ORIGINAL ARTICLE

Normal clinical and ultrasound findings indicate a low risk to sustain jumper's knee patellar tendinopathy: a longitudinal study on Swedish elite junior volleyball players

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Background: Jumper's knee patellar tendinopathy is well known to be a common and difficult injury in volleyball. Knowledge about its aetiology and pathogenesis is sparse.

Objective: To prospectively follow clinical status, tendon structure and vascularity in elite junior volleyball players.

Methods: 22 volleyball players (44 patellar tendons) beginning their first grade at the Swedish National Centre for high school volleyball were continuously evaluated clinically and by ultrasonography (US) and power Doppler (PD) over the 3 school years.

Results: At inclusion, there were 44 tendons being assessed. Jumper's knee was diagnosed clinically in eight patellar tendons (seven of eight had structural changes and vascularity on US+PD). There were 27 normal (clinical and US+PD) tendons. At 3 years, there were 36 tendons still being assessed. Four individuals (eight tendons) had been excluded. Jumper's knee had developed in 2 of 25 (2 were excluded) tendons that were normal (clinical and US+PD) at inclusion. Jumper's knee (clinical and US+PD) was also present in six tendons.

Conclusions: Normal clinical tests and ultrasound findings at the start indicated a low risk for these elite junior volleyball players to sustain jumper's knee during three school years with intensive training and playing.

Jumper's knee patellar tendinopathy is a troublesome condition, most often seen among athletes engaged in explosive jumping sports,^{1–4} and known to be difficult to treat.^{5–12} The highest prevalence of jumper's knee in sports is reported for volleyball,⁴ where up to 50% of elite players^{3, 4, 13} have it. The aetiology and pathogenesis of jumper's knee is still unclear, and there are multiple suggested theories.^{14–25}

The diagnosis of jumper's knee is commonly based on clinical symptoms,^{4, 11, 26, 27} and the benefits of methods like ultrasonography (US) or MRI have been questioned due to a low prediction value in diagnosing patellar tendinopathy.^{13, 28–32} However, clinical diagnosis is not always easy and there are differential diagnoses, such as patello-femoral cartilage injuries, which can be difficult to exclude clinically.^{4, 33–35} Therefore, an objective measure, such as US or MRI, might be of value in verifying whether a tendon is normal.^{35, 36}

Recently, power Doppler (PD) and colour Doppler have been used to study vascularity in tendons.^{37–39} Studies on chronic painful Achilles tendon^{39, 40} and patellar tendon^{22, 37, 41–44} indicate an association between pain during tendon-loading activity and the occurrence of vascularisation in the area with structural tendon changes. In symptomatic patellar tendons, the amount of vascularity has been shown to be associated with the intensity of pain.^{41, 44} Studies over a longer period of time can possibly clarify whether there is a dynamic pattern between the development of clinical symptoms and structural and vascular tendon changes. To our knowledge, no studies have continuously investigated the patellar tendon clinically and using US+PD, during a long-term exposure to high-intensity training and playing in an explosive jumping sport like volleyball. The aim of this prospective study was to follow the patellar tendons of a group of elite junior volleyball players during their 3 school years at the Swedish National Centre for high school volleyball clinically, clinically and using US+PD.

MATERIAL AND METHODS

Subjects

The most talented junior volleyball players in Sweden are recruited to the Swedish National Centre for high school volleyball. General physical tests and sport-specific tests are undertaken regularly. During their 3 years at the Swedish National Centre for high school volleyball, the players consistently train and play 13–15 h/week throughout the 37-week match/training season. The majority of the volleyball players represent the Swedish Junior National Team in international tournaments (often played during vacations). Four teams represent the high school in the Swedish Volleyball Federation leagues, from the women's top elite division to the first and second division for women and men.

After permission from the Educational Board of the Swedish National Centre for high school volleyball, all 22 players (11 male and 11 female) in the first grade (15–16 years) were invited to participate in the study.

The ethical committee of the Medical Faculty at the University of Gothenburg, Sweden, approved the study. All volleyball players provided written informed consent.

