

Training volume and body composition as risk factors for developing jumper's knee among young elite volleyball players

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Training volume and body composition have been suggested as risk factors for jumper's knee among athletic youth, but research is lacking. The aim of this 4-year prospective cohort study was to examine the relationship between training and competition load, body composition, and risk for developing jumper's knee. Participants are elite volleyball players, aged 16–18 years. Training and competition load was recorded continuously and body composition semiannually. Jumper's knee was diagnosed on a standardized clinical examination. We recruited 141 healthy students (69 males and 72 females), and 28 developed jumper's knee (22 boys and six girls). In

a multivariate analyses, boys had three to four times higher risk compared with girls. Volleyball training had an odds ratio (OR) 1.72 (1.18–2.53) for every extra hour trained, and match exposure was the strongest sports-related predictor for developing jumper's knee with an OR of 3.88 (1.80–8.40) for every extra set played per week. We did not detect any significant differences between the groups in body composition at the time of inclusion or in the change of body composition during the study period. Conclusion, male gender, a high volume of volleyball training and match exposure were risk factors for developing jumper's knee.

The prevalence of jumper's knee is high, up to 40–50%, in sports characterized by high demands on leg extensor speed and power, such as volleyball, basketball, football, and athletics (Ferretti et al., 1990; Lian et al., 2005). Treatment is challenging, and many athletes continue their careers despite having substantial problems, and the mean duration of symptoms among active participants can be as high as 19–72 months (Lian et al., 2005; Visnes et al., 2005; Zwerver et al., 2011). As the prevalence and severity of the condition is high and effective treatment programs remain elusive, there is an urgent need to prevent this condition. However, to develop effective prevention strategies and programs, we need to identify the risk factors (van Mechelen et al., 1992).

Jumper's knee is usually described as an overuse injury (Ferretti, 1986). Still, a recent review (van der Worp et al., 2011a) concluded that none of the sports-related factors studied have been identified as risk factors for jumper's knee. They found only three studies showing an association with the amount of training and playing (Ferretti et al. 1984; Lian et al., 1996; Gaida et al., 2004) and two with no association (Lian et al., 2003; Malliaras et al., 2006). In promising young athletes, a sudden change and increase in the volume of training when they are promoted from the junior to the

senior level is hypothesized as a risk factor of jumper's knee (Reeser et al., 2006).

A cross-sectional study among volleyball players showed that athletes that develop jumper's knee had higher body mass compared with asymptomatic controls (Lian et al., 1996), and a more recent cohort study found that men with a waist girth greater than 83 cm seemed to be at greater risk of developing patellar tendon pathology (Malliaras et al., 2007). A systematic review from 2009 (Gaida et al., 2009) found 28 studies about the relationship between tendinopathy and adiposity, concluding that adiposity is frequently associated with tendon injury. Mechanical and biochemical theories have been postulated for this purported connection (Malliaras et al., 2007). The mechanical explanation is that higher weight results in higher tendon load, and the systemic hypothesis is that bioactive peptides released by adipose tissue may influence tendon structure (Gaida et al., 2009). However, many of these studies are on nonathletes, adults, and obese, and there is to our knowledge no data available to determine whether body composition has a role in the development of patellar tendinopathy among athletic youth.

Thus, the aim of this prospective cohort study was to study the effects of training/competition load and body composition as potential risk factors for jumper's knee.

Methods

Subjects and setting

Participants for this prospective cohort study were recruited among players entering the Toppvolley Norge (TVN) program. TVN is located in Sand, Norway and combines an elite volleyball training program with a 3-year senior high school boarding school program. The students started at the age of 15–16 years, and they were expected to complete 3 years for a college-entry baccalaureate degree. Some students entered the program in the second or third year directly. TVN aimed to recruit the most talented junior volleyball players in Norway, and the athletes represented the school in the Norwegian national leagues at various levels. However, players could also play tournaments and league matches for their home clubs. Many of the players also qualified for different junior national team programs.

The recruitment process began when school started every autumn with an information meeting. Potential participants were also informed in writing before their written consent was obtained, and also that of their parents if the athlete was younger than 18 years old. To be included, they had to be free of jumper's knee at the time of inclusion. The athletes were a part of the study as long as they attended TVN until they first developed jumper's knee on at least one side. The study was approved by the Regional Committee for Research Ethics and the Data Inspectorate.

