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Performance Characteristics of Volleyball Players with Patellar Tendinopathy

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Background: Patellar tendinopathy is assumed to result from chronic tendon overload. There may be a relationship between tendon pain and jumping ability.
Hypothesis: There is no difference in performance characteristics between volleyball players with patellar tendinopathy and those without.
Study Design: Prospective cohort study.
Method: We examined the performance of the leg extensor apparatus in high-level male volleyball players with patellar tendinopathy ($N = 24$) compared with a control group ($N = 23$) without knee symptoms. The testing program consisted of different jump tests with and without added load, and a composite jump score was calculated to reflect overall performance.
Results: The groups were similar in age, height, and playing experience, but the patellar tendinopathy group did more specific strength training and had greater body weight. They scored significantly higher than the control group on the composite jump score (50.3 versus 39.2), and significant differences were also observed for work done in the drop-jump and average force and power in the standing jumps with half- and full-body weight loads.
Conclusions: Greater body weight, more weight training, and better jumping performance may increase susceptibility to patellar tendinopathy in volleyball players.

Epidemiologic studies have shown a prevalence of patellar tendinopathy of 40% to 50% among high-level volleyball players.[6,8,19] No epidemiologic data are available on the prevalence in other sports, but results of clinical studies among patients undergoing surgical treatment for patellar tendinopathy suggest that there is a high prevalence among soccer players and in sprinters and jumpers as well.[13,20,23,24] Evidence from histologic and imaging studies suggests that the pathologic process involved consists of unhealed or incompletely healed microtears in the tendon substance, usually in the proximal part of the patellar tendon. The histologic changes are compatible with a degenerative condition without signs of inflammation.[5,7,9–12,14,21–25] Training volume and floor hardness are extrinsic factors that correlate with the prevalence of patellar tendinopathy.[8] Data on intrinsic factors are conflicting and mostly related to static biomechanical parameters.[8,16,17,19] In a previous case-control study, we evaluated some dynamic characteristics of the leg extensor apparatus, and the results suggest that players who have patellar tendinopathy perform better on jump tests than do healthy control subjects, especially on tests involving eccentric work.[18] The purpose of the present study was to examine the leg extensor characteristics in a larger cohort of players by using a more comprehensive jump- and strength-testing program.

MATERIALS AND METHODS

Study Design

This study was performed during an international volleyball tournament in Oslo, Norway, with approval from the ethics committee of the Norwegian Research Council. The tournament was played 2 months after the end of the ordinary competitive season, with teams competing in classes according to their level of play. The six Norwegian teams that participated in the men's elite class were invited

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to take part in the study. These were amateur teams that otherwise compete in the top division of the Norwegian Volleyball Federation (NVBF) leagues. The teams consisted of 53 players, and 47 of these (89%) consented to take part in an interview, clinical examination, and a series of standardized jump and power tests. Their patellar tendons were also examined ultrasonographically, and the results of this investigation have been presented in a separate article.[19]

Interview and Clinical Examination

Information requested from each player included age, height, weight, number of years participating in organized volleyball training, years of participation at the senior level and in the top division of the NVBF league system, number of training hours per week (volleyball training, weight training, and jump training), and stretching habits during the previous season.

Each player underwent a standard knee examination and clinical interview on present and former knee injuries and complaints. The following diagnostic criteria for patellar tendinopathy were used: history of pain localized to the lower patellar pole or insertion of the quadriceps tendon in connection with volleyball play and distinct palpation tenderness corresponding to the painful area.[1] A diagnosis of previous patellar tendinopathy was based on history alone. The subjects were classified according to criteria modified by Lian et al.,[19] based on Roels et al.[25] and Blazina et al.[1] (Table 1), and divided into two groups: those with current patellar tendinopathy and those with no history of patellar tendinopathy.

