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Injuries in badminton: A review

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Titre / Title

Blessure en badminton : une revue / Injuries in badminton: a review

Titre court / Short title

Blessure en badminton / Badminton injuries

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1 **Titre / Title**

2 Blessures en badminton : une revue / Injuries in badminton: a review

3 **Titre court / Short title**

4 Blessures en badminton / Badminton injuries

5 **Résumé :**

6 Objectifs. – L'objectif de cette revue est de fournir un aperçu sur les risques de blessures en
7 badminton en explorant et en adoptant une approche globale des blessures des yeux, des
8 membres supérieurs et inférieurs. Cela explique comment la blessure a eu lieu et de ce fait,
9 propose des recommandations médicales et d'entraînement pour les sportifs.

10 Actualités. – Les blessures en badminton sont autour de 1%-5% des blessures sportives. Elles
11 sont classées sixième après celles du football, du basketball, du volleyball, de la course à pied
12 et du vélo.

13 Perspectives et projets. – Les connaissances pourraient aider les entraîneurs et les préparateurs
14 physiques à se focaliser sur les activités musculaires spécifiques dans la prévention des
15 blessures. La relation entre les scientifiques et les entraîneurs, notamment en biomécanique et
16 en physiothérapie contribuera à améliorer les performances et prévenir les blessures.

17 Conclusion. – Le badminton sera influencé par l'évolution de l'intensité des échanges. Il est
18 visible que les modèles et les exigences des mouvements vont augmenter le nombre de blessures
19 et d'en générer de nouvelles. Une blessure oculaire survient suite à un coup de volant frappé par
20 l'adversaire. Le port de lunette peut réduire considérablement le risque de blessure aux yeux.

21 Les blessures au bras et à l'épaule sont dues à une mauvaise technique, tandis que les blessures
22 aux jambes et au dos sont principalement causées par un manque de force ou de mobilité. La
23 contribution du tronc dans la prévention des blessures des membres inférieurs suggère une
24 attention toute particulière à cette zone. La fatigue influence la production des fentes et la

25 réception des sauts rend les tendons moins puissants et plus instables. Les programmes ciblés
26 d'entraînements augmentent la force du corps afin de prévenir les blessures.

27 **Abstract:**

28 Objectives. – The aim of this review is to provide an overview of the injury risks in badminton,
29 by exploring and takes a global approach related to the eyes, and upper and lower limbs. This
30 explain how the injury occurred and as well as medical and training recommendations for
31 athletic population.

32 News. – Badminton injuries are around 1%-5% of all sports injuries. It ranked six after soccer,
33 basketball, volleyball, long-distance running and cycling.

34 Prospects and projects. – Such knowledge could help coaches and fitness trainers focus on the
35 specific muscular activities required to prevent injuries. The relationship between scientists and
36 coaches, particularly in terms of biomechanics and physiotherapy, will help improve
37 performance and prevent injury.

38 Conclusion. – Badminton will be influenced by the evolution of intensity of the game. It is
39 apparent that the movement patterns and movement demands are related to an increase in
40 injuries and the generation of new injuries. Eye injury occurs when shuttlecock impact from an
41 opponent's stroke. Wearing glasses can considerably reduce the risk of eye injury. Injuries to
42 the arm and shoulder are due to faulty technique, while leg and back injuries are caused mainly
43 by a lack of strength or mobility. The contribution of the trunk to the prevention of lower limb
44 injuries suggests that specific attention should be paid to this area. Fatigue influences the way
45 that lunges are performed, and the jump is received by making these tendons less powerful and
46 more unstable. Training program increases body strength to prevent injuries.

47 **Mots Clés :**

48 Badminton ; Blessure ; Traumatisme ; Épidémiologie

49 **Keywords:**

50 Badminton; Injury; Trauma; Epidemiology

51 **1. Introduction**

52 Badminton is originated in China and created in England and is one of the most popular sports
53 in the world with 200 million adherents [1]. It is considered as the fastest racket game [2]. This
54 sport has five events: men's and women's singles and doubles and mixed doubles. The decision
55 to include badminton in the 1992 Olympics Game increased participation in the game. This
56 sport can be practiced by anyone, regardless of age or experience [3]. During a tournament,
57 badminton match are generally played with one to three matches over the course of 4 or 5 days.

58 Badminton is an individual non-contact sport that is considered very safe because it involves
59 no physical impact with other players [4]. Quick changes of direction, jumps, lunges at the net
60 and rapid arm movements in order to strike the shuttlecock from a variety of postural positions
61 increase the risk of injury [5]. Existing studies have demonstrated the risk of injury in
62 badminton to be 0.85 injuries per year [6], 1.6 to 2.9 injuries per 1000 hours of play [3], 2 to 5
63 injuries per 1000 players [7] and 1% to 5% of all sports injuries [8]. The way those injuries
64 occur will be discussed in this review.

65 Participation in badminton training and tournaments was found to increase the risk of injury
66 by 15 to 39% [9]. The injury rate was higher in training than in competition [10]. Non-contact
67 trauma occurs frequently in badminton playing (35%) and a higher injury rate was found among
68 athletes competing in badminton tournaments at the London Olympic Games in 2012 (11%)
69 [9]. Study has reported a higher injury risk among recreational rather than elite players [11].
70 However, other studies have reported similar risks among these players [12].

71 Male badminton players were found to be more frequently injured than females [10], [12],
72 [13]. However, when the higher participant rate of male players was considered, the incidence
73 rate did not differ much between the genders [14]; 0.09 for males and 0.14 for females per
74 person and per year [15]. Most badminton injuries can be classified as chronic overuse injuries
75 (~74%) [16]. The lower limbs account for 58 to 76% of all badminton injuries, the upper limbs

76 for 19 to 32%, and 11 to 16% of back injuries [16]. Eye injuries in sports have been linked to
77 racket sports (42%) [17], [18]. Based on this finding, the objective of this review is to
78 summarize the existing literature of badminton injuries, their location, nature and causes. In
79 addition, this explain how the injury occurred and as well as medical and training
80 recommendations for athletic population.

81 **2. Methods**

82 We conducted a literature search for English language and non-English language papers on
83 the following databases: PubMed, EBSCOhost, PsycINFO, ScienceDirect, Cairn and Web of
84 Science. An additional search was performed on the Internet using Google Scholar and
85 ResearchGate. Keywords and combinations of these words were used to carry out a
86 comprehensive search of the databases: badminton injury, badminton knee, badminton eye,
87 badminton legs, badminton trunk, racket sports injury, performance injury badminton, shoulder
88 badminton, elbow badminton, muscle badminton and arm badminton. Database searches
89 covered the period from 1974 to 2015.