Risk factors

Sports-related factors

Training volume was recorded prospectively on a weekly basis. We organized the registration on an individual basis through a web-based weekly training diary, with six questions about the number of hours of volleyball, beach volleyball, strength, jump training, and other training. The numbers of sets played in matches during the last week were also recorded. An individual registration was necessary because not all training is organized and the athletes play matches for their home clubs and junior national teams, as well. In case data were incomplete, we interviewed the player and their coach to estimate exposure as precisely as possible. Information was also collected about their previous training volume in volleyball, strength training, and other training during the last year before attending TVN. We only collected data during the 10-month school year.

Body composition

All athletes were examined by the same examiner (H.V.) when they were included. Body composition was assessed by measuring height and weight, waist circumference, and skinfold caliper tests. Waist circumference (nearest mm) was measured with anthropometric tape around the umbilicus at the end of a normal expiration (Steene-Johannessen et al., 2010). Four skinfold thickness measurements (triceps, biceps, subscapular, and suprailiac) were taken using a Harpenden skinfold caliper (John Bull; British Indicators Ltd, West Sussex, England) on the nondominant side of the body according to the criteria described by Lohman et al. (1991). These examinations were repeated twice a year as long as they remained in the cohort.

Diagnosis

The end point was a clinical diagnosis of jumper's knee. The following diagnostic criteria were used: (a) a history of pain in the quadriceps or patellar tendons at their patellar insertions in connection with training or competition; and (b) tenderness to

palpation corresponding to the painful area (Lian et al., 1996, 2003, 2005; Visnes et al., 2005). The symptoms had to have been present for a minimum of 12 weeks and the athlete had to consider that the symptoms were sufficient to represent a substantial problem. The school physician and physiotherapist recorded cases prospectively, and the principal investigator (H.V.) visited TVN a minimum of twice a year (August/September and March/April) to examine all athletes.

Statistical methods

We used Statistical Package for the Social Sciences (SPSS) version 18.0 (SPSS Inc., Chicago, IL, USA) to perform the analyses. Training volume was calculated as the mean number of hours per week and match exposure as the mean number of sets per week for the included period. Subject characteristics are reported as means \pm standard deviation unless otherwise noted. All potential risk factors were compared using unpaired *t*-tests examined in univariate analyses and those with a *P*-value <0.20 were investigated further in a multivariate regression model. Different logistic regression models were run to compare the strengths of association between injury and exposure of training and matches. Model prognostic indexes were also used to compare predictive ability between the different models by receiver operating characteristic analysis. In the multivariate analyses, we have combined data on present and previous training and match exposure with gender; but because of limitations in statistical power, we could only include two or three factors at the time. Also, as there was a strong correlation between total training volume and the other training forms, these factors could not be included in the same model. Odds ratio (OR) are reported with 95% confidence limits and *P*-values. *P*-values of <0.05 were considered statistically significant.

Results

The recruitment process is shown in Fig. 1. During the 4-year study period, 164 students were informed and examined. Some students were excluded because of pre-existing jumper's knee when they entered the program ($n = 19$) and some quit school before they had finished a full year ($n = 4$). We were able to recruit 141 healthy students (69 males and 72 females), with a mean age at inclusion of 16.8 ± 0.8 years. On average, they were included in the cohort for 1.8 ± 0.8 years (1 year: 58 students, 2 years: 57, 3 years: 25, and 4 years: 1).

The training volume during the last year prior to entering TVN was recorded for 124 of 141 athletes. They had trained volleyball 8.1 ± 5.1 h/week (males: 8.5 ± 5.4 , females: 7.7 ± 4.7 ; $P = 0.40$), strength training 1.6 ± 2.0 h/week (males: 1.8 ± 2.3 , females: 1.3 ± 1.7 ; $P = 0.12$), and other sports 1.3 ± 2.1 h/week (males: 1.2 ± 2.0 , females: 1.4 ± 2.2 ; $P = 0.59$).