The study started at the beginning of the semester (September 2002), with a lecture about jumper's knee patellar tendinopathy for all students. Thereafter, all students filled in a questionnaire with the assistance of an investigator (KG).

Questionnaire and clinical examination

Questions included date of birth, amount and type of training, present and former symptoms of the patellar tendon, treatments, other knee injuries and results of any treatment. The volleyball players who reported pain at the patellar tendon marked the area with pain on a special knee-chart.

Abbreviations: PD, power Doppler; US, ultrasonography

The players were seen by the physiotherapist (KG) weekly, and individual examinations were carried out if the players had pain or stiffness in the knee. A full knee examination was carried out in all players every third month over the 3 years' (134 weeks) of investigation.

The examination included palpation of the patellar tendon, especially its attachment to the inferior pole of the patella. Tests that aimed to reproduce pain from patellar tendinopathy included one-leg body-weighted squats and drop jumps (plyometric jumps) on each leg from 20 cm and/or 43 cm. Clinical tests and/or taping techniques were used to try to exclude differential diagnoses such as patello-femoral pathology, fat pad impingement, bursitis, synovial or retinacular abnormalities and ligament and meniscus injuries.^{13 33 45}

The following diagnostic criteria were used for jumper's knee patellar tendinopathy: history (>4 weeks) of exercise/volleyball-associated pain at the patellar tendon insertion into the inferior pole of the patella,¹ tenderness to palpation^{1 27} and pain during provocative tests of the knee extensors.^{14 46 47}

Sonography

A single experienced musculoskeletal radiologist (CG), who was blinded to the volleyball players' clinical history, carried out all (six occasions) US and PD examinations. The same technical equipment was used during all examinations over the study period.

Grey-scale US

US was performed using a high-resolution, linear array, 8 MHz ultrasound transducer (Sequoia 512, Acuson Mountain View, California, USA). Longitudinal and transverse grey-scale scans of both the left and right patellar tendon were carried out with the patient lying supine, first with the knee in extension and then with the knee in slight flexion (20°). The thickness of the tendon was measured, and structural changes (hypoechoic areas) evident in both the longitudinal and the transverse scans were recorded.

PD examination

PD was used to study vascularity in the patellar tendon. To our knowledge, there is no method to reliably quantify flow in the tendon. Therefore, we used the same semiquantitative method that has been used in our previous studies^{42 43}: no flow = 0; flow outside the tendon = 1; one or two vessels inside the tendon = 2; and multiple vessels inside the tendon = 3.

For analysis, only those tendons with vessels inside the tendon (2 and 3) were considered to have an increased vascularity.

Statistical methods

The results are presented as means (SD) and were analysed using Microsoft Excel 2000.

RESULTS

Subject characteristics

Altogether 22 volleyball players, 11 males and 11 females, studying at The Swedish National Centre for high school volleyball were included in the study. Table 1 presents descriptive data of the individuals. All results are presented as numbers of tendons (not number of individuals).

At inclusion

At inclusion, jumper's knee patellar tendinopathy was diagnosed clinically in eight patellar tendons, and in seven of eight tendons there were also structural changes and vascularity (US+PD; table 2). There were 27 clinically and sonographically normal tendons (fig 1).

Nine tendons were clinically normal, but in six of nine tendons there were structural abnormalities on US, and in three of nine tendons there were structural abnormalities (US) together with intratendinous vascularity (PD).

At 3 years

At 3 years (three school years = 134 weeks), 36 tendons remained. Jumper's knee had developed in 2 of 25 (two were excluded) tendons that were normal (clinically, US+PD) at inclusion (fig 1).

In 10 of 25 tendons that were normal (clinically, US+PD) at inclusion, there were structural changes (US) alone. In 2 of 25 tendons that were normal (clinically, US+PD) at inclusion, there were structural changes (US) and intratendinous vascularity (PD). In 11 of 25 tendons that were normal (clinically, US+PD) at inclusion, there were normal clinical tests and normal US+PD. Of these 11 tendons, only 4 tendons remained normal throughout the study period.