Jump and Power Testing

The players went through a standardized jump- and power-testing program. The testing program was performed by using a contact mat connected to a computer (Intervall A/S, Oslo, Norway) (Fig. 1). The equipment measures the flight time of each jump, and from this the height of rise of the center of gravity is calculated.[3,26] In addition, power can be calculated from flight and contact times during rebound jumps.[4]

The jumps performed were standing jump (SJ), counter-movement jump (CMJ), drop-jump from a dropping height of 45 cm ($DJ_{45\ cm}$), standing jump with a 20-kg load ($SJ_{20\ kg}$), standing jump with loads corresponding to one-half body weight ($SJ_{1/2\ bw}$) and full body weight ($SJ_{1/1\ bw}$), and a 15-second maximal rebound jump test (RJ). Standing jumps were performed with the subject starting from a stationary semisquatting position with 90° of knee flexion and with both hands kept fixed on the hips. No counter movement was allowed with any body segment. In the counter-movement jump the subject started the movement from a stationary erect position with knees fully extended, and was allowed to bend down to approximately 90° of knee flexion before starting the upward motion of the jump. Standing jumps with loads were performed with barbells on the shoulders of the players. The drop-jump was performed as a counter-movement jump, except that the player dropped from a height of 45 cm. In the 15-second maximal rebound jump test, the subjects were encouraged to jump as high and as fast as possible during 15 seconds (Fig. 1).[15]

The players were encouraged vocally during the jumps and were watched carefully to ensure that the proper

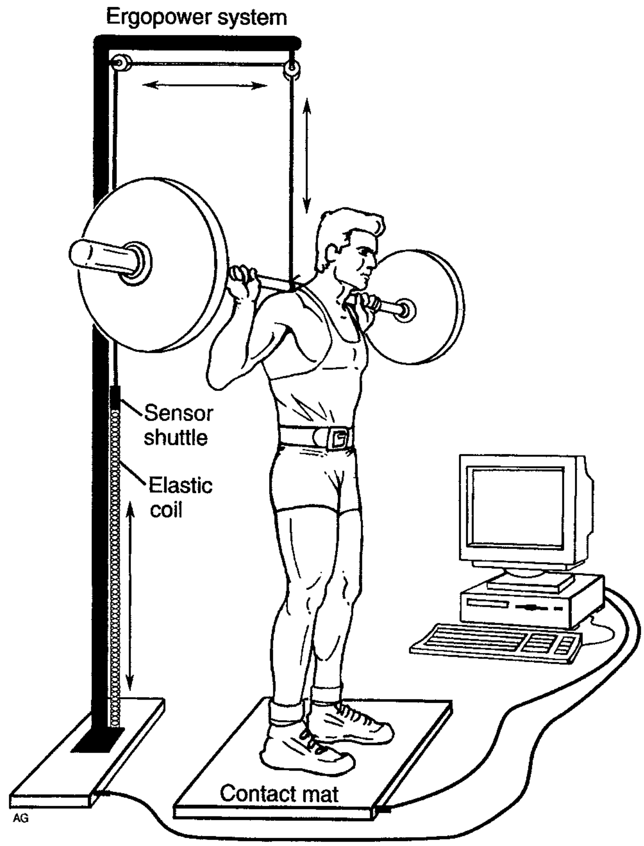

Figure 1. Schematic of the experimental setup for the jump tests. During all tests the players jumped on a contact mat connected to a computer, making it possible to compute jumping height.[4] Also, during jumps with an added load, the barbell was mechanically linked with the Ergojump system connected to a shuttle, making it possible to calculate force, velocity, and power.[2]

TABLE 1
Classification of Patellar Tendinopathy According to Symptoms[a]

Grade	Symptoms
I	Pain at the infrapatellar or suprapatellar region after practice or after an event
II	Pain at the beginning of the activity, disappearing after warm-up and reappearing after completion of activity
IIIa	Pain during and after activity, but the patient is able to participate in sports at the same level
IIIb	Pain during and after activity, and the patient is unable to participate in sports at the same level
IV	Complete rupture of the tendon

[a] Symptoms as outlined by Roels et al.,[25] Blazina et al.,[1] and Lian et al.[19]

technique was used. In particular, care was taken to ensure that there was no counter movement in the standing jumps and that the subjects landed with straight legs. The best of three technically correctly performed jumps was used for the final calculations.