In total, 28 out of the 141 athletes (22 boys and six girls) included developed jumper's knee during their time at TVN. Nearly one in three boys (32%) and 8% of the girls developed jumper's knee during their time at TVN. The mean annual incidence was 21% per year for boys and 5.08% for girls, but in most cases, their knee problems developed during their first year at TVN (first year: 19 cases, second year: eight cases, and third year: one case), and the mean time until symptom onset was

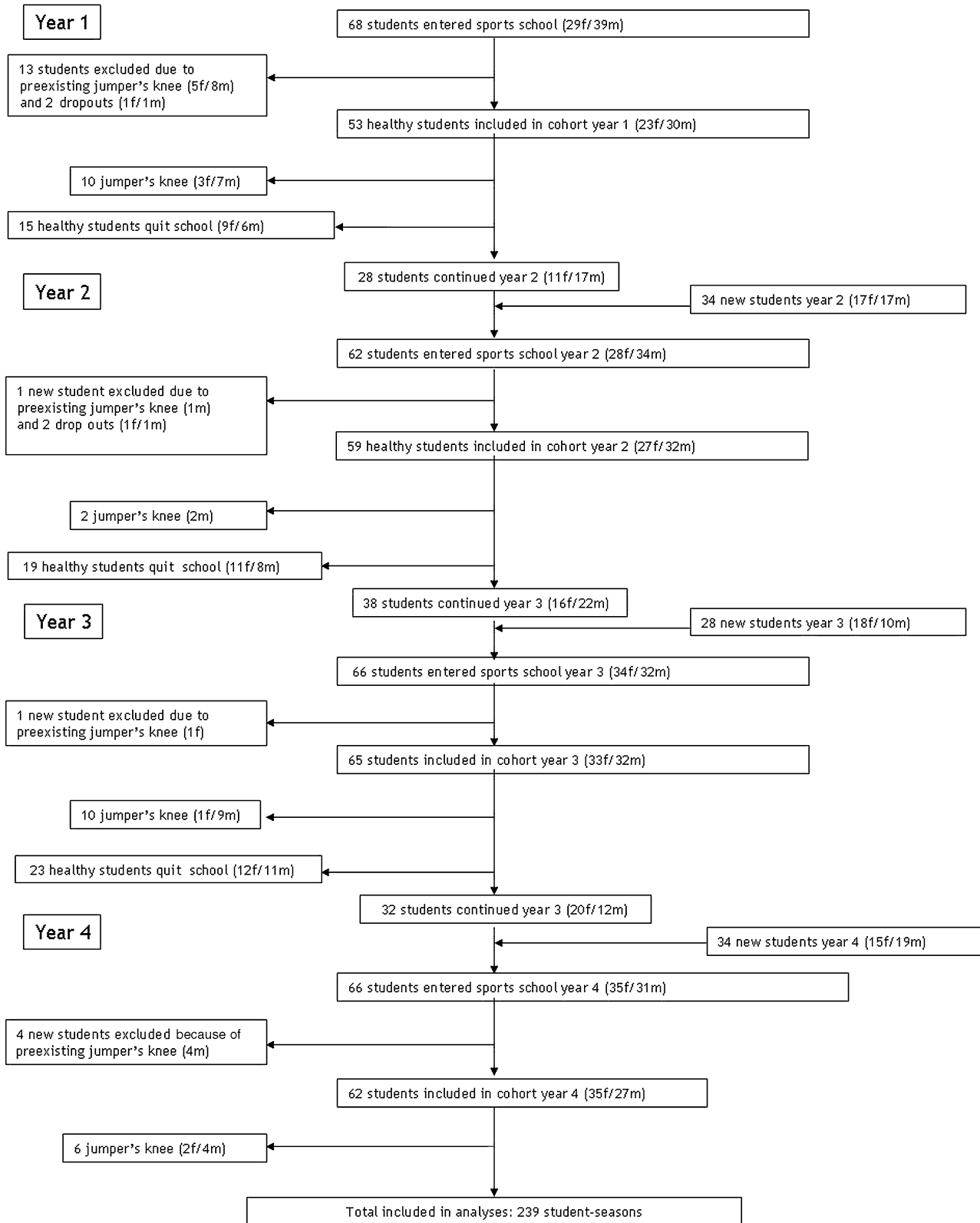


Fig.1. Flowchart.

0.9 years. In most cases, their symptoms stemmed from the proximal patellar tendon ($n = 25$); only three cases (two boys/one girl) were located in the distal quadriceps tendon.