Jumper's knee was diagnosed clinically and sonographically (US+PD) in six tendons (table 2).

During the study period, there was clinical jumper's knee intermittently in another two tendons, one with normal US+PD and one with abnormal US+PD.

Altogether, during the study period, jumper's knee was diagnosed clinically in 11 patellar tendons and in 9 of 11 tendons there were also structural changes (US) and vascularity (PD). In three of nine tendons, that were clinically normal at inclusion, but with abnormal US or US+PD, jumper's knee developed clinically.

One tendon diagnosed as jumper's knee at inclusion clinically normalised, had structural abnormalities, but was without intratendinous vascularity.

One tendon clinically diagnosed as jumper's knee with normal US+PD at inclusion, was clinically normalised.

In one player, one tendon shifted from proximal tendon pain until the beginning of the third school year to pain during activity in the distal insertion (but there was still pain during palpation in the proximal tendon).

Table 1 Volleyball players' (n = 22) basic data mean (SD) at baseline and during 3 years' (134 weeks) of investigation

Variable	Baseline 2002		3 years' follow-up	
	Male (n = 11)	Female (n = 11)	Male (n = 10)	Female (n = 8)
Age (years)	16.3 (0.3)	16.2 (0.5)	19.0 (0.3)	18.8 (0.5)
Height (cm)	189.6 (6.5)	173.6 (3.8)	192.4 (5.6)	174.3 (4.5)
Weight (kg)	81.0 (12.5)	67.6 (5.6)	85.6 (9.5)	69.5 (7.4)
Volleyball played (years)	3.7 (2.3)	3.7 (1.7)	6.9 (2.4)	7.0 (1.5)

Table 2 Clinically diagnosed jumper's knee patellar tendinopathy, at the time of sonographical investigations, in volleyball players (n = 22) during the school grades 1–3 at baseline and during 3 years' (134 weeks) follow-up

	Grade 1				Grade 2				Grade 3			
	Baseline 2002		To follow-up (30 weeks)		To follow-up (65 weeks)		To follow-up (81 weeks)		To follow-up (106 weeks)		To follow-up (134 weeks)	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Number of tendons	22	22	20	16	20	16	20	16	20	16	20	16
Presence of jumper's knee	4	4	5	2	5	2	5	0	5	0	4	2

Dropouts

There were eight dropouts (four players). One girl left school after the first school year, for social reasons. She had jumper's knee in one tendon (clinical diagnosis and abnormal US+PD). One girl was excluded because of an acute lumbar disc herniation at the end of the second school year. This player had jumper's knee in both tendons (clinical diagnosis and abnormal US+PD) from inclusion, but recovered clinically and sonographically when she had a long period of rest during recovery from her back injury. She then regained sonographical changes when gradually returning to play volleyball, but was clinically pain-free at the 3-year follow-up. She was considered as a dropout because she was not back at her previous (before injury) level of training and playing at the 3-year follow-up. One girl, clinically and sonographically normal, was excluded because of surgery (anterior cruciate ligament reconstruction) due to an acute knee injury. She never returned to full training and playing during the study period. One boy with jumper's knee (clinically, US+PD) was excluded after sustaining meniscus injuries, and never returned to full training and playing during the study period.

DISCUSSION

From this longitudinal study on elite junior volleyball players, it seems that if clinical tests and ultrasound findings are normal at the start, there is a low risk of sustaining jumper's knee despite training and playing 13–15 h per week for three school years. Thus, 27 tendons were clinically and sonographically (US+PD) normal at the start and interestingly only 2 of these 27 tendons developed jumper's knee during the 3 years' with intensive training and playing volleyball. Also, it seems that if jumper's knee is clinically diagnosed at starting school, in several tendons the symptoms remain.