In addition, during the execution of the standing jumps with loads, the average velocity, force, and power during the jump were measured with the Ergopower system (Ergotest Technology AS, Langesund, Norway) (Fig. 1). The equipment measured the displacement of gravitational loads (in this case, barbells) as external resistance.[2] The vertical displacements of the loads were monitored with mechanical and sensor arrangements. The loads were mechanically linked to a shuttle gliding on a track bar. The movement of this shuttle was recorded by the sensor, which was interfaced to an electronic device that included a microprocessor and software. The microprocessor worked internally with a 10-μm time resolution. When the subject moved the loads, the signal from the sensor interrupted the microprocessor every 3 mm of displacement. Thus, it was possible to calculate velocity, acceleration, force, power, and work corresponding to the load displacements. This system has been shown to be accurate and reproducible.[2]

Data Analysis

For each player, a composite jump score to evaluate the performance ability of the leg extensor apparatus was calculated by rating each player's result on a scale from 0 to 100 on each of the jump tests, where 0 represents the lowest test score among all the players tested and 100, the best score. The overall score was computed as the average of the results from each of these eight scores. Results are given as means ± SD unless otherwise noted.

Prevalence was compared between the two groups by using chi-square tests. Comparisons of the jump and strength test results between the patellar tendinopathy group and the control group were made with unpaired *t*-tests. An alpha level of 0.05 was used.

RESULTS

Prevalence of Jumper's Knee

Of the 47 players participating in the study, 24 (51.0%) were given a diagnosis of current patellar tendinopathy affecting at least one side, based on the clinical examination (typical history and clinical findings). Twenty players (42.6%) had never experienced problems in either knee, whereas three players (6.4%) reported having had previous knee problems identified as patellar tendinopathy. The severity of symptoms among those with current patellar tendinopathy (33 knees) was classified as grade I in 6 knees, grade II in 18 knees, and grade IIIa in 9 knees (Table 1). The onset of symptoms was gradual in 31 knees (94%) and acute in 2 knees, and the duration of symptoms reported by the players who had patellar tendinopathy was 3.5 ± 2.4 years (range, 0.1 to 10). The age at symptom onset was 18.8 ± 2.8 years (range, 13.5 to 25.9).

Player Characteristics

The characteristics of the players and their training backgrounds are shown in Table 2. Players with a diagnosis of patellar tendinopathy had a significantly greater body weight than the control subjects and trained more with weights. The prevalence of current patellar tendinopathy was significantly higher among outside hitters (12 of 18, 67%) and middle blockers (9 of 14, 64%), compared with utility players (1 of 6, 17%) or setters (2 of 9, 22%).

Thirty-seven players (79%) reported using a right-left step-close takeoff technique in the spike jump, whereas 10 players (21%) used a left-right takeoff. Only 1 player reported preferring the right leg when landing after the attack, whereas 31 players (66%) reported a balanced landing technique, and 15 players (32%) reported favoring their left leg when landing. The takeoff and landing techniques among the players with current symptoms of jumper's knee are shown in Table 3.

TABLE 2
Characteristics of Players with Current Symptoms of Patellar Tendinopathy and Players with No History of Patellar Tendinopathy (Means ± SD)

Variable	Current symptoms (N = 24)	No history (N = 20)	Significance level (P)
Age (years)	22.4 ± 2.5	22.0 ± 4.0	0.65
Height (cm)	191.1 ± 7.0	189.5 ± 6.2	0.43
Weight (kg)	86.7 ± 7.9[a]	81.9 ± 8.1	0.05
Organized volleyball training (years)	8.0 ± 2.8	7.5 ± 3.6	0.55
Training at senior level (years)	6.8 ± 2.5	5.7 ± 3.6	0.28
Training at elite level (years)	2.5 ± 2.6	2.2 ± 3.2	0.70
Volleyball training (hours/week)	7.7 ± 2.1	7.4 ± 1.6	0.53
Weight training (hours/week)	4.5 ± 2.8[a]	2.3 ± 2.3	0.009
Jump training (hours/week)	0.4 ± 0.9	0.6 ± 1.1	0.53
Total training (hours/week)	12.6 ± 4.2	10.3 ± 3.9	0.06
Stretching during warm-up (minutes)	3.4 ± 3.0	3.1 ± 2.7	0.71
Stretching after training (minutes)	6.2 ± 5.8	7.1 ± 3.9	0.55

[a] Significantly different from players with no history of patellar tendinopathy (unpaired *t*-tests).

