [9]. Therefore there was an estimated national incidence of 0.66% (1,909 lower limb injuries sustained/288,000 players × 100%).

3.2. Injured Players' Characteristics

The mean age of all players was 37.6 ± 16.7 years (range 10–85 years; females 38.1 ± 17.5 years; males 37.2 ± 16.1 years). The age-bands most frequently injured were 10–19 (22%), 40–49 (22%), 30–39 (14%) and 50–59 (13%) years. The ethnicity of the majority of claimants was NZ European (44%) or Asian (37%). The proportion of total injuries for males (55%) and females (45%) was similar.

3.3. Body Site Injured and Type of Injury

There were no substantial differences in the injuries to left (48%) or right (52%) limbs. Soft tissue injuries (contusions, strains and sprains) accounted for 95% of all claims. There were 64.8% knee ligament sprain/tears (32.2% knee and leg sprains unspecified, 17.3% medial collateral, 7.7% lateral collateral, 6.0% cruciate), 17.0% meniscal tears (11.2% medial, 5.8% lateral) and contusions (6.2%) (Table 1). Males sustained more acute meniscal tear medial (59%), cruciate ligament sprains (66%), knee abrasions (63%), bucket handle tears (75%) and quadriceps tendon sprains (63%) than females.

Table 1. Frequency and percent of lower limb injuries to badminton players by injury type.

Injury type	Frequency	Percent
Nonspecific sprain of knee and leg	615	32.2
Sprain of medial collateral ligament of knee	331	17.3
Sprain or partial tear, knee, lateral collateral ligament	146	7.7
Sprain of cruciate ligament of knee	114	6.0
Acute meniscal tear medial	213	11.2
Acute meniscal tear lateral	110	5.8
Contusion, knee and/or lower leg	120	6.2
Closed traumatic dislocation patello-femoral	41	2.1
Other specified	168	7.9
Ankle sprains	18	0.9
Not specified	51	2.7
Total	1909	100

3.4. Causes of Injury

The most common causes of injury were movements involving turning (*i.e.*, turning, changing direction, shifting weight, pivot, or twist) (34.4%) followed by general movements (*i.e.*, running, moving sideways or backwards (22.5%), rather than specific badminton movements of lunging (10.9%) or landing from jumps (7.3%) (Table 2).

Table 2. Frequency and percent of the cause of badminton lower limb injuries.

Cause	Frequency	Percent
Turning/changing direction/shifting weight/pivot/twist	657	34.4
Movement/running/moving sideways or backwards	429	22.5
Lunge/pushing off/reaching	209	10.9
Landing/jump and land	140	7.3
Not specified	138	7.2
Fall	136	7.1
Slip/slip and fall/slip and twist	103	5.4
Stretch/stretch to shoot	64	3.4
Tripped/loss of balance/stumble	25	1.3
Collision with person or equipment	8	0.4
Total	1909	100

The mechanisms that were most frequent (*i.e.*, greater than 18%) for specific injury types were calculated. Turning movements were most frequent with more lateral meniscal tears (51%) and medial meniscal tears (43%) than general movements (17% lateral and 22% medial). Turning accounted for 42% of cruciate ligament sprains (compared to 22% for general movements), 29% of sprains of the knee and leg (compared to 22% general), 42% of medial collateral ligament knee sprains (compared to 27% general) and 41% of lateral collateral ligament knee sprains (compared to 23% general). Causes of knee and lower leg contusions were falls (32%), general movement (19%) and turning (19%).

4. Discussion

4.1. Injury Incidence

Previous epidemiology studies (Table 3) on badminton have ranged from 1 to 8 years in duration, with an average of three years [7,10–19]. Injuries to the lower extremity represented between 50% and 92% of all injuries in these studies with the majority being mild to moderate in nature. Our proportion of lower limb injuries was 44% for our dataset. To our knowledge only three studies have reported incidence of injury [7,10,18], and this has varied depending on player performance level and method of injury data collection. In players ranging from club to international level, the incidence of injury was reported [10] as 0.09 and 0.14 injuries per person per year for males and females respectively using an injury questionnaire for data collection. These incidence rates (1% and 1.4%) were much lower than the study [7] of elite players in Hong Kong where the incidence was 5.04 injuries per 1000 (0.5%) of elite players using data collection from medical records. Goh *et al.* also used medical records as the source of data [18] and reported an incidence rate of 0.90 calculated as the number of injuries divided by the total athlete-time at risk.