We did not detect any significant differences in body composition at the time of inclusion or in the change of body composition during the study period between players who developed jumper's knee and those who did

Table 1. Body composition at inclusion and change (Δ) in body composition during the study period

	Healthy			Jumper's knee			P-values	
	N	Inclusion (mean \pm SD)	Δ (95% CI)*	N	Inclusion (mean \pm SD)	Δ (95% CI) [†]	Inclusion	Δ
Men								
Height (cm)	47	187 \pm 5.5	1.4 (-0.5, 1.8)	22	186 \pm 6.7	0.7 (-0.3, 6.2)	0.50	0.25
Weight (kg)	47	75.3 \pm 7.8	4.6 (-1.1, 4.0)	22	76.3 \pm 8.5	3.2 (-0.9, 3.7)	0.64	0.27
Skin caliper test (mm)	47	40.1 \pm 8.7	6.6 (-3.8, 3.7)	22	39.6 \pm 10.3	3.3 (-4.1, 4.0)	0.58	0.99
Waist circumference (cm)	47	77.5 \pm 4.5	1.4 (-1.2, 5.2)	22	77.7 \pm 8.0	3.4 (-2.2, 6.2)	0.92	0.25
Women								
Height (cm)	66	171.8 \pm 6.5	0.5 (-0.3, 1.2)	6	173.9 \pm 6.7	0.2 (-0.6, 1.4)	0.45	0.31
Weight (kg)	66	65.2 \pm 7.5	2.8 (-2.3, 4.2)	6	66.0 \pm 13.0	1.9 (-2.2, 4.1)	0.82	0.57
Skin caliper test (mm)	66	69.1 \pm 16.2	3.8 (-4.7, 17.2)	6	60.8 \pm 18.0	10.1 (-7.0, 9.4)	0.24	0.26
Waist circumference (cm)	66	74.5 \pm 4.8	0.6 (-19.1, 5.1)	6	71.2 \pm 4.9	2.2 (-5.9, 9.1)	0.27	0.37

Data are shown as the average \pm SD.

*N = 41.

[†]N = 22.

[‡]N = 59.

[§]N = 5.

CI, confidence interval; SD, standard deviation.

Table 2. Training volume (h/week) and number of sets played in matches

	All			Men			Women		
	Healthy	Jumper's knee	P-value	Healthy	Jumper's knee	P-value	Healthy	Jumper's knee	P-value
	(n = 113)	(n = 28)		(n = 47)	(n = 22)		(n = 66)	(n = 6)	
Volleyball training	12.0 \pm 3.7	14.9 \pm 2.8	0.001	13.0 \pm 3.8	15.0 \pm 3.0	0.04	11.2 \pm 3.4	14.3 \pm 1.8	0.03
Beach volleyball training	0.2 \pm 0.5	0.2 \pm 0.5	0.80	0.4 \pm 0.6	0.3 \pm 0.6	0.52	0.2 \pm 0.3	0.0 \pm 0.1	0.26
Strength training	2.9 \pm 1.3	3.0 \pm 1.2	0.70	2.8 \pm 1.2	2.9 \pm 1.2	0.76	3.0 \pm 1.5	3.4 \pm 1.5	0.52
Jump training	0.4 \pm 0.5	0.6 \pm 0.5	0.04	0.5 \pm 0.5	0.7 \pm 0.6	0.15	0.4 \pm 0.5	0.4 \pm 0.3	0.73
Other training	1.3 \pm 0.8	1.1 \pm 0.9	0.26	1.1 \pm 0.6	1.1 \pm 0.9	0.97	1.4 \pm 1.0	1.0 \pm 1.0	0.31
Total	16.8 \pm 4.4	19.8 \pm 3.4	0.01	17.9 \pm 4.7	20.0 \pm 3.6	0.06	16.1 \pm 4.0	19.1 \pm 2.8	0.08
Number of sets played	2.7 \pm 2.1	6.1 \pm 4.9	0.01	3.4 \pm 2.7	5.7 \pm 5.1	0.05	2.2 \pm 1.4	7.2 \pm 4.6	0.001

Data are shown as the average \pm standard deviation.

not (Table 1). Some athletes only had inclusion data and therefore the footnotes in Table 1 represent the number of students analyzed for change in body composition.