90 **3. Frequency, epidemiology and traumatology of injuries**

91 Although it is widely accepted that warming up is vital for the attainment of optimum and safe
92 performance [19], most players still only spend less than 15 minutes on warm-up activities.
93 Only 20.0% of players spend 30 minutes or more before playing and players older than 30 years
94 old spend less time warming up than younger players [19]. Studies have shown that badminton
95 injuries constitute 4.1% of the total number of registered injuries in the literature of sport injury
96 [8], [20].

3.1 Temporal distribution of badminton injuries

Study was found that most injuries occur at the beginning of the season, in September, and in January, after the Christmas holidays [8] (Figure 1). Most of July is spent to rest and holidays for the athletes. In addition, many tournaments begin in September in different countries, which may explain the increased risk of injury in this month. In the study of Kroner et al. (1990), around 75% of the badminton players included were recreational players [8]. To prepare the beginning of the season, greater care should be taken at these times. In addition, Achilles tendon rupture occurred during the winter months (October to March) for recreational players [21]. Athletes should engage in a high level of physical preparation, individual training programs (physical activities) and prophylactic intervention.

***** Please insert Figure 1 here *****

Figure 1: Percentage in each month according to the total number of injuries during one year

3.2 Injured players' characteristics

Age has been seen as a risk factor for sport injuries [22]. The mean age of players reported is 29.5 ± 8.9 years, for males 28.9 ± 8.5 (Table 1) and for females 30.5 ± 8.4 years (Table 2). The age bands most frequently injured are 20 to 29 years (52%), 30 to 39 years (13%), and 40 to 49 years (35%); specifically for males 20 to 29 years (52%), 30 to 39 years (20%), and 40 to 49 years (28%) and for females 20 to 29 years (52%), and 40 to 49 years (48%), according to the entire studies in this literature.

***** Please insert Table 1 here *****

Table 1: Male players characteristics on the different studies. NS: no specify.

***** Please insert Table 2 here *****

Table 2: Female players characteristics on the different studies. NS: no specify.

121 3.3 Distribution of badminton injuries

122 Even if training sessions are highly necessary to avoid further injuries, existing literature has
123 shown that injuries could occur during the training, with a high frequency of occurrences at the
124 end of training (48%), followed by the middle of training (41%) and the beginning of training
125 (11%). This can be explained by a decline in force output and proprioception brought about by
126 muscle fatigue at the end of training [23]. Furthermore, rapid changes in direction, jumps,
127 lunges and the high repetition of ‘stop-and-go’ maneuvers [1] are required in badminton and
128 these constitute a major source of muscle fatigue. Thus, according to the literature, the lower
129 body extremities are involved in 49.7% of injuries, whereas the upper body extremities are
130 involved in 42.3% of injuries (Figure 2).

131 ***** Please insert Figure 2 here *****

132 Figure 2: Body sites distribution of badminton injuries

133 The head and eyes are injured in 2.0% of cases in different studies [8], [15]. Most injuries
134 have been shown to occur to the joints and ligaments, such as sprains (35.8%) and strains
135 (35.2%), followed by overuse injuries (i.e., tendons, tissue) (22.4%) and bone fractures (3.8%)
136 (Figure 2).

137 3.4 Identification of injury type

138 A sprain can be defined as a minor ligamentous injury that requires no surgery and causes no
139 major time off from training or competition [11]. Ligamentous injury can be defined as major
140 ligamentous damage that requires surgery and leads to major time off (more than one month)
141 from training or competition [11]. A strain can be defined as muscular fiber, or tendon tears,
142 including acute or chronic tendinopathy [11]. A fracture can be defined as bony damage that
143 results in discontinuity of trabeculae, with radiographic confirmation [11].

144 4. Eye injury

145 It has been shown that the extent of eye injuries depends on the type of sports played in a
146 particular country or area, with racket sports appearing to generate the most eye injuries in
147 Europe and Asia [13], [24]. All injuries were found to be unilateral [24]. In the United Kingdom
148 and Australia, in particular, studies have shown that squash and badminton account for half of
149 all sports-related eye injuries [25]. Whilst in Malaysia, badminton generates two-thirds of all
150 ocular sports injuries [26]. The evolution of badminton playing with an increasing shuttlecock
151 velocity during the last 30 years [27] can be associated with physical and ocular injuries [24].
152 Several research studies have examined the causes and types of eye injuries (Table 3).

153 ***** Please insert Table 3 here *****

154 Table 3: Different eye injuries on badminton. NS: no specify.

155 4.1 Cause of eye injuries

156 Hensley and Paup (1979) have shown that when eye injuries occur by an opponent (65%), by a
157 partner (26%), and self-inflicted (9%) [28]. Generally, 6% are related by shuttlecock, whilst 7%
158 related by racket [15]. Patient records have indicated that eye injuries are generated during
159 doubles matches (78%) [24] (Table 3). Indeed, existing studies have reported that doubles
160 matches are associated with more injuries than singles matches [29]. Injuries in these matches
161 occur when a player turns round to look at his or her partner [25] or when the shaft of the racket
162 head becomes separated from the handle of one of the players [30]. In singles matches, injuries
163 can be seen to occur when a player is close to the net and hit by a shuttlecock from the
164 opponent's smash [28] (Table 3). In these cases, the high speeds involved are enough to cause
165 injury when the shuttlecock hits the eye [24]. The shuttlecock head has a small diameter that
166 fits the human orbits [24].

167 **4.2 Types of related eye injuries**

168 Modifications of racket properties and technology innovation have a great influence on
169 shuttlecock velocity [2]. The speed at which shuttlecocks travel increases with the players' level
170 of skill [31]. Studies have shown that when eye injuries occur, the right eye is involved in 52%
171 of cases, the left in 48% of cases (Table 3). No instances have been recorded in which both eyes
172 are involved [13]. Generally, the injuries are all unilateral with none of the players wearing eye
173 protection [28]. Hyphemia is seen to be the most common eye injury [24], [25], [28], with
174 macular changes, traumatic cataracts, and glaucoma being the main causes of visual impairment
175 in badminton injuries [26] (Table 3).