4.2. Injured players' Characteristics

Age has been reported as a risk factors for sports injuries [20], and for our badminton study, there were more injuries in players aged 10–19 years and 40–49 years. Other authors have also reported age as a risk factor for badminton (Table 3). Previous studies using data across performance levels have presented three age-bands: under 16, 16–25 and above 25 [11]; or under 18, 18–25 and above 25 years old [12,13]. Although the greater number of injuries was seen in the higher age-groups, the results lack specificity due to a much wider age range of 7–57 years [12] and 10–60 years [13]. The lower age-bands used in previous work may have been chosen due to a lower mean age of players compared to our study.

Kimura *et al.* [16] reported the greatest number of anterior cruciate ligament (ACL) injuries occurred in the 16–20 years age-group. This may support the evidence of the mechanisms of injuries among the 10–19 years age group in our current study. The high incidence of injuries among 40–49 years old could be due to the ageing process, which may result in reduced mobility, musculoskeletal strength and kinaesthetic awareness [21–23]. The difference in mean age was greater for females when comparing the present study (38.1 ± 17.5 years) with earlier studies; 21.6 years [12] and 26.0 years [13]. As the risk of injury varies with age, attempts to plan training individually and to institute injury prevention measures should be made. As an example, the FIFA 11+ warm-up programme, is designed to reduce lower limb injuries, including ACL injuries, among football players aged 14 years and older (http://f-marc.com/11plus/home/).

Table 3. Epidemiology studies on badminton injuries.

Reference	Badminton players gender and age bands	% of players injured	Main injury type (%)	Causes of injuries (%)	Source of data
Chard *et al.* [11]	74 M; 54 F. ≤ 15; 16–25; ≥ 26.	3.1 (≤15 years); 46.9 (16–25 years); 50.0 (≥26 years)	collateral ligament injuries (28); meniscal injuries (25); cruciate ligament injuries (12.5)	NA	hospital registration
Fahlström *et al.* [19]	67 M; 11 F. 31.9 (range 11–52).	80.8 (<40 years)	Achilles tendon ruptures (34.6); ankle sprains/fractures (29.5); knee injuries (16.7)	NA	hospital registration
Goh *et al.* [18]	34 M; 24 F. 14.3 ± 1.1 (range 13–16)	56.9 (61.8 M; 50 F)	knee injuries (27), sprain/strain in lower limb (36.5); back/spine injuries (25.4); sprain/strain in trunk (25.4)	NA	medical records
Hensley *et al.* [10]	157 M; 74 F. 33 ± 13.1 M; 27 ± 8.2 F.	82.8 (M); 81.1 (F)	sprains or ligament injuries (43.7); blisters (37.8); muscle strains or tears (24.3); bruises (23.2)	Retrieving or positioning (36); stroking (29); collision with person (22)	badminton injury questionnaire
Hoy *et al.* [13]	2620 injured; 1650 M; 970 F. 28.2 (range 10–60).	2.8 (<18 years); 4.5 (18–25 years); 4.2 (>25 years)	sprains (54); Achilles tendon ruptures (13); tears (10); fractures (6)	NA	hospital registration
Kimura *et al.* [16]	6 M; 15 F. 21.9 ± 7.9 (range 13–38).	9.5 (<15 years); 52.4 (16–20 years); 19.0 (21–25 years); 4.8 (31–35 years); 14.3 (36–40 years)	ACL injuries (100)	single leg landing (48); plant-and-cut (38)	medical records
Kroner *et al.* [12]	217 injuries in 208 patients; 136 M; 72 F. 29.6 (range 7–57).	1.4 (<18 years); 2.3 (18–25 years); 2.3 (>25 years)	joint/ligament injuries (58.5); muscle injuries: strains/tears (19.8)	falling (62); struck by shuttle or racket (8)	hospital registration
Shariff *et al.* [15]	190 (no sex stated). 19.2 (range 13–52).	58.8 (<20 years)	patellar tendinopathy (42.7); muscle strain (11.8); meniscus or ligamentous injuries (10.9)	NA	medical records
Yung *et al.* [7]	20 M; 24 F. 20.1 ± 4.4 (range 13–28).	43.2 (21–28 years, elite senior); 25.0 (16–21 years, elite junior); 31.8 (13–18 years, potential)	strains (64); sprains (14.4); facet injury (14.4)	NA	medical records

M = male, F = female, NA = not applicable, ACL = anterior cruciate ligament.

The greater proportion of some injuries in males in the current study was similar to that in previous work [11,13,14]; nevertheless participation rate was not accounted for as gender participation numbers were not available from Badminton New Zealand. In studies where an elite sample [15] and community participation [12] were adjusted for, the risk of injuries to males and to females was comparable. In our study we reported a greater number of sprains to the cruciate ligament in males (75/114) than in females. In contrast, Kimura *et al.* [16] reported a greater frequency of ACL injuries to females (15/21). Our review of articles that reported the incidence of ACL injuries by gender [24,25] showed there was a greater risk of ACL injuries for females. Although biomechanical, structural and neuromuscular risk factors for ACL injury have been established [25], they are not necessarily unique to females. These risk factors may be considered as associations and not necessarily causal [26]. Further work is required to examine gender differences for risk of ACL injury, and causative risk factors for injury in badminton players.

