Prevalence of Jumper's Knee Among Elite Athletes From Different Sports

A Cross-sectional Study

Øystein B. Lian,*† MD, Lars Engebretsen,*‡ MD, PhD, and Roald Bahr,*§ MD, PhD
*From the *Oslo Sport Trauma Research Center, Norwegian University of Sport and Physical Education, Oslo, Norway, †Kristiansund Hospital, Kristiansund, Norway, and the ‡Orthopaedic Center, Ullevål University Hospital, Oslo, Norway*

Background: The prevalence of jumper's knee across different sports has not been examined, and it is not known if there is a gender difference. Data from surgical case series indicate that there may be a high prevalence in sports with high speed and power demands.

Hypothesis: The aim of this study was to estimate the prevalence of jumper's knee in different sports among female and male athletes and to correlate the prevalence to the loading characteristics of the extensor mechanism in these sports.

Study Design: Cross-sectional study; Level of evidence, 4.

Methods: The authors examined approximately 50 Norwegian male and female athletes at the national elite level from each of the following 9 sports: athletics (male athletes: high jump, 100- and 200-m sprint), basketball (male athletes), ice hockey (male athletes), volleyball (male athletes), orienteering (male athletes), road cycling (male athletes), soccer (male and female athletes), team handball (male and female athletes), and wrestling (male athletes). The examination included an interview on individual characteristics (weight, age, height, and training background), a clinical examination, and self-recorded Victorian Institute of Sport Assessment score from 0 (worst) to 100 (best).

Results: The overall prevalence of current jumper's knee was 14.2% (87 of 613 athletes), with a significant difference between sports with different performance characteristics (range, 0%-45%). In addition, 51 athletes (8%) reported previous symptoms. The prevalence of current symptoms was highest in volleyball (44.6% ± 6.6%) and basketball (31.9% ± 6.8%), whereas there were no cases in cycling or orienteering. The prevalence of current jumper's knee was lower among women (5.6% ± 2.2%) compared with men (13.5% ± 3.0%; χ^2 test, $P = .042$). The duration of symptoms among athletes with current jumper's knee (n = 87) was 32 ± 25 (standard deviation) months, with a Victorian Institute of Sport Assessment score of 64 ± 19.

Conclusion: The prevalence of jumper's knee is high in sports characterized by high demands on speed and power for the leg extensors. The symptoms are often serious, resulting in long-standing impairment of athletic performance.

Keywords: knee injuries; epidemiology; risk factors; patellar tendinopathy

The prevalence of jumper's knee in different sports is mostly unknown. However, among male volleyball players at the elite level, the prevalence is 40% to 50%.[13,14,24] Publications from studies on the outcome after surgery suggest that the prevalence is high in sports with high demands on speed and power, such as volleyball, soccer, and athletics.[17,27,31] As sports physicians, it seems that we see an increasing number of athletes affected by this condition, as well as more serious and long-standing complaints among those athletes diagnosed with jumper's knee. Many athletes have to reduce their training and competition levels for long periods of time, which impairs their performance levels. Despite the currently available treatment options,[5,11,26] some athletes are affected to such a degree that they have to quit sports activities. In this way, jumper's knee may seriously impair an athletic career.

The aim of the present study was to estimate the prevalence of jumper's knee in different sports and to correlate the prevalence to the sport-specific performance characteristics of these sports.[24,25] Some of the sports included were selected based on data from surgical case series,[17,27,31]

§Address correspondence to Roald Bahr, MD, PhD, Oslo Sport Trauma Research Center, Norwegian University of Sport and Physical Education, PO Box 4014, Ullevål Stadion, 0806 Oslo, Norway (e-mail: roald@nih.no).

No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 33, No. 4
DOI: 10.1177/0363546504270454

whereas others were selected to represent sports that were thought to typify different performance characteristics. Moreover, because the prevalence among female athletes is unknown, we wanted to examine if there is a gender difference in the risk for jumper's knee. We chose to include athletes from female team handball and soccer because these are the female team sports in Norway in which the training loads are highest and so are comparable to those of male athletes in the same sports. In addition, soccer and team handball are sports characterized by high loads on the extensor mechanism, which is thought to make the athletes susceptible to jumper's knee.