176 Thus, badminton players and coaches need to be aware of the risk associated with delivering
177 powerful strokes in doubles matches by the opponent or partner. To prevent the occurrence of
178 eye injuries (such as hyphemia), athletes should hold their racket to protect their head or use
179 protective eyewear. The forward players should hold the racket in the front of the face while
180 awaiting the smash [28]. The illusion that contact lenses [13] or glass lenses [28] offer partial
181 protection should be dispelled, they merely complicate an injury. In some sports, there is
182 already an awareness of the risk of eye injuries [13]. However, the lack of knowledge is
183 responsible for athletes failing to use eye protection [13]. The value of ocular protection in sport
184 has already been demonstrated [32]. Eye injuries in sports can easily be prevented with the
185 proper use of protective eyewear [33]. Protective polycarbonate spectacles are available for
186 wearing on the court; these are designed to deflect blows [13]. They merely complicate an injury
187 [13]. While vision loss is uncommon, these injuries can lead to permanently diminished visual
188 function.

5. Upper limb injury

Badminton is a sport that requires a large number of overhead strokes (30%) with clear drop shots and smash shots [27]. Studies have shown that female players play a higher percentage of shots from the back of the court [34] and that the upper extremity injuries that occur are unique to racket sports [35]. A retrospective study found that the incidence rate of injuries is 5.04 per 1000 hours of play, and that the shoulder [11] is the most frequently affected location, followed by the hand (Table 4).

*** Please insert Table 4 here ***

Table 4: Different upper limb injury on badminton. NS: No specify.

5.1 Shoulder pain

Badminton requires a considerable amount of over-shoulder motion, with the shoulder in abduction or external rotation [16]. It has been reported that shoulder pain occurs frequently, as does impingement of the rotator cuff caused by anterior instability of the shoulder joint [36]. A large proportion of badminton players continue to play with an ongoing injury to the shoulder (17-28%) [37]. Studies have observed no differences between male and female players [38]. During the World Mixed Team Championship in 2003, shoulder pain on the dominant side was reported by 52% of players, with 37% of players reporting previous shoulder pain and 20% ongoing pain [38]. With regard to badminton players in Hong Kong, shoulder injuries accounted for 19% of all injuries [11]. Similarly, a Swedish study found that 52% of players had existing or present pain in the dominant shoulder, with 16% of them experiencing ongoing pain [16]. Injury does not prevent a player from playing; however, it does affect the quality of his or her performance [37].

Stroke repetition that is suggestive of an overuse epiphyseal injury to the shoulder may occur as the result of a repetitive explosive action [39]. It has been noted that the repetitive

213 movement from the cocking to the follow-through phases generates a stress to the epiphyseal
214 plate. In fact, a study has shown that the rotator cuff in badminton players on the dominant arm
215 is stronger than that of the non-dominant arm [37]. The ratio between eccentric antagonist and
216 concentric agonist strength is important when analyzing shoulder symptoms experienced by
217 badminton players [40]. During the cocking phase, the ratios of strength were found to be 2.15:1
218 for the dominant side and 1.71:1 for the non-dominant side; whereas the ratios were 0.97:1 for
219 the dominant side and 1.08:1 for the non-dominant side during the deceleration phase [40].

220 Rehabilitation for these players should include muscle-strengthening exercises (i.e.,
221 shoulder stabilizers and rotator cuff muscles), and exercises to avoid loss of motion [16]. The
222 ratio between eccentric antagonist and concentric agonist strength is important when analyzing
223 shoulder symptoms experienced by badminton players [40].

224 **5.2 Elbow injuries**

225 Tennis elbow and golfer's elbow are the most commonly reported diagnoses related to the
226 elbow in badminton players [3] (Table 4). Tennis elbow is mainly caused by lateral
227 epicondylitis [41] whereas golfer's elbow is caused by medial epicondylitis [42]. Training
228 errors are one of most common causes of overuse injuries [42]. Players who have hitting
229 technique problems are at an increased risk of injury [43]. Poor technique can often be related
230 to an incorrect grip or the holding of the racket too tightly by the beginner.

231 **5.3 Hand injuries**

232 Players were found to rarely use a 'wrist snap' [44]; however, they can use it to increase the
233 power of the smash. The grip, the intensive practice of the badminton game and the repetitive
234 hyperextension movements of the wrist are risk factors for scaphoid fractures [45], even without
235 axial load (Table 4). The scaphoid bone is a connecting rod between the two carpal rows and

236 may be exposed to shearing and torsional forces by excessive and repetitive movement of wrist
237 flexion and extension [46].

238 **5.4 Trunk function to prevent injury**

239 Studies have shown that badminton players hold a racket in their dominant hand, which limits
240 their arm position and leads to an asymmetric posture through lateral trunk flexion, especially
241 during overhead strokes [47]. In general, core stability is essential to the control of movements
242 of the trunk and distal segments [48].

243 Trunk sway greatly contributes to a change of direction in the knee adduction movement.
244 The badminton-specific movement in the upper extremity and trunk motion during an overhead
245 stroke may affect the hip and knee joint kinematics and kinetics [49]. During an overhead stroke
246 in the left rear court, players have to laterally bend their trunk to their left side as their arm
247 comes through [50]. Deficits in neuromuscular control of the trunk may contribute to lower
248 extremity joint instability and injury [50]. Neuromuscular training should be carried out to
249 increase trunk and hip control, thus preventing injury to the lower limb [51].

250 Stroke repetition and hitting technique problems can increase the risk of arm injuries. Most
251 players continue to play through the pain, but the discomfort affects their quality of play. The
252 badminton-specific movement engages the trunk, which makes a specific contribution during a
253 stroke, forming a link between lower limb movement and upper limb stroke.

254 **6. Lower limb injury**

255 Injuries are common in badminton, and overuse injuries are frequent, particularly those
256 localized to the lower extremities [7]; in studies, these accounted for 58% of the injuries [6]
257 (Table 5).

258

*** Please insert Table 5 here ***

259

Table 5: Different lower limb injury on badminton. NS: No specify.

260

6.1 Achilles tendon rupture

261

The most severe overuse injuries were found to be tendon related, including Achilles

262

tendinopathy [6], and patella tendinopathies [12]. Indeed, Hess [52] has shown a relatively high

263

incidence of acute Achilles tendon ruptures. Such injuries are a major problem among athletes

264

[53]. Badminton is a sport where tendons are placed under a heavy strain [6]. Existing studies

265

of badminton players and fencers have used magnetic resonance imaging to show that the cross

266

sectional area of the patella tendon on the dominant leg is up to 28% greater than that of the

267

non-dominant patella tendon [54]. Chronic Achilles tendon pain associated with structural

268

tendon changes is often located in the middle portion of the tendon [55].