The jumper's knee group had higher total training volume compared with those who remained asymptomatic (Table 2). Significant differences were observed for indoor volleyball training and jump training, while we did not see any differences for beach volleyball training, strength training, or other training. The number of sets played in matches was also higher in the jumper's knee group. These trends were similar for males and females.

Previous training history was recorded for 124 athletes (24 of these developed jumper's knee). The jumper's knee group did significantly more volleyball training before entering the TVN program (10.5 \pm 6.2 h/week) compared with the asymptomatic group (7.6 \pm 4.6 h/week, $P = 0.01$). We found no difference in previous strength training (2.3 \pm 2.3 h/week vs 1.4 \pm 1.9 h/week, $P = 0.052$). The asymptomatic group did more training in

other sports (1.5 \pm 2.2 h/week) compared with the jumper's knee group (0.5 \pm 0.9 h/week, $P = 0.03$).

The results from the multivariate analyses are shown in Table 3. Across all models, boys had three to four times higher risk for developing jumper's knee compared with girls, independent of training and match exposure. After correcting for gender, the analyses show that the risk for developing jumper's knee increased with total training volume, volleyball training, match exposure, and previous training volume. Of these factors, match exposure was the strongest sports-related predictor for developing jumper's knee with an OR of 3.88 [95% confidence interval (CI) 1.80–8.40] for every extra set played per week. Match exposure also remained a strong predictor (OR: 3.21, 95% CI 1.44–7.16) even when combined with volleyball training volume. As we only had information about previous training volume in 124 out of 141 athletes, this factor had to be analyzed separately. We found that a high volume of previous volleyball training increased the risk of

Table 3. Results from multivariate regression analyses based on various combinations of potential risk factors

Model	Factors	OR	95% CI	P-value
Gender + total training volume (<i>n</i> = 141)	Gender	4.03	(1.47, 11.04)	0.007
	Total training volume*	1.61	(1.10, 2.36)	0.02
Gender + volleyball training (<i>n</i> = 141)	Gender	3.65	(1.32, 10.10)	0.01
	Volleyball training*	1.72	(1.18, 2.53)	0.005
Gender + number of sets (<i>n</i> = 141)	Gender	3.89	(1.37, 11.02)	0.01
	Number of sets [†]	3.88	(1.80, 8.40)	0.001
Gender + volleyball training + number of sets (<i>n</i> = 141)	Gender	3.36	(1.17, 9.67)	0.02
	Volleyball training*	1.39	(0.91, 2.12)	0.13
	Number of sets [†]	3.21	(1.44, 7.16)	0.004
Gender + volleyball training + previous volleyball training (<i>n</i> = 124)	Gender	2.89	(0.96, 8.65)	0.058
	Volleyball training*	1.96	(1.27, 3.01)	0.002
	Previous volleyball training*	2.22	(1.20, 4.11)	0.011

*Hours per week, OR shown is per one hour increase in volume.

[†]Per one set increase played per week.

CI, confidence interval; OR, odds ratio.

jumper's knee (OR: 2.22, 95% CI 1.20–4.11) per hour of training.

Discussion

The main findings in this prospective cohort study on young, elite volleyball players investigating total training and competition load and body composition as potential risk factors for developing jumper's knee were that previous and current training and match exposure were significant risk factors, as was gender. In contrast, we detected no association between body composition and injury risk.

The volume of training and match exposure for these young athletes was high. The total training volume for the group that developed jumper's knee was significantly higher than the group that remained asymptomatic, and volleyball training accounted for nearly all of the difference. The jumper's knee group did about 3 h more volleyball training per week compared with the group that remained asymptomatic. As the daily volleyball training schedule on weekdays was organized by TVN, we found these group differences somewhat surprising. However, a closer look at the data revealed that many of the athletes affected were selected for different training camps with junior national teams or their home clubs on weekends and school holidays. During these periods, they could train up to 30 h per week and also play a number of matches compared with those who went home to their families to relax. We also observed that some of the most motivated athletes took part in extra volleyball training sessions with another group after they finished their own afternoon session or they organized their own volleyball training during off-weekends.

Training intensity varies, including how much jumping each player did during volleyball sessions. We did not record any data on intensity, but as the players in jumper's knee group are distributed across the different

training groups, there is no indication of any systematic differences in training methods between groups/coaches.