METHOD

Study Design

This investigation was designed as a cross-sectional study among Norwegian athletes at the national elite level from different sports. Male athletes from 9 different sports were examined: athletics (high jump, 100- and 200-m sprint), basketball, ice hockey, orienteering, road cycling, soccer, team handball, volleyball, and wrestling. In addition, female athletes from 2 of the same sports were examined: team handball and soccer. We wanted to examine approximately 50 athletes in each sport, to provide a precision of 2% to 7% (proportion SE) for the prevalence estimate in each group. In the team sports (basketball, ice hockey, team handball, volleyball, and soccer), teams from the largest cities were invited to take part in the investigation, and all invited teams agreed to take part. The teams were examined toward the end of their competitive seasons. In the individual sports (athletics, orienteering, road cycling, wrestling), we asked athletes participating in the national championships, which were organized during the peak competition seasons, to take part in the study. All athletes who were present when we visited their teams and all athletes we approached in the individual sports agreed to take part in the study. The study was approved by the regional committee for research ethics, participation was voluntary, and consent was obtained.

Interview and Clinical Examination

Each athlete went through a standardized interview, and the information requested from each athlete included age, height, weight, and number of years participating in organized athletic training. In the team sports, we registered the number of years of participation in the top 2 divisions of the Norwegian league systems; in the individual sports, we registered the number of years of participation at the national championship level. All athletes were asked to report the number of training hours per week during the competition season (sport-specific training, weight training, jump training, and other types of training).

All athletes were also interviewed regarding present and former knee injuries and complaints. Those with current knee complaints compatible with jumper's knee went through a standard knee examination, which was conducted by 8 different sports medicine specialists. The following diagnostic criteria for jumper's knee were used: history of pain localized to the lower patellar pole or insertion of the quadriceps tendon in connection with athletic activity, and distinct palpation tenderness corresponding to the painful area.[3] The diagnosis was based on a typical history and clinical findings alone because imaging techniques such as MRI and ultrasonography have shown low specificity, sensitivity, and positive predictive value in diagnosing jumper's knee.[7,9,19,24] Previous jumper's knee was diagnosed based on history alone. To assess the severity of the condition, the athletes diagnosed with current jumper's knee also self-recorded their Victorian Institute of Sport Assessment (VISA) scores.[34] This is a validated pain and function index with a high score of 100 (no symptoms) and low score of 0 (maximum symptoms) that has been developed specifically for this purpose and has been shown to be a valid measure of symptoms.[32]

Data Analysis

For continuous variables, the results are given as means ± SD, unless otherwise noted. Proportions are reported with the corresponding SE, where relevant. Prevalence was compared between groups using Pearson chi-square tests. Multiple logistic regression analysis was used to test the effect of potential risk factors for patellar tendinopathy (age, height, weight, experience at the elite level, and volume of sport-specific training, weight training, and jump training), adjusting for differences between sports. Comparisons of continuous data between groups were done using analysis of variance (ANOVA) or unpaired *t* tests, as noted in the Results. An alpha level of .05 was considered significant.

RESULTS

The overall prevalence of current jumper's knee was 14.2% ± 1.4% (87 of 613 athletes). Of the 87 athletes with current symptoms, 37 had bilateral symptoms, whereas 30 athletes had symptoms from the right side only, and 20 athletes had symptoms from the left side only. This finding means that the prevalence of current jumper's knee affecting the right knee was 10.9% (67 players) and affecting the left knee was 9.3% (57 players). In addition, 51 athletes (8.3%) reported previous symptoms of jumper's knee affecting one or both legs, resulting in a prevalence of current or previous symptoms of 22.5% (138 of 613 athletes). Only 1 athlete with a diagnosis of current jumper's knee localized the pain to the quadriceps tendon insertion at the upper patellar pole, and the rest localized the pain to the patellar tendon.