269

Badminton development has increased the number of hours per person and per day [56],

270

increasing the risk of injuries as well. The cause of Achilles tendon ruptures is based on

271

mechanical and degenerative factors [57] and the weight of the player [58]. The Achilles tendon

272

is most loaded during badminton [6], because of the abrupt repetitive jumping and sprinting

273

movements involved [59]. Studies have shown that Achilles tendon rupture occurs in the middle

274

or at the end of a match or training session in 87% of cases [58]. One reason for this is that

275

players tend to tire at this stage of play. Tiredness can lead to poor muscle coordination and

276

increased tension in the Achilles tendon with acceleration and deceleration [58]. The occurrence

277

of Achilles tendon injuries in athletes has been shown to increase with age [60]. Athletes with

278

acute Achilles tendon ruptures reported previous Achilles tendon pain in 15 to 21% of cases

279

[21].

280

Ultrasound is used in rehabilitation and to diagnose Achilles tendon ruptures and other

281

tendon pathology [61]. This technique has been supplemented by the color Doppler technique

282

for finding and treating hyperemia in tendinopathy in the Achilles tendon [62]. Surgical

283 techniques and rehabilitation programs should lead to a decrease in complications [63], whilst
284 treatment by Kinesio taping is aimed at decreasing tenderness and pain [64]. The majority of
285 players play with orthoses (inserts in the shoes) [56]. However, it has not yet been established
286 that orthoses prevent Achilles tendinopathy or achillodynia [56].

287 **6.2 Anterior cruciate ligament injuries and prevention**

288 Most anterior cruciate ligament (ACL) injuries occur during sports activity (Table 5).
289 According to existing research, up to 70% of all incidents are non-contact injuries [49], whilst
290 ACL injuries account for 37% of all injuries requiring surgically treatment [65]. The greater
291 activation of the knee extensor is a predictor of knee injury, because of increased tension on the
292 ACL [49].

293 Players need to move from back to front and side to side rapidly; they also need to return to
294 the center of the court to prepare for the next shot by performing footwork that is unique to
295 badminton [49]. The injury patterns recorded appear to be the result of frequently performed
296 movements. In badminton, ACL injuries were found to be the result of two injury mechanisms
297 (Table 5). First, the knee opposite the racket-hand side is at risk of injury during a single-leg
298 landing after an overhead stroke. This usually occurs in the backhand side of the court (48%)
299 [47]. The knee of the racket hand side is susceptible to injury because of plant-and-cut
300 movements during side or backward stepping in the forehand side of the court (38%). ACL
301 injury can also be explained by a greater increase in the knee valgus angle and movement during
302 single-leg landing following back-steps to the backhand-side rear than with back-steps to the
303 forehand-side rear [49]. Landing requires high levels of neuromuscular control to maintain
304 stability and performance [66].

305 In order to prevent ACL injuries, it is important to study the biomechanics of players'
306 movements and to put physiological knowledge into action with respect to knee joints [49].

307 Adequate muscular training of the lower extremities is necessary to prevent badminton injuries
308 [7].

309 **6.3 Impact of the lunge on the knee**

310 Lunge motions require a high level of knee dynamic stability; thus, they place a high physical
311 demand on the lower limbs [67]. Two types of lunges exist according to the axe of the foot, the
312 standard one and the “break-foot lunge” [68]. The repetition of lunges on the same leg can lead
313 to players adopting an asymmetric posture [47]. The intensive braking phase of the dominant
314 leg during the net stroke can increase the stress on the Achilles tendon by 6 to 12 times the
315 player’s body weight and by 5 times for the knee patellar tendon [64]. Core stability plays a key
316 role in preventing knee joint injury [50]. The contraction of the core muscles provides a stable
317 base for the movement of the lower extremities [48]. With unbalanced core muscle strength,
318 players are at a higher risk of knee injury [69]. Thus, the trunk position affects the recruitment
319 of the knee flexors [70]. During the performance of forehand and backhand backward lunges,
320 the trunk movement affects the knee joint kinematics [49]. The skill level of players affects
321 their lunge performance [67] (Table 5). The combination of greater knee flexion and a smaller
322 root mean square of knee extensor in the injured player was seen to be the compensatory
323 strategy required to complete the task and avoid injury [48].

324 **7. Conclusion**

325 This review takes a global approach to badminton-related injuries related to the eyes, and upper
326 and lower limbs. Each of these factors may play an important role in the prevention of injuries
327 to badminton players. Future badminton research is likely to continue to be heavily influenced
328 by the evolution of temporal and notational structure. It is apparent that the movement patterns
329 and movement demands of badminton are related to an increase in injuries and the generation

330 of new injuries. Furthermore, it would be of interest to compare badminton with other racket
331 sports.

332 **8. Summary**

333 Studies that have reported on eye injuries have determined the nature of these injuries and
334 the way they occur. They have also suggested possible preventive measures. The main reason
335 for eye injury is shuttlecock impact from an opponent's stroke; thus, by wearing glasses,
336 badminton players can considerably reduce the risk of eye injury. Injuries to the arm and
337 shoulder in badminton are largely due to faulty technique, while leg and back injuries are caused
338 mainly by a lack of strength or mobility. The contribution of the trunk to the prevention of lower
339 limb injuries suggests that specific attention should be paid to this area.

340 In general, the patellar tendon is put under serious stress in badminton [6]. Studies have
341 shown that a substantial number of elite badminton players have patellar tendon pain and
342 'jumper's knee' [71]. Male badminton players have a significantly higher incidence of painful
343 patellar tendons [71].

344 Rapid changes in the direction of movement, jumps and lunges can all result in injuries to
345 the Achilles tendon and anterior cruciate ligament. Tendons are put under high pressure during
346 each movement and, in general, injuries occur at the end of a training session or tournament.
347 Fatigue influences the way that lunges are performed and the way that the jump is received by
348 making these tendons less powerful and more unstable.

349 Such knowledge could help coaches and fitness trainers focus on the specific muscular
350 activities required to prevent injuries. For example, they could design a training program that
351 increases body strength to prevent injuries to badminton players. The relationship between
352 coaches and scientists, particularly in terms of biomechanics and physiotherapy, will help
353 improve performance and prevent injury.