Match exposure, i.e., the number of sets played per week, was the strongest sports-related predictor for developing jumper's knee in the multivariate analysis. Even if the athletes who trained the most also tended to play the most matches, match exposure remained a strong predictor even when combined with volleyball training volume in the multivariate model. These athletes played matches for their home clubs as well as the school teams, and many of the league matches are organized as weekend tournaments. Therefore, the number of sets played in a week can in some periods be high. The number of matches played varies throughout the year. As many developed jumper's knee during the first 6 months, the fall season when match frequency is high, this could have caused a bias. However, this factor alone cannot explain all of the difference between the groups. A more likely explanation is that the players affected are the best players, and the player and their school, club and national team coach had the same interest in their playing as much as possible, without much thought of the consequences for injury.

Based on the literature, we expected that the athletes who increased their training volume the most also had the highest risk (Lian et al., 2003; Reeser et al., 2006). We therefore found it interesting that the jumper's knee group had trained significantly more volleyball the year before they started at TVN, about 3 h more per week. Both groups increased their volume with approximately 5 h more volleyball per week, an increase of 42% for the jumper's knee group and 66% for the asymptomatic players. These numbers may indicate that the total volume of training over a period is more important than the relative increase in training exposure from 1 year to the next. However, in most cases, players developed jumper's knee during their first year at TVN and the mean time until symptom onset was less than 1 year.

Because only one out of 28 cases debuted during the final year, it seems as if a player is able to tolerate the high volume of training and matches the first 1–2 years wherein the risk of developing jumper's knee is lower. An alternative explanation could be that the at-risk players have been affected by the condition by then. However, the prevalence of jumper's knee in volleyball is high (Ferretti, 1986; Cook et al., 1997; Lian et al., 2005), and we do not know if the asymptomatic group represent a more resistant group of players that will also avoid developing symptoms later in their career.

We also observed that the group that remained healthy previously had trained more in other sport compared with the jumper's knee group, with a background from sports like football, handball, or skiing. These numbers are small and should be interpreted with caution, but still, this raises questions about early specialization in sports for these young athletes.

Boys had three to four times higher risk for developing jumper's knee compared with girls, and this is somewhat higher compared with a previous cross-sectional study (Lian et al., 2005; van der Worp et al., 2011b; Zwerver et al., 2011). There is no evidence to explain why men have a greater risk, but possible explanations could be higher body mass, larger muscle mass, and an ability to jump higher, resulting in greater tendon load.

Body composition does not appear to be a risk factor for these young athletes, as we did not find any trend that increased body mass or higher skinfold values were associated with injury risk. It is important to note that the volleyball players studied represent a selected group of relatively tall and lean athletes, and therefore not comparable with previous studies, showing a correlation of tendinopathy and body composition in the general population (Wendelboe et al., 2004; Werner et al., 2005). A recent systematic review on the relationship between adiposity and tendinopathy (Gaida et al., 2009) identified only found one study among young athletes (Cook et al., 2004). This cross-sectional study investigated anthropometry, physical performance, and ultrasound patellar tendon abnormalities in elite junior basketball players, and they did not find any differences in height, weight, or skinfold thickness between players with ultrasound abnormalities and players with normal tendons (Cook et al., 2004). In other words, there is no evidence

for a link between body composition and the risk for patellar tendinopathy among young, well-trained athletes.

Perspectives

A high volume of volleyball training, high match exposure, and gender were important risk factors for developing jumper's knee, and the results of this cohort study indicate that total tendon loading and jumper's knee are closely connected. Often, young promising players who are promoted from the junior to the senior level experience a rapid increase in their training volume and competition volume. The intensity of training and the load on the tendon during a training session are possible to control. However, the challenge is that these players are the most talented, and the player and their school, club, and national team coaches have the same interest in their playing as much as possible. Therefore, in the transition from the junior to the senior ranks, they may quickly end up in a situation where they are playing for and training with several different teams at the same time, without much thought of the consequences for injury. Therefore, one lesson learned from this study is that there needs to be a focus on how many different teams youth players should represent during the season and how many matches they should play. This issue is unlikely to be raised by the player; this is the responsibility of the coaching staff.

Key words: prevention, tendinosis, cohort, patellar tendinopathy, athletes, adiposity.

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