As shown in Figure 1, there were significant differences in the prevalence of current jumper's knee (χ^2 test, $P < .001$), as well as in the prevalence of previous symptoms (χ^2 test, $P < .001$). The prevalence of current symptoms was highest in volleyball with 44.6% ± 6.6% and in basketball with 31.9% ± 6.8%, whereas there were no cases in cycling or orienteering. Also, the prevalence of current jumper's

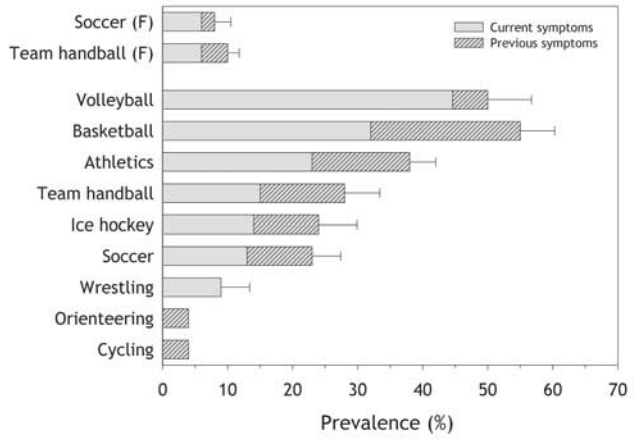

Figure 1. Prevalence (%) of current (gray bars) and previous (hatched bars) symptoms of jumper's knee. The results for female athletes (F) are shown in the 2 upper bars; the rest of the results are for male athletes. Error bars denote SE.

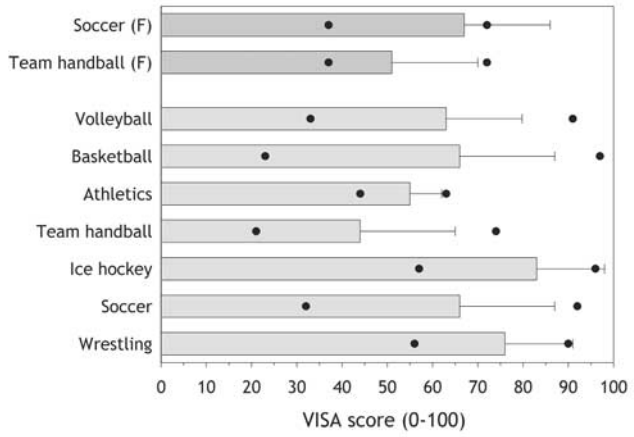

Figure 2. The Victorian Institute of Sport Assessment (VISA) scores for players with current symptoms of jumper's knee in the various sports groups. For players with bilateral symptoms, the lowest value (worst knee) has been used. The top 2 hatched bars show the results for female athletes (F) from soccer and team handball; the gray bars show the results for male athletes. No results are given for orienteering and cycling because there were no athletes with current symptoms in these groups. The bars and error bars denote the mean and SD. In addition, the filled circles show the lowest and highest values in each group.

knee was lower among women, with 5.6% ± 2.2% (6 of 107 team handball and soccer players) compared with a combined prevalence of 13.5% ± 3.0% (18 of 133) in the corresponding male sports (χ^2 test, $P = .042$).

The mean symptom duration among athletes with current jumper's knee was 32 ± 25 months (range, 1-144 months; n = 87). There was a significant difference in symptom duration between the 9 different sports (analysis of variance, $P = .04$). Moreover, there was no difference (t test, $P = .48$) in the duration of symptoms between female (22 ± 12 months; n = 6) and male athletes (28 ± 21 months; n = 55).

The mean VISA score reported across sports and genders was 64 ± 19. As seen in Figure 2, the VISA score reported by players with current symptoms of jumper's knee was significantly different between sports (ANOVA, $P = .003$). The lowest VISA score was reported by male team handball players and the highest by ice hockey players. However, there was no gender difference. The VISA score in female team handball and soccer was 59 ± 15, compared with 58 ± 23 in the same male sports (ANOVA, $P = .9$).

The number of years of participation in organized training was 15.2 ± 5.1, with 6.1 ± 4.2 years at the elite level (Table 1). The number of hours with sport-specific training was 11.8 ± 3.9 (Table 2). There was no significant difference in these variables between athletes with current jumper's knee and those without. However, athletes with current jumper's knee weighed more (83.6 ± 11.6 kg vs 77.3 ± 11.9 kg; $P < .001$), were taller (186 ± 9.5 cm vs 181 ± 9.2 cm; $P < .001$), and did significantly more weight training (3.5 ± 2.4 h/wk vs 2.5 ± 2.1 h/wk; $P < .001$) and jump training (1.1 ± 1.8 h/wk vs 0.5 ± 1.0 h/wk; $P < .001$).