354 **Disclosure of interest**

355 The authors declare that they have no competing interest.

Study	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m ²)	Experience (years)
Boesen et al. [6]	25.9 ± 3.2	76.4 ± 6.4	183.5 ± 6.6	22.7 ± 1.0	18.8 ± 4.1
Fahlström et al. [7]	32.9 ± NS	NS	NS	NS	24.5 ± NS
Fahlström et al. [16]	43.1 ± 7.0	NS	NS	NS	22.1 ± 10.9
Fahlström et al. [53]	24.4 ± 4.3	76.9 ± 8.8	183.0 ± 6.6	22.9 ± 1.4	15.6 ± 4.4
Fahlström et al. [72]	44.7 ± 6.1	NS	NS	25.0 ± 3.2	29.8 ± 4.3
Fahlström et al. [38]	23.5 ± 4.3	NS	NS	NS	14.2 ± 4.9
Fu [73]	20.1 ± 1.9	71.1 ± 7.6	179.1 ± 3.4	NS	10.7 ± 2.5
Fu et al [74]	20.1 ± 1.9	71.1 ± 7.6	179.1 ± 3.4	10.7 ± 2.5	NS
Hensley and Paup [15]	33 ± 13.1	73.8 ± 9.2	177.8 ± 7.3	NS	13.4 ± 10.1
Huang et al. [48]	24.9 ± 5.2	75.0 ± 11.9	178.0 ± 8.7	13.6 ± 2.6	11.6 ± 5.3
Koenig et al. [71]	25.0 ± 3.5	73.5 ± 9.2	179.1 ± 14.0	22.5 1.7	17.9 ± 4.3

356 Table 1: Male players characteristics on the different studies. NS: no specify.

Study	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m ²)	Experience (years)
Fahlström et al. [7]	25.8 ± NS	NS	NS	NS	22.2 ± NS
Fahlström et al. [16]	44.3 ± 12.1	NS	NS	NS	26.8 ± 13.9
Fahlström et al. [53]	21.9 ± 4.1	64.0 ± 4.9	170.1 ± 3.7	22.1 ± 1.3	13.3 ± 4.3
Fahlström et al. [72]	42.7 ± 5.4	NS	NS	25.9 ± 4.8	29.1 ± 3.1
Hensley and Paup [15]	27 ± 8.2	57.2 ± 6.2	165.1 ± 7.2	NS	9.5 ± 8.4
Huang et al. [48]	21.4 ± 2.9	54.6 ± 5.1	166.8 ± 4.5	19.6 ± 2.1	7.3 ± 2.3

357 Table 2: Female players characteristics on the different studies. NS: no specify.

Study	Players	Main injury (%)	Causes (%)
Chandran [26]	63 novices	Hyphaemia (78), traumatic mydriasis (54), commotion retinae (19), haematoma of lid (14), corneal abrasion (13), vitreous haemorrhage (13), subconjunctival haemorrhage (6), laceration of lids (3)	Struck by racket (9), struck by shuttlecock (54), double play (44), single play (19)
Jones [18]	45 males and 7 females (range 11-68)	Skin lacerations (19.2), blowout fracture of orbit (9.6), macroscopic hyphaemia (59.6), raised intraocular pressure (23), iris tears or dialysis (9.6), significant angle recession (15.4), cataract (1.9), vitreous haemorrhage (13.5), commotion retinae (23), retinal break (7.7), choroidal rupture (1.9), penetrating injury (5.8)	Struck by shuttlecock (73.1), instrument (19.2), opponents (7.7)
Kelly [28]	4 males and 2 females	Corneoscleral perforation (16), uveal prolapse (16), glass intraocular (16), hyphaemia (50), sphincter pupillae tear (16), retinal dialysis and detachment (16), choroidal rupture involving macula (16), angle recession glaucoma (33), vitreous haemorrhage (16), optic atrophy (16)	Struck by racket (16), struck by shuttlecock (84)
Zamora and Harvey [24]	14 males and 9 females	Iridocyclitis / iritis (48), secondary glaucoma (26), hyphaemia (22), posterior vitreous detachment (13), eyelid contusion (9), corneal abrasion (9), corneal oedema (9), cystoid macular oedema (4), peripheral intraretinal haemorrhage (4), lid laceration (4), commotio retina (4), vitreous haemorrhage (4), berlin's oedema (4), subconjunctival haemorrhage (4), bulbar congestion, conjunctivitis (4), iridoplegia (4), macular hole (4), retinal detachment (4)	Struck by racket (26), struck by shuttlecock (74)

358 Table 3: Different eye injuries on badminton. NS: no specify.

Study	Players	Main injury (%)	Causes (%)
Shoulder			
Boyd and Batt [39]	1 elite junior (15 years)	Stress fracture of the proximal humeral epiphysis	Overuse
Fahlström et al. [38]	96 males and 92 females	On-going shoulder pain (20)	Overuse
Fahlström et al. [16]	73 inexperienced and 49 professional players	Pain (65)	Overuse
Goh et al. [76]	34 males and 24 females (range 13-16)	Sprain (2), fracture (2)	Acute
Jafari et al. [75]	23 males and 7 females professional	Muscle tendon (18.8), joint ligaments (3.1), bone (3.1)	NS
Elbow			
Jafari et al. [75]	23 males and 7 females professional	Muscle tendon (12.5), joint ligaments (9.4), bone (3.1)	NS
Wrist			
Jafari et al. [75]	23 males and 7 females professional	Muscle tendon (65.6), joint ligaments (43.8), bone (12.5)	NS
Finger			
Brutus and Chahidi [45]	1 inexperienced (23 years)	Scaphoid fracture	Stress fracture

Fukuda et al. [77]	1 females (14 years)	Stress fracture of the second metacarpal bone	Overuse
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359 Table 4: Different upper limb injury on badminton. NS: No specify.