Clinical tests

From these results, in junior volleyball players a normal clinical test indicates a low risk of sustaining jumper's knee, despite 3 years' of intensive training and playing volleyball. To define a normal clinical test, we used the combination of palpation of the patellar tendon attachment to the inferior pole of the patella (having straight knee) and one-leg body-weighted squats and drop jumps (plyometric jump) from 20 cm and/or 43 cm. For a "normal clinical test" there should be no pain in the proximal patellar tendon during squats and drop jumps. Tenderness at palpation alone is considered normal in elite volleyball and basketball players.^{13 27}

US findings

At inclusion, nine tendons were clinically normal, but had abnormal US or US+PD. In three of these nine tendons, jumper's knee developed during the study period. This is in agreement with the findings in a longitudinal study on elite soccer players, where 3 of 18 tendons with structural tendon changes developed jumper's knee.⁴⁸ Also, in a study on basketball players, it was shown that sonographical changes

can resolve, remain unchanged or expand, without predicting symptoms of jumper's knee.³⁰ In our study, the results of six sonographic examinations during three school years indicated an often dynamic pattern considering the structural tendon changes and vascularity. However, considering the occurrence of structural changes and vascularity, the tendons with the clinical diagnosis of jumper's knee were relatively stable, whereas the tendons that were clinically normal showed more fluctuations.

Interestingly, one patient with bilateral jumper's knee (clinical and US+PD) was excluded because of an acute lumbar disc herniation. The tendon structure and vascularity were completely normalised after 6 months of withdrawal from volleyball training and playing. But after recommencing volleyball training, she regained structural changes in the tendon within 1 year.

It is not considered easy to clinically diagnose jumper's knee because there are differential diagnoses, such as patello-femoral cartilage injuries, that can produce similar clinical findings. US and MRI are reliable methods to study the tendon structure.^{36 49 50} However, there is no strong correlation between structural changes on imaging and clinical symptoms.^{13 28 30} To minimise the risk of an incorrect diagnosis, imaging can be used to verify that there are structural changes in a clinically painful tendon.^{35 37 42 43} The weak correlation between structural tendon changes and clinical symptoms is demonstrated at inclusion, when 9 of 44 tendons (20%) were clinically normal but had sonographical changes, and at 3 years, when 18 of 36 tendons (50%) were clinically normal but had sonographical changes. Our findings at inclusion are in agreement with the results of a study by Cook *et al*,² who found structural changes, but no pain, in 21% of the patellar tendons in a similar group of junior basketball players. However, at 3 years our findings (50%) are much higher, possibly indicating that intensive training and playing volleyball during adolescence induces structural tendon changes. In a group of asymptomatic male elite soccer players, structural changes were present in 18 of 98 (18%) tendons at baseline, and in 15 of 98 (15%) tendons at follow-up.⁴⁸ Comparing the results of these two longitudinal studies, it appears that playing soccer might be less provocative for the tendon. However, age, gender, sport-specific characteristics, amount and type of training and training intensity are important factors that might affect the tendon response. Interestingly, adolescence has been suggested to be the most critical time for tendon development.^{43 44}

Doppler findings: vascularity

Colour-Doppler or PD examination can be used in addition to the grey-scale US examination to provide information about vascularity in the region of interest. Due to the low flow rates in the vessels in normal tendons, the flow cannot be registered using Doppler; only high flow rates, like what have been found in chronic painful Achilles³⁹ and patellar (jumper's knee) tendons,^{22 37 38 42 43} can be registered. In patients with chronic painful mid-portion Achilles tendinosis^{39 40} we have demonstrated

Figure 1 Flow chart summarising the longitudinal outcomes of the volleyball players' patellar tendons, which were clinically and sonographically normal at baseline. US, ultrasound.

an association between the occurrence of vascularisation in the area with structural tendon changes and pain during tendon-loading activity. For the patellar tendon, Cook *et al*⁴¹ reported an association between vascularity and pain among volleyball players with jumper's knee, and Terslev *et al*³⁷ reported that association in a small sample of elite male basketball players with patellar tendinopathy. Recently, we have demonstrated vascularity in elite

junior volleyball players with the clinical diagnosis of jumper's knee.^{42, 43} However, there were also pain-free tendons with vascularity and painful tendons without vascularity.