The comparison between athletes with current jumper's knee and those without in each specific sport showed that in basketball, the athletes with jumper's knee did significantly more sport-specific training than did those without jumper's knee (14.7 ± 2.7 h/wk vs 12.3 ± 2.5 h/wk; $P = .005$). In male handball, the athletes with jumper's knee did significantly more plyometric training compared with those without jumper's knee (0.7 ± 1.0 h/wk vs 0.2 ± 0.3 h/wk; $P = .01$). In male soccer, the jumper's knee group was significant taller than were the others (186 ± 4.3 cm vs 183 ± 5.5 cm; $P = .05$). Otherwise, there were no other significant differences between those with jumper's knee compared to those without in the other variables outlined in Tables 1 and 2. In a logistic regression model that included gender, sport, age, height, weight, training background, and the volume of the different types of training, only weight training and jump training were significant factors.

DISCUSSION

The main finding of this study was that the overall prevalence of jumper's knee was 14% across the sports included. In addition, 8% of the athletes reported previous symptoms, indicating that every fifth elite athlete is affected by jumper's knee during his or her athletic career. The prevalence varied between sports—from no cases in cycling and orienteering to 45% with current symptoms in male volleyball. It should also be noted that the mean duration of the symptoms was 32 months, with a mean VISA score of 64. The information on the duration of the symptoms was based on memory, which means that the precision of this information is uncertain. Nevertheless, it seems clear that even with this limitation, there is no doubt that the majority of patients have played with symptoms for several years. The VISA score is a validated method to describe the seriousness of symptoms in tendinopathy.[32,34] This

TABLE 1
Athlete Characteristics[a]

	n	Age, y	Height, cm	Weight, kg	Organized Training, y	Elite Level, y
Male athletes						
Bicycling	50	24.7 ± 5.1	182 ± 7.6	72.0 ± 6.2	13.5 ± 6.3	6.4 ± 4.2
Orienteering	52	22.1 ± 5.3	182 ± 5.6	71.3 ± 7.4	12.4 ± 4.6	5.4 ± 3.1
Wrestling	43	24.2 ± 5.9	174 ± 9.5	75.8 ± 12.0	15.5 ± 5.8	7.8 ± 6.1
Ice hockey	51	25.0 ± 4.1	182 ± 5.1	85.1 ± 7.0	17.6 ± 4.5	7.9 ± 4.2
Athletics	48	25.1 ± 4.7	185 ± 8.2	78.3 ± 8.0	12.5 ± 4.7	6.1 ± 3.9
Basketball	47	24.1 ± 5.1	191 ± 8.6	87.3 ± 10.5	12.4 ± 5.6	4.9 ± 4.8
Soccer	85	25.6 ± 4.1	183 ± 5.5	79.5 ± 11.4	18.3 ± 4.1	6.7 ± 3.8
Team handball	48	23.6 ± 3.8	187 ± 6.2	89.6 ± 10.4	14.6 ± 4.9	5.0 ± 3.9
Volleyball	56	26.8 ± 4.2	192 ± 6.0	88.8 ± 7.2	16.7 ± 4.7	7.2 ± 4.0
Female athletes						
Soccer	55	23.1 ± 3.3	169 ± 4.8	63.2 ± 5.1	15.7 ± 3.2	4.7 ± 2.9
Team handball	52	22.8 ± 4.3	172 ± 6.0	68.8 ± 8.4	14.9 ± 4.2	4.7 ± 4.6

[a]Values are presented as means ± SD.

TABLE 2
Training Volumes Reported by the Different Groups of Athletes[a]

	Sport-Specific Training, h/wk	Weight Training, h/wk	Jump Training, h/wk	Other Types of Training, h/wk
Male athletes				
Bicycling	17.9 ± 4.0	2.8 ± 1.4	0.0 ± 0.0	4.5 ± 4.8
Orienteering	10.8 ± 3.6	2.7 ± 1.1	1.2 ± 0.7	2.6 ± 1.6
Wrestling	8.6 ± 2.9	5.0 ± 2.7	0.0 ± 0.3	1.0 ± 1.8
Ice hockey	13.0 ± 3.2	2.7 ± 1.1	1.0 ± 0.1	2.6 ± 1.6
Athletics	9.0 ± 3.5	4.5 ± 2.1	3.0 ± 2.3	0.9 ± 1.8
Basketball	13.0 ± 2.8	5.5 ± 2.3	0.9 ± 1.4	0.4 ± 1.1
Soccer	13.0 ± 3.9	2.5 ± 0.5	0.7 ± 0.4	1.3 ± 1.3
Team handball	10.7 ± 2.4	3.5 ± 1.7	0.3 ± 0.5	0.8 ± 1.1
Volleyball	10.4 ± 2.4	2.1 ± 1.9	0.6 ± 0.9	0.2 ± 1.3
Female athletes				
Soccer	10.6 ± 2.1	2.0 ± 1.5	1.0 ± 0.6	1.7 ± 0.9
Team handball	11.4 ± 3.1	2.6 ± 0.9	1.0 ± 0.6	2.2 ± 1.5