Study	Players	Main injury (%)	Causes (%)
Leg			
Goh et al. [76]	34 males and 24 females (range 13-16)	Sprain (40), fracture (3), contusion (5) apophysistis (10), bursitis (3), tendinopathy (7), stress fracture (5), patellofemoral joint syndrome (2)	Acute and overuse
Shariff et al. [3]	190 players	Patellar tendinopathy (42.7), muscle strain (11.8) meniscus or ligamentous injuries (10.9)	NS
Yung et al. [11]	14 males and 16 females elite players (range 13-28)	Strains (64), sprains (14), facet injury (14)	NS
Knee			
Boesen et al. [78]	96 semi-professional	Dominant tendon pain (23), non-dominant tendon pain (13)	NS
Chard and Lachmann [41]	74 males and 54 females college (4: 15 and under years, 60: 16-25 years, 64: 26 and over)	Collateral ligament (28), cruciate ligament (12.5), meniscal injury (25)	NS
Couppé et al. [54]	7 professionals	Tendinopathy	Overuse and repetitive load
Fahlström et al. [7]	67 males and 11 females (range 11-52)	Knee injuries (16.7)	Overuse
Huang et al. [48]	17 injured players	Knee pain (100)	NS
Jafari et al. [75]	23 males and 7 females professional	Muscle tendon (56.2), joint ligaments (28.1), bone (9.4)	NS
Kimura et al. [47]	6 males and 15 females	Anterior cruciate ligament	Single leg landing (48), plant-and-cut (38)

Koenig et al. [70]	50 males and 22 females professional	Painful knee tendons (62.5)	Overuse
Kroner et al. [8]	136 males and 72 females (range 7-72)	Joint ligament (58.5), muscle injuries strains/tears (19.8)	Falling (62), struck by shuttlecock or racket (8)
Achilles tendon			
Boesen et al. [78]	96 semi-professional	Dominant tendon pain (15), non-dominant tendon pain (8)	NS
Boesen et al. [56]	50 males and 22 females professional	Dominant tendon pain (18), non-dominant tendon pain (16)	NS
Fahlström et al. [7]	67 males and 11 females (range 11-52)	Achilles tendon rupture (34.6)	Overuse
Fahlström et al. [71]	25 males and 7 females professional	Achilles tendon pain (22)	Overuse
Fahlström et al. [53]	41 males and 25 females	Overuse injury (5), bursitis (6), Achilles tendinitis (4)	Overuse
Houshian et al. [59]	192 males and 54	Achilles tendon rupture (46.29)	Overuse
Hoy et al. [5]	1650 males and 970 females (520 males, 293 females under 18 years; 243 males, 179 females between 18 and 25; 887 males, 498 females above 25 years)	Sprain (2), tear (0.4), rupture Achilles tendon (0.5), fracture (0.2)	NS
Lee and Yoo [64]	1 inexperienced (22 years)	Achilles tendon pain	Overuse
Malliaras et al. [62]	24 recreational and 12 elite males, 13 recreational and 12 elite females	Parallel tendons pain (8), spindle-shaped tendons pain (21)	Overuse
Ankle			

Fahlström et al. [7]	67 males and 11 females (range 11-52)	Spains/fractures (29.5)	Overuse
Jafari et al. [75]	23 males and 7 females professional	Muscle tendon (31.2), joint ligaments (21.9), bone (12.5)	NS
Kroner et al. [8]	136 males and 72 females (range 7-72)	Joint ligament (58.5), muscle injuries strains/tears (19.8)	Falling (62), struck by shuttlecock or racket (8)

360 Table 5: Different lower limb injury on badminton. NS: No specify.

361 **References**

- 362 [1] Phomsoupha M, Laffaye G. The science of badminton: game characteristics,
363 anthropometry, physiology, visual fitness and biomechanics. *Sport Med.*
364 2015;45(4):473–95.
- 365 [2] Phomsoupha M, Laffaye G, Cohen C, Clanet C. How to use the elasticity of a badminton
366 racket to increase its speed by 80%? *Comput Methods Biomech Biomed Engin.*
367 2015;18(Suppl 1):2028–9.
- 368 [3] Shariff AH, George J, Ramlan AA. Musculoskeletal injuries among Malaysian
369 badminton players. *Singapore Med J.* 2009;50(11):1095–7.
- 370 [4] Backx F, Erich W, Kemper A, Verbeek A. Sports injuries epidemiologic study. *Am J*
371 *Sports Med.* 1989;17(2):234–40.
- 372 [5] Hoy K, Lindblad BE, Terkelsen CJ, Helleland HE, Terkelsen CJ. Badminton injuries--a
373 prospective epidemiological and socioeconomic study. *Br J Sports Med.*
374 1994;28(4):276–9.
- 375 [6] Boesen AP, Boesen MI, Koenig MJ, Bliddal H, Torp-Pedersen S, Langberg H. Evidence
376 of accumulated stress in Achilles and anterior knee tendons in elite badminton players.
377 *Knee Surgery, Sport Traumatol Arthrosc.* 2011;19(1):30–7.
- 378 [7] Fahlström M, Björnstig U, Lorentzon R. Acute badminton injuries. *Scand J Med Sci*
379 *Sport.* 1998;8:145–8.
- 380 [8] Kroner K, Schmidt S, Nielsen A, Yde J, Jakobsen BW, Moller-Madsen B, et al.
381 Badminton injuries. *Br J Sports Med.* 1990 Sep 1;24(3):169–72.
- 382 [9] Engebretsen L, Soligard T, Steffen K, Alonso JM, Aubry M, Budgett R, et al. Sports
383 injuries and illnesses during the London summer Olympic Games 2012. *Br J Sports Med.*

- 384 2013;47(7):407–14.
- 385 [10] Jørgensen U, Winge S. Injuries in badminton. *Sport Med.* 1990;10(1):59–64.
- 386 [11] Yung PSH, Chan RHK, Wong FCY, Cheuk PWL, Fong DTK. Epidemiology of injuries
387 in Hong Kong elite badminton athletes. *Res Sport Med.* 2007;15:133–46.
- 388 [12] Jørgensen U, Winge S. Epidemiology of badminton injuries. *Int J Sports Med.*
389 1987;8(6):379–82.
- 390 [13] Jones NP. One year of severe eye injuries in sport. *Eye (Lond).* 1988;2:484–7.
- 391 [14] Weir M, Watson W. A twelve month study of sports injuries in one Irish school. *Ir J Med*
392 *Sci.* 1996;165(3):165–9.
- 393 [15] Hensley LD, Paup DC. A survey of badminton injuries. *Br J Sports Med.*
394 1979;13(4):156–60.
- 395 [16] Fahlström M, Söderman K. Decreased shoulder function and pain common in
396 recreational badminton players. *Scand J Med Sci Sport.* 2007;17(3):246–51.
- 397 [17] MacEwen CJ. Sport associated eye injury: a casualty department survey. *Br J*
398 *Ophthalmol.* 1987;71(9):701–5.
- 399 [18] Jones NP. Eye injuries in sport: an increasing problem. *Br J Sports Med.*
400 1987;21(4):168–70.
- 401 [19] McGowan CJ, Pyne DB, Thompson KG, Rattray B. Warm-up strategies for sport and
402 exercise: mechanisms and applications. *Sport Med.* 2015;45(11):1523–46.
- 403 [20] Laoruengthana A, Poosamsai P, Fangsanau T, Supanpaiboon P, Tungkasamesamran K.
404 The epidemiology of sports injury during the 37th Thailand National Games 2008 in
405 Phitsanulok. *J Med Assoc Thai.* 2009;92 Suppl 6:204–10.
- 406 [21] Fahlström M, Björnstig U, Lorentzon R. Acute Achilles tendon rupture in badminton