It seems likely that adding Doppler to US examination could provide valuable information. At inclusion, seven of eight tendons with the clinical diagnosis of jumper's knee also had structural changes together with vascularity, and at 3 years all

What is already known on this topic

- Structural patellar tendon changes are common findings among volleyball players, both in pain-free and painful tendons.

What this study adds

- From this longitudinal study on junior elite volleyball players there is new information about the fate of the patellar tendon.
- If there is a normal clinical status and normal US+PD findings at the start, there is a low risk of having jumper's knee-patellar tendinopathy during 3 years' of intensive playing and training.
- If jumper's knee patellar tendinopathy is diagnosed clinically and sonographically at the start in several tendons the symptoms remain if intensive training and playing volleyball is continued.

six tendons with jumper's knee had structural changes together with vascularity. Interestingly, during the three school years, there were 11 tendons that were found to have intermittent vascularity, together with structural changes, but without clinical symptoms. Altogether, this indicates that vascularity in the area with structural tendon changes might be, but is not always, associated with pain in this condition. From studies on chronic painful Achilles tendons, it has recently been demonstrated that sensory nerves "travel together" with vessels,⁵¹ and theoretically, the amount and activity of sensory nerves in the area with vascularity possibly sets the limits for pain. When this study was started, there was no reliable method to quantify vascularity. However, recently a new method allowing for quantification of the blood flow in the tendon has been introduced.⁵²

CONCLUSION

For elite junior volleyball players it is tempting to believe that if normal clinical tests (using our definition) and ultrasound findings are diagnosed at start, there is a low risk of developing jumper's knee during the three school years of intensive training and playing volleyball.

Also, it seems that if jumper's knee is diagnosed clinically at the start, the symptoms may remain. This has also been demonstrated by Khan *et al*³⁰ previously in a longitudinal study on female basketball players.

This is valuable information for adolescent volleyball players, coaches and physiotherapists. With this information in hand, and with the knowledge that there are unpredictable results of treatment, especially among volleyball players,^{7 11 12} it can be argued whether an individual with jumper's knee should be recommended to participate in the 3 years of volleyball education.

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Competing interests: None.

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ECHO.....

Diagnosis of exercise induced asthma in elite athletes

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Asthmatic elite athletes currently require evidence of asthma to obtain a therapeutic use exemption certificate, which enables them to use doses of inhaled β_2 agonists in and out of competition. A fall in forced expiratory volume in 1 second (FEV_1) of $\geq 10\%$ following bronchoprovocation is regarded as the gold standard for diagnosing exercise induced asthma (EIA) in athletes. Previous studies have suggested that mid-expiratory flow—that is, forced expiratory flow at 50% of vital capacity (FEF_{50}), might be used to supplement FEV_1 to improve the sensitivity and specificity of the diagnosis.

A study involving 66 men (36 asthmatic, 30 non-asthmatic) and 50 women (24 asthmatic, 26 non-asthmatic) investigated these claims. Maximum voluntary flow-volume loops were measured before and 3, 5, 10, and 15 minutes after stopping eucapnic voluntary hyperventilation (EVH) or exercise. A fall in FEV_1 of $\geq 10\%$ and a fall in FEF_{50} of $\geq 26\%$ were used as the cut-off criteria for identification of EIA.

Sixty athletes had a fall in FEV_1 of $\geq 10\%$ leading to the diagnosis of EIA. The lowest fall in FEF_{50} in an athlete with a $\geq 10\%$ fall in FEV_1 was 14.3%. Of the 60 athletes who were diagnosed with EIA using the International Olympic Committee's Medical Commission criteria of a $\geq 10\%$ fall in FEV_1 , 21 (35%) would have received a false negative diagnosis using a combination of FEV_1 and FEF_{50} falls. The authors conclude that the inclusion of FEF_{50} in the diagnosis of EIA in elite athletes reduces the sensitivity of the diagnosis. The use of FEF_{50} alone is insufficiently sensitive to diagnose EIA reliably in elite athletes.

▲ Dickinson JW, *et al*. *Thorax* 2006;**61**:111–4.