[a]Values are presented as means ± SD.

means that this condition can severely interfere with athletic performance and even threaten an athletic career. Based on these data, it could be claimed that for some sports, jumper's knee may cause at least as much impairment for athletic performance as do acute knee injuries.

These prevalence figures probably represent minimum estimates. The clubs of the team sport athletes were typically visited during a training session, in which all those present were invited to be examined. Similarly, in the individual sports, we examined the athletes at their national championships. The response rate was excellent—none of the athletes declined the invitation to participate. However, the athletes with the most serious problems, those who could not participate in training or competition, were not included in the study. As an example, we know that in men's team handball, there were 4 players who had recently been treated surgically for jumper's knee among the teams included in this study. We do not know the number of athletes in the other sports who were too disabled to be included. This may be a significant source of error, particularly in the individual sports where it is more likely that athletes would withdraw or not even enter the national championships if they thought that they could not perform fully. Also, an unknown number of athletes may have retired early because of jumper's knee, and some may have settled for a career at a lower level of performance because they could not tolerate the heavy training and competition load at the elite level. Thus, the elite samples we were able to study represent the survivors, and the true career prevalence is higher than the 22% reported here as an overall result across the sports included.

Another methodological limitation that must be considered when interpreting the findings is that the results were based on clinical examination alone. For practical reasons, we were not able to do MR or ultrasound imaging to confirm the presence of structural tendon changes. This means that to be recorded as having current symptoms of jumper's knee, the athlete had to report a painful tendon

during athletic activity with corresponding palpation tenderness. It may be argued that this definition is unspecific because we did not know for certain that the tendon was the source of the pain in all cases. For instance, we could not rule out cases with referred pain, principally from the distal aspects of the articular surface of the patella. In fact, a number of studies have shown that the correlation between clinical findings and ultrasound[9,19,22,24,30] or MR examinations is low[4,10,18] and even that symptoms and tendon changes come and go independently.[8,9] A significant number of athletes have or develop visible tendon changes without symptoms of jumper's knee, and some have significant pain without detectable tendon changes.[8,23] Thus, we would argue that the current clinical definition provides the most valid estimate for the prevalence of jumper's knee because it will detect all players with tendon symptoms during athletic performance.

To our knowledge, there are no previous reports on the prevalence of jumper's knee across different sports. A number of case series presenting the outcome after surgical treatment indicate that the majority of patients are from sports with high demands on speed and power.[17,27,31] Raatikainen et al[31] from Finland described 182 patients who underwent surgery for jumper's knee and found that 46% were from athletics, 37% from volleyball, 5% from soccer, and the rest from other sports. On the other hand, Martens et al[27] from Belgium found that only 8% of their 90 surgically treated patients were from athletics, whereas 34% were volleyball players and 32% were soccer players. Furthermore, Karlsson et al[17] from Sweden reported that of 81 patients they treated for jumper's knee, only 9% were volleyball players, whereas 37% were from athletics and 27% were from soccer. In these 3 studies, basketball accounted for less than 10% of patients. As illustrated by the conflicting results from these[17,27,31] and other studies (for a complete review of surgical studies, see Coleman et al[5]), it is not possible to estimate prevalence from case series because the population at risk is unknown. The differences observed in the proportion of patients from different sports may simply reflect how popular these sports are in the different countries.