- 407 players. *Am J Sports Med.* 1998;26(3):467–70.
- 408 [22] Reeves J, Hume PA, Gianotti S, Wilson B, Ikeda E. A retrospective review from 2006
409 to 2011 of lower extremity injuries in badminton in New Zealand. *Sports.* 2015;3(2):77–
410 86.
- 411 [23] Wassinger CA, McKinney H, Roane S, Davenport MJ, Owens B, Breese U, et al. The
412 influence of upper body fatigue on dynamic standing balance. *Int J Sports Phys Ther.*
413 2014;9(1):40–6.
- 414 [24] Zamora VK, Harvey U. Multicenter survey of badminton-related eye injuries. *Philipp J*
415 *Ophtalmol.* 2006;31(1):26–8.
- 416 [25] Barr A, Baines PS, Desai P, MacEwen CJ. Ocular sports injuries: the current picture. *Br*
417 *J Sports Med.* 2000;34(6):456–8.
- 418 [26] Chandran S. Ocular hazards of playing badminton. *Br J Ophthalmol.* 1974;58(8):757–
419 60.
- 420 [27] Laffaye G, Phomsoupha M, Dor F. Changes in the game characteristics of a badminton
421 match: a longitudinal study through the Olympic Game finals analysis in men’s singles.
422 *J Sport Sci Med.* 2015;14:584–90.
- 423 [28] Kelly SP. Serious eye injury in badminton players. *Br J Ophthalmol.* 1987;71:746–7.
- 424 [29] Jones NP. Eye injury in sport. *Sport Med.* 1989;7(3):163–81.
- 425 [30] Pappano D, Murray E, Cimpello LB, Connors G. Penetrating missile-type head injury
426 from a defective badminton racquet. *Eur J Pediatr.* 2009;168:749–51.
- 427 [31] Phomsoupha M, Laffaye G. Shuttlecock velocity during a smash stroke in badminton
428 evolves linearly with skill level. *Comput Methods Biomech Biomed Engin.*
429 2014;17(Suppl 1):140–1.

- 430 [32] Pashby T. Eye injuries in canadian amateur hockey. *Can J Ophthalmol.* 1985;20(1):2–4.
- 431 [33] Capão Filipe JA, Rocha-Sousa A, Falcão-Reis F, Castro-Correia J. Modern sports eye
432 injuries. *Br J Ophthalmol.* 2003;87(11):1336–9.
- 433 [34] Abian-vicen J, Castanedo A, Abian P, Sampedro J. Temporal and notational comparison
434 of badminton matches between men’s singles and women’s singles. *Int J Perform Anal*
435 *Sport.* 2013;13(2):310–20.
- 436 [35] Lees A. Science and the major racket sports: a review. *J Sports Sci.* 2003;21(9):707–32.
- 437 [36] Ticker JB, Fealy S, Fu FH. Instability and impingement in the athlete’s shoulder. *Sport*
438 *Med.* 1995;19(6):418–26.
- 439 [37] Arora M, Shetty SH, Khedekar RG, Kale S. Over half of badminton players suffer from
440 shoulder pain: Is impingement to blame? *J Arthrosc Jt Surg.* 2015;2(1):33–6.
- 441 [38] Fahlström M, Yeap JS, Alfredson H, Soderman K. Shoulder pain – a common problem
442 in world-class badminton players. *Scand J Med Sci Sport.* 2006;16:168–73.
- 443 [39] Boyd KT, Batt ME. Stress fracture of the proximal humeral epiphysis in an elite junior
444 badminton player. *Br J Sports Med.* 1997;31(3):252–3.
- 445 [40] Ng GYF, Lam PCW. A study of antagonist/agonist isokinetic work ratios of shoulder
446 rotators in men who play badminton. *J Orthop Sports Phys Ther.* 2002;32(8):399–404.
- 447 [41] Chard MD, Lachmann SM. Racquet sports--patterns of injury presenting to a sports
448 injury clinic. *Br J Sports Med.* 1987;21(4):150–3.
- 449 [42] Karahan AY, Yesilyurt S, Kaydok E, Olcucu B, Bagcaci S. Kienbock’s disease that
450 manifested in a badminton player: case report. *Int J Sport Sci.* 2013;3(4):132–4.
- 451 [43] Mills R. Injuries in badminton. *Br J Sports Med.* 1977;11(1):51–3.
- 452 [44] Gowitzke BA, Waddell DB. Myths and realities in badminton and tennis strokes. In: 3

- 453 International Symposium on Biomechanics in Sports. 1985. p. 52–5.
- 454 [45] Brutus JP, Chahidi N. Could this unusual scaphoid fracture occurring in a badminton
455 player be a stress fracture? *Chir Main.* 2004;23:52–4.
- 456 [46] Inagaki H, Inoue G. Stress fracture of the scaphoid combined with the distal radial
457 epiphysiolysis. *Br J Sports Med.* 1997;31(3):256–7.
- 458 [47] Kimura Y, Ishibashi Y, Tsuda E, Yamamoto Y, Tsukada H, Toh S. Mechanisms for
459 anterior cruciate ligament injuries in badminton. *Br J Sports Med.* 2010;44(15):1124–7.
- 460 [48] Huang MT, Lee HH, Lin CF, Tsai YJ, Liao JC. How does knee pain affect trunk and
461 knee motion during badminton forehand lunges? *J Sports Sci.* 2014;32(7):690–700.
- 462 [49] Kimura Y, Ishibashi Y, Tsuda E, Yamamoto Y, Hayashi Y, Sato S. Increased knee valgus
463 alignment and moment during single-leg landing after overhead stroke as a potential risk
464 factor of anterior cruciate ligament injury in badminton. *Br J Sports Med.*
465 2012;46(3):207–13.
- 466 [50] Kimura Y, Tsuda E, Hiraga Y, Maeda S, Sasaki S, Sasaki E, et al. Trunk motion and
467 muscular strength affect knee valgus moment during single-leg landing after overhead
468 stroke in badminton. *Br J Sports Med.* 2014;48(7):620–620.
- 469 [51] Myer GD, Ford KR, McLean SG, Hewett TE. The effects of plyometric versus dynamic
470 stabilization and balance training on lower extremity biomechanics. *Am J Sports Med.*
471 2006;34(3):445–55.
- 472 [52] Hess GW. Achilles tendon rupture: a review of etiology, population, anatomy, risk
473 factors, and injury prevention. *Foot Ankle Spec.* 2010;3(1):29–32.
- 474 [53] Fahlström M, Lorentzon R, Alfredson H, Fahlstro M. Painful conditions in the Achilles
475 tendon region in elite badminton players. *Am J Sports Med.* 2002;30(1):51–4.
- 476 [54] Couppé C, Kongsgaard M, Aagaard P, Vinther A, Boesen M, Kjær M, et al. Differences