TABLE 3
Takeoff and Landing Technique in Spike Jump for each of the Knees with Patellar Tendinopathy (N = 33)

Technique	Right knee (N = 22)	Left knee (N = 11)
Right-left takeoff	20	11
Left-right takeoff	2	0
Right-left landing	0	0
Left-right landing	6	4
Simultaneous landing	16	7

Jump and Power Testing

The test results for players with current symptoms of patellar tendinopathy and players without a history of patellar tendinopathy are shown in Table 4. The patellar tendinopathy group scored significantly higher than the control group on the composite jump score (50.3 versus 39.2, P = 0.02), and significant differences were also observed for work done in the drop-jump and average force and power in the standing jumps with half- and full-body weight loads.

DISCUSSION

The main findings of the present study were that players with a clinical diagnosis of patellar tendinopathy generally performed better on the dynamic testing program than did players without patellar tendinopathy. The symptomatic group had a greater body weight and did more specific weight training than did those in the control group.

Patellar tendinopathy is a condition characterized by histologic[7,10,12,22–25] and soft tissue imaging findings[5,9–12,14,21,22] compatible with an unhealed or insufficiently healed partial patellar tendon tear. These partial tears probably occur when the strength of the tendon is insufficient in relation to the applied forces.[29] The tendon may be subject to fatigue under the high chronic repetitive loading, despite the fact that the cyclical loads may be well within the ultimate failure stress range of the tendon,[28] which is in the range of 56.7 ± 4.4 MPa. This view is supported by the fact that most of the players with patellar tendinopathy reported a gradual onset of their symptoms. Because eccentric force production in certain circumstances may be three times the concentric force, it is believed to be a primary cause of the microruptures.[29] It has been suggested that tendon overload may result from a combination of extrinsic (such as floor type)[6,8] and intrinsic (such as malalignment) factors,[16,17] with the sum of these factors determining whether a player develops patellar tendinopathy.

In this study, we evaluated intrinsic factors with the jump-testing program. The composite jump score was designed as an overall indicator of a player's ability to load the extensor apparatus during conditions ranging from slow-speed concentric (standing jump with added load) to high-speed ballistic (rebound jumps) movements. The dynamic testing program was selected to resemble the various loading conditions imposed on the leg extensors during different jumping and cutting movements used in the game of volleyball. The significant difference in the composite jump score observed between the groups may be taken as an indication that the leg extensor apparatus in the group of players with patellar tendinopathy may be subjected to higher loads during volleyball play as well. There were significant differences between the players with current patellar tendinopathy and those without, both in average force and average power in standing jumps with added loads corresponding to one-half and whole body weight. Consequently, the forces acting on the tendon or the rate of force development during jumping may surpass the adaptive abilities of the tendon, and, in that way, cause microtears in the tendon substance among players with high performance ability.

In a previous case-control study, we found significant differences between two smaller groups of players in the results of a counter-movement jump, in the difference in jumping height between a counter-movement jump and a standing jump, and in a rebound test.[18] In this previous study the jumps were performed in the same manner as described in detail in the methods for the present study. However, we could not reproduce these results. The previous study included a smaller number of players, and in a case-control study it is possible that a selection bias may have occurred. However, the performance of the players with patellar tendinopathy in the first study in the counter-movement jump test and the rebound jump test

TABLE 4
Results of Jump and Power Tests in Players with Current Symptoms of Patellar Tendinopathy and Players with No History of Patellar Tendinopathy (Means ± SD)