Previous studies reporting on the prevalence of jumper's knee in a defined cohort of players are few and mainly limited to volleyball[12,15,24] and basketball.[7,9] Ferretti[12] and Ferretti et al[15] found in their studies on volleyball players that approximately 40% had jumper's knee. Similarly, Lian et al[24] showed, based on a clinical examination of 47 male elite volleyball players, that 25 had current symptoms and an additional 7 reported previous symptoms of jumper's knee. In other words, it appears that the prevalence of jumper's knee among elite volleyball players is between 40% and 50%, and this is confirmed by the present data. Cook et al[7] examined the patellar tendons of a cohort of elite basketball players using ultrasonography. They showed that 29% of the tendons examined displayed hypoechoic sonographic regions. However, the study did not report how the tendon changes correlated with symptoms. In other sports investigated in this study, the prevalence of tendon changes was lower than in basketball (14% Australian Rules football, 7% cricket, and 6% netball). In adolescent basketball players (14-18 years old), the prevalence was similar to that of adults, with 26% having imaging changes, whereas only 7% had symptoms (11% males and 2% females).[9] In these 2 studies, 2% to 4% of the control populations studied exhibited tendon changes.[7,9]

In both of the ultrasound imaging studies, the ratio of male to female abnormalities was 2:1. However, to date, it is not known if there is a gender difference in the risk for jumper's knee, as there is for acute knee injuries, particularly ACL tears.[1,29] The present results suggest that jumper's knee is twice as common among male athletes as it is among female athletes. The prevalence of current symptoms was 5.6% among female team handball and soccer players, compared with 13.5% in the corresponding male sports. The question is, What is the cause of the apparent gender difference? We chose team handball and soccer to examine the gender difference because these are sports in Norway that are played at an equally high performance level by men and women; therefore, we thought player experience and training volumes would be similar, and we expected a high prevalence of jumper's knee. As seen from Tables 1 and 2, the training volumes (15-17 h/wk total training time) and background (15-18 years of organized training, 5-7 years at the elite level) were similar between men and women. The difference in prevalence can be attributed to a number of other factors. It is well documented that jumping ability and force-generating capacity are lower among women than men.[28] So, even if the number of sprints and jumps may be similar between men and women playing the same sports, the lower prevalence may simply reflect that the lower forces transmitted through the quadriceps and patellar tendons are lower among women.

As expected, in the present study, the prevalence was high in basketball (55% reporting current or previous jumper's knee), a sport characterized by high demands on speed and power. The maximal muscle force that can be generated eccentrically is 1.5 to 2.0 times higher than is the maximal isometric force and is several-fold higher than the maximal concentric force, especially at high speeds.[16] Also, the ground reaction force is different between different tasks, ranging from 2.8 times body weight during distance running to 6 times body weight during jumping in volleyball and 10 times body weight in a long jump takeoff.[28] The highest ground reaction forces are seen with ballistic drop jumps, and the resulting forces through the extensor tendons are proportional to the ground reaction force. Therefore, it is reasonable to suggest a connection between the loading pattern of the knee extensors and the prevalence of jumper's knee. This supposition seems to match the prevalence distribution seen in the present and previous studies, with the highest in basketball and volleyball (high jump volume and eccentric load); athletics (sprinters and jumpers, high load but less volume); team handball, soccer, and ice hockey (less jumping, some sprinting); and low prevalence among orienteerers (high volumes of running but no sprinting) and road cycling (high volumes of concentric work, no ballistic loading).

We have previously shown in a case-control study[23] and a cohort study[25] that volleyball players with jumper's knee

have better jumping ability and power generation than do players who do not report symptoms from their tendons, presumably because they subject their knee extensors to higher loads when jumping and landing. Ferretti et al[15] have shown that there is a linear relationship between training volume and prevalence of jumper's knee among volleyball players and that the harder the floor type they trained on, the higher the prevalence of jumper's knee. In line with this finding, it has recently been shown that the prevalence of jumper's knee among elite beach volleyball players was only 9%, considerably lower than in indoor volleyball players.[2] The explanation for this difference in prevalence is probably that jumping and landing in the soft sand are less demanding on the tendon than is jumping on indoor playing surfaces. In other words, there is ample evidence to suggest a link between the total load on the tendon and the prevalence of tendon injury.