- 477 in tendon properties in elite badminton players with or without patellar tendinopathy.
478 Scand J Med Sci Sport. 2013;23(2):89–95.
- 479 [55] Alfredson H, Lorentzon R. Chronic Achilles tendinosis: recommendations for treatment
480 and prevention. Sport Med. 2000;29(2):135–46.
- 481 [56] Boesen MI, Boesen A, Koenig MJ, Bliddal H, Torp-Pedersen S. Ultrasonographic
482 investigation of the Achilles tendon in elite badminton players using color Doppler. Am
483 J Sports Med. 2006;34(12):2013–21.
- 484 [57] Khan KM, Cook JL, Kannus P, Maffulli N, Bonar SF. Time to abandon the “tendinitis”
485 myth. Br Med J. 2002;324(7338):626–7.
- 486 [58] Kaalund S, Lass P, Hogsaa B, Nohr M. Achilles tendon rupture in badminton. Br J Sports
487 Med. 1989;23(2):102–4.
- 488 [59] Houshian S, Tscherning T, Riegels-Nielsen P. The epidemiology of achilles tendon
489 rupture in a Danish county. Injury. 1998;29(9):651–4.
- 490 [60] Saltzman CL, Tearse DS. Achilles tendon injuries. J Am Acad Orthop Surg.
491 1998;6(5):316–25.
- 492 [61] Aström M, Gentz CF, Nilsson P, Rausing A, Sjöberg S, Westlin N. Imaging in chronic
493 achilles tendinopathy: a comparison of ultrasonography, magnetic resonance imaging
494 and surgical findings in 27 histologically verified cases. Skelet Radiol. 1996;25(7):615–
495 20.
- 496 [62] Malliaras P, Voss C, Garau G, Richards P, Maffulli N. Achilles tendon shape and
497 echogenicity on ultrasound among active badminton players. Scand J Med Sci Sport.
498 2012;22(2):149–55.
- 499 [63] Sjöström M, Nyström B. Achilles tendon injury. Virchows Arch A. 1983;399:177–89.
- 500 [64] Lee JH, Yoo WG. Treatment of chronic Achilles tendon pain by Kinesio taping in an

- 501 amateur badminton player. *Phys Ther Sport*. 2012;13(2):115–9.
- 502 [65] Uchiyama E. Sports injuries in different athletic events, authored by national team
503 physicians. In: Hayashi M, Iwasaki Y, editors. *Badminton*. Nankodo. Tokyo; 2007. p.
504 180–5.
- 505 [66] Loram ID, Lakie M. Human balancing of an inverted pendulum: position control by
506 small, ballistic-like, throw and catch movements. *J Physiol*. 2002;540(Pt 3):1111–24.
- 507 [67] Kuntze G, Mansfield N, Sellers W. Biomechanical analysis of common lunge tasks in
508 badminton. *J Sports Sci*. 2010 Jan;28(2):183–91.
- 509 [68] Phomsoupha M, Deslauriers S, Tanneau M, Ibrahime S. Vertical ground reactions of two
510 types of lunges according to foot axis. *Comput Methods Biomech Biomed Engin*.
511 2019;22(Suppl 1):S260-262.
- 512 [69] Devlin L. Recurrent posterior thigh symptoms detrimental to performance in rugby
513 union: predisposing factors. *Sport Med*. 2000;29(4):273–87.
- 514 [70] Farrokhi S, Pollard CD, Souza RB, Chen YJ, Reischl S, Powers CM. Trunk position
515 influences the kinematics, kinetics, and muscle activity of the lead lower extremity
516 during the forward lunge exercise. *J Orthop Sport Phys Ther*. 2008;38(7):403–9.
- 517 [71] Koenig MJ, Torp-Pedersen S, Boesen MI, Holm CC, Bliddal H. Doppler
518 ultrasonography of the anterior knee tendons in elite badminton players: colour fraction
519 before and after match. *Br J Sports Med*. 2010;44(2):134–9.
- 520 [72] Fahlström M, Lorentzon R, Alfredson H. Painful conditions in the Achilles tendon
521 region: a common problem in middle-aged competitive badminton players. *Knee
522 Surgery, Sport Traumatol Arthrosc*. 2002;10(1):57–60.
- 523 [73] Fu WJ. The role of footwear on plantar pressure performance during badminton
524 movements. *Appl Mech Mater*. 2011;55–57:1675–8.

- 525 [74] Fu W, Liu Y, Wei Y. The characteristics of plantar pressure in typical footwork of
526 badminton. *Footwear Sci.* 2009;1:113–5.
- 527 [75] Jafari A, Masoud MM, Golami M, Mina MM. The prevalence and causes of sport injuries
528 in well-trained badminton players of Iran. *Int J Basic Sci Appl Res.* 2012;3(1):40–4.
- 529 [76] Goh SL, Mokhtar AH, Mohamad Ali MR. Badminton injuries in youth competitive
530 players. *J Sports Med Phys Fitness.* 2013;53(1):65–70.
- 531 [77] Fukuda K, Fujioka H, Fujita I, Uemoto H, Hiranaka T, Tsuji M, et al. Stress fracture of
532 the second metacarpal bone in a badminton player. *Kobe J Med Sci.* 2008;54(3):159–62.
- 533 [78] Boesen AP, Boesen MI, Torp-Pedersen S, Christensen R, Boesen L, Holmich P, et al.
534 Associations between abnormal ultrasound color Doppler measures and tendon pain
535 symptoms in badminton players during a season: a prospective cohort study. *Am J Sports*
536 *Med.* 2012;40(3):548–55.