In terms of ethnicity, the high percentage of Asians (37%) injured in the current study was greater than the proportion of Asians in the NZ population (12%) [27], which could be due to a preference for badminton as a sport for Asians in New Zealand compared with other activities.

4.3. Causes of Injury

Injuries can result from the player's own movements and may arise from a rapid change to a motor control plan [6]. Few studies have detailed the causes of badminton injury. Hensley and Paup [10] reported that most injuries were intrinsic rather than extrinsic, either from a retrieving/positioning (36%) or stroking (29%). Using interviews and an examination of the medical records of 21 badminton players with ACL injuries over six years, Kimura *et al.* [16] established that the most common cause of ACL injury was a single-leg landing after an overhead shot, typically on the knee opposite to the racket-hand side. The next most common cause of ACL injury was planting and cutting during a side-step with the knee on the racket-hand side [16]. Ten out of 21 (47.6%) players injured their ACL when landing on a single leg after an overhead shot following a backward step [16], whereas landing and jump-landing accounted for 12.5% of ACL sprains in our study. Turning the body and side-stepping was responsible for 38% of ACL injuries in Kimura *et al.*'s study [16] compared with 34.4% as a result of turning/changing direction/shifting weight/pivot/twist in our study.

Depending on the degree of flexion, multi-planar loading during the plant-and-cut movement may increase the force through the ACL above that of sagittal motion alone [28–30]. Greater force increases the strain through the ligament which could increase the potential for injury [28–30]. Badminton is a fast paced game where players have little time to react to the stimulus of the shuttle, similar to unanticipated planting and cutting in other sports. There is some evidence that unanticipated movements result in greater varus/valgus and internal/external rotation moments at the knee compared to anticipated ones [31]. Additionally, holding a racket may further increase peak external knee abduction moment due to postural alterations [32].

4.4. Limitations of Injury Data Sources

Different sources of injury data can result in different conclusions being drawn around risk factors for injury. Our data source was the national insurance compensation system that provides treatment and

rehabilitation for any person in New Zealand via a medical practitioner (e.g. general practitioner, hospital, physiotherapist). In both studies by Kroner *et al.* [12] and Hoy *et al.* [13] records were obtained from admissions to a casualty ward. Using the ACC database as a source has a greater analytical scope as it also includes patients that did not require emergency treatment at a hospital. This means lower severity injuries are recorded in the ACC database, resulting in a relatively high proportion of sprains and contusions being reported.

A strength of this study is the inclusion of mechanism data, which is lacking in most injury databases. However, like reports from other injury databases, this study is limited by an absence of information on training characteristics at the time of injury such as the level or intensity of participation. For example, the larger proportion of injuries in the 10–19 years age-group may be due to them playing more often or having a greater training intensity than other older age groups. Shariff *et al.* [15] reported that Malaysian national badminton players under 20 years old had the greatest proportion of injuries and suggested that this may have been due to a lack of experience or more aggressive style of play.

Limitations in our study as a result of incomplete injury mechanisms information in the ACC database were: (a) Whether the injury occurred during training or match play; (b) The period during training/match that the injury occurred; (c) The court area where the player was injured; (d) The players' performance level or the intensity of their training/participation.

5. Conclusions

From 2006 to 2011 the knee was the most frequently injured lower extremity site in badminton players in New Zealand. Movements involving turning, changing direction, shifting weight, pivoting or twisting were responsible for a large proportion of lower extremity injuries. Turning or cutting movements incorporate motion in the frontal and transverse planes with sagittal plane motion and result in multi-planar loading that likely place the knee at greater risk of injury. Further research on badminton specific movements is warranted to better understand the mechanisms of lower extremity injuries in the sport. Sports medicine and support personnel should take into account the susceptibility of the knee to injury when designing training and injury prevention programmes given the large number of change of direction movements during badminton.

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Author Contributions

Joanna Reeves had the idea for the paper, reviewed literature and conducted the initial analysis of data, and drafted the first version of the paper. Patria Hume provided advice on the methods, reviewed the data analysis and edited the paper. Simon Gianotti sourced the data from the ACC and edited the paper. Barry Wilson provided advice on the methods and edited the paper. Erika Ikeda provided additional data analysis, literature searching and edited the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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