However, the link between the mechanical loading conditions and the pathophysiological response is obscure. It has been suggested that mechanical overload produces partial tears in the ligament substance,[23,25] and the histologic findings have been interpreted as partial tendon ruptures.[17,27] This theory has been questioned,[20,21] and it has recently been suggested that the initial injury is to the tenocyte, not to the collagen fibers.[6,35] However, to date, there is insufficient evidence to provide a direct explanation for the apparent connection between the loading pattern and the pathologic response. Skutek et al[33] suggested that mechanical stretching of tendon fibroblasts activates signaling pathways that in the next step induce apoptosis. Tendon tissue is characterized by a homeostatic balance, as in all other living tissues, with both inhibitory and stimulating signals. The uniform histologic findings seen with tendinopathy are compatible with an apoptotic process. It may be that when the mechanical loading conditions surpass the adaptive responses of the cells, an apoptotic process is induced.

CONCLUSION

The overall prevalence of jumper's knee is 14%, with an additional 8% reporting previous symptoms, which suggests that the career prevalence is at least 22%. Jumper's knee is twice as common among male athletes as it is among female athletes. However, the prevalence varies greatly between sports—with a high prevalence in sports characterized by high-impact ballistic loading of the knee extensors and low prevalence in sports with low loads—suggesting that there is a link between the prevalence of jumper's knee and total tendon load. The high prevalence, long duration of symptoms, and low function scores suggest that in some sports, jumper's knee may be one of the main causes of impairment in athletic performance.

ACKNOWLEDGMENT

The Oslo Sports Trauma Research Center has been established at the Norwegian University of Sport and Physical Education through generous grants from the Royal Norwegian Ministry of Culture, the Norwegian Olympic Committee & Confederation of Sport, Norsk Tipping AS, and Pfizer AS. In addition, the authors thank the national federations and clubs for their involvement in the study. We also thank Eva K. Birkeland, Ketil Holen, Harald Schwabe, Bjørn Solem, Arnhild Skjølberg, and Odd E. Olsen for their assistance in data collection.

REFERENCES

1. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med.* 1995;23:694-701.
2. Bahr R, Reeser JC. Injuries among world-class professional beach volleyball players: the Federation Internationale de Volleyball beach volleyball injury study. *Am J Sports Med.* 2003;31:119-125.
3. Blazina ME, Kerlan RK, Jobe FW, Carter VS, Carlson GJ. Jumper's knee. *Orthop Clin North Am.* 1973;4:665-673.
4. Bodne D, Quinn SF, Murray WT, et al. Magnetic resonance imaging of chronic patella tendinitis. *Skeletal Radiol.* 1988;17:24-28.
5. Coleman BD, Kahn K, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. *Scand J Med Sci Sports.* 2000;10:2-11.
6. Cook JL, Feller JA, Bonar SF, Khan KM. Abnormal tenocyte morphology is more prevalent than collagen disruption in asymptomatic athletes' patellar tendons. *J Orthop Res.* 2004;22:334-338.
7. Cook JL, Khan KM, Harcourt PR, et al. Patellar tendon ultrasonography in asymptomatic active athletes reveals hypoechoic regions: a study of 320 tendons. *Clin J Sport Med.* 1998;8:73-77.
8. Cook JL, Khan KM, Kiss ZS, Coleman BD, Griffiths L. Asymptomatic hypoechoic regions on patellar tendon ultrasound: a 4-year clinical and ultrasound followup of 46 tendons. *Scand J Med Sci Sports.* 2001;11:321-327.
9. Cook JL, Khan KM, Kiss ZS, Purdam CR, Griffiths L. Prospective imaging study of asymptomatic patellar tendinopathy in elite junior basketball players. *J Ultrasound Med.* 2000;19:473-479.
10. Davies SG, Baudouin CJ, King JB, Perry JD. Ultrasound, computed tomography and magnetic resonance imaging in patellar tendinitis. *Clin Radiol.* 1991;43:52-56.
11. Fahlström M, Jonsson P, Lorentzon R, Alfredson H. Chronic Achilles tendon pain treated with eccentric calf-muscle training. *Knee Surg Sports Traumatol Arthrosc.* 2003;11:327-333.
12. Ferretti A. Epidemiology of jumper's knee. *Sports Med.* 1986;3:289-295.
13. Ferretti A, Ippolito E, Mariani P, Puddu G. Jumper's knee. *Am J Sports Med.* 1983;11:58-62.
14. Ferretti A, Papandrea P, Conteduca F. Knee injuries in volleyball. *Sports Med.* 1990;10:132-138.
15. Ferretti A, Puddu G, Mariani PP, et al. Jumper's knee: an epidemiological study of volleyball players. *Physician Sportsmed.* 1984;12:97-106.
16. Herzog W. Mechanical properties and performance in skeletal muscles. In: Zatziorsky V, ed. *Biomechanics in Sport*. Vol. 9 of *Encyclopaedia of Sports Medicine*. Oxford, England: Blackwell Science; 2000.
17. Karlsson J, Lundin O, Lossing IW, Peterson L. Partial rupture of the patellar ligament: results after operative treatment. *Am J Sports Med.* 1991;19:403-408.
18. Khan KM, Bonar F, Desmond PM, et al. Patellar tendinosis (jumper's knee): findings at histopathologic examination, US, and MR imaging. *Radiology.* 1996;200:821-827.
19. Khan KM, Cook JL, Kiss ZS, et al. Patellar tendon ultrasonography and jumper's knee in female basketball players: a longitudinal study. *Clin J Sport Med.* 1997;7:199-206.

20. Khan KM, Cook JL, Maffulli N, Kannus P. Where is the pain coming from in tendinopathy? It may be biochemical, not only structural, in origin. *Br J Sports Med.* 2000;34:81-83.
21. Khan KM, Cook JL, Taunton JE, Bonar F. Overuse tendinosis, not tendonitis, part 1: a new paradigm for a difficult clinical problem. *Physician Sportsmed.* 2000;28:38-48.
22. Khan KM, Visentini PJ, Kiss Z, et al. Correlation of ultrasound and magnetic resonance imaging with clinical outcome after patellar tenotomy: prospective and retrospective studies. *Clin J Sport Med.* 1999;9:129-137.
23. Lian Ø, Engebretsen L, Øvrebø R, Bahr R. Characteristics of the leg extensors in male volleyball players with jumper's knee. *Am J Sports Med.* 1996;24:380-385.
24. Lian Ø, Holen K, Engebretsen L, Bahr R. Relationship between symptoms of jumper's knee and the ultrasound characteristics of the patellar tendon among high level male volleyball players. *Scand J Med Sci Sports.* 1996;6:291-296.
25. Lian Ø, Refsnes PE, Engebretsen L, Bahr R. Performance characteristics of volleyball players with patellar tendinopathy. *Am J Sports Med.* 2003;31:408-413.
26. Mafi N, Lorentzon R, Alfredson H. Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. *Knee Surg Sports Traumatol Arthrosc.* 2001;9:42-47.
27. Martens M, Wouters P, Burssens A, Mulier JC. Patellar tendinitis: pathology and results of treatment. *Acta Orthop Scand.* 1982;53:445-450.
28. McNitt-Gray JL. Musculoskeletal loading during landing. In: Zatziorsky V, ed. *Biomechanics in Sport*. Vol. 9 of *Encyclopaedia of Sports Medicine*. Oxford, England: Blackwell Science; 2000.
29. Myklebust G, Maehlum S, Holm I, Bahr R. A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. *Scand J Med Sci Sports.* 1998;8:149-153.
30. Myllymäki T, Bondestam S, Suramo I, Cederberg A, Peltokallio P. Ultrasonography of jumper's knee. *Acta Radiol.* 1990;31:147-149.
31. Raatikainen T, Karpakka J, Puranen J, Orava S. Operative treatment of partial rupture of the patellar ligament: a study of 138 cases. *Int J Sports Med.* 1994;15:46-49.
32. Robinson JM, Cook JL, Purdam C, et al, for the Victorian Institute of Sport Tendon Study Group. The VISA-A questionnaire: a valid and reliable index of the clinical severity of Achilles tendinopathy. *Br J Sports Med.* 2001;35:335-341.
33. Skutek M, van Griensven M, Zeichen J, Brauer N, Bosch U. Cyclic mechanical stretching of human patellar tendon fibroblasts: activation of JNK and modulation of apoptosis. *Knee Surg Sports Traumatol Arthrosc.* 2003;11:122-129.
34. Visentini PJ, Khan K, Cook J, Kiss ZS, Harcourt PR, Wark JD. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). *J Sci Med Sport.* 1998;1:22-28.
35. Yuan J, Wang MX, Murrell GA. Cell death and tendinopathy. *Clin Sports Med.* 2003;4:693-701.