Measurement and jump[a]	Current symptoms (N = 24)	No history (N = 20)	Significance level (P)
Jump height (cm)			
SJ	36.2 ± 5.8	36.0 ± 4.0	0.88
CMJ	41.3 ± 6.5	40.3 ± 4.1	0.54
CMJ–SJ	5.1 ± 2.1	4.3 ± 1.8	0.19
DJ_{45cm}	53.1 ± 7.1	50.5 ± 6.0	0.20
SJ_{20kg}	27.3 ± 5.1	26.6 ± 3.7	0.60
$SJ_{1/2bw}$	19.5 ± 4.4	18.3 ± 3.4	0.33
$SJ_{1/1bw}$	10.0 ± 2.3	9.5 ± 2.4	0.55
Work (J)			
SJ	306 ± 46	286 ± 34	0.14
CMJ	349 ± 56	322 ± 35	0.06
DJ_{45cm}	449 ± 67[b]	404 ± 53	0.02
Average power (W)			
Rebound jumps 15 s	67.4 ± 13.4	60.3 ± 11.5	0.07
$SJ_{1/2bw}$	705 ± 133[b]	621 ± 104	0.04
$SJ_{1/1bw}$	1048 ± 161[b]	865 ± 147	0.003
Average force (N)			
$SJ_{1/2bw}$	528 ± 47[b]	485 ± 49	0.01
$SJ_{1/1bw}$	1011 ± 83[b]	908 ± 70	0.001
Average velocity (m/s)			
$SJ_{1/2bw}$	1.33 ± 0.17	1.27 ± 0.14	0.28
$SJ_{1/1bw}$	1.03 ± 0.12	0.95 ± 0.14	0.10

[a] SJ, standing jump; CMJ, counter-movement jump; DJ_{45cm}, drop-jump from 45 cm height; SJ_{20kg}, standing jump with 20 kg weight; $SJ_{1/2bw}$, standing jump with loads corresponding to one-half body weight; $SJ_{1/1bw}$, standing jump with loads corresponding to full body weight.

[b] Significantly different from players with no history of patellar tendinopathy (unpaired t-tests).

was significantly better than the results of the players in the present study. This suggests that the injured players in the first study had a highly developed leg extensor apparatus, which may indicate a stronger disposition to patellar tendinopathy.

Data from previous studies concerning other potentially important intrinsic factors are conflicting; these studies have mostly evaluated static biomechanical parameters. Ferretti[6] found no differences in sex, alignment of the knee, alignment of the extensor mechanism, position of the patella, characteristics of the tibial tuberosity, rotation of the femur, rotation of the tibia, degree of constitutional instability, characteristics of the foot, or morphotype between subjects with and without jumper's knee. On the other hand, Kujala et al.[16,17] found more leg-length inequality and patella alta in patients with patellar tendinopathy compared with controls, on the basis of standing radiographs. With use of the same group of subjects as in the present study, we found no difference in the length of the patellar tendon or the Insall-Salvati index when we compared patients with patellar tendinopathy and control subjects.[19]

Epidemiologic studies on extrinsic risk factors have shown that the hardness of the playing surface and an increased frequency of training sessions correlate positively with the prevalence of patellar tendinopathy.[6,8] As expected, we found no difference between the groups in the total amount of specific volleyball training because all of the players were selected from the same teams—a well-trained group with a similar training history. However, we do not have detailed information on the training history of the players at the time they were first injured. At that time there may have been differences in training volume or intensity that we were unable to detect in a cross-sectional study. Longitudinal studies are necessary to examine in detail how training programs may lead to tendon overload.

It can be argued that the additional weight room training and better jumping characteristics were a consequence of the symptoms because the athlete with tendinopathy could be expected to spend more time in the training room, strengthening and stretching the aching muscle-tendon group. We find it highly unlikely that a painful condition regarded as a chronic overuse injury should improve the jumping capacity of these athletes. None of the teams had a physical therapist or athletic trainer working systematically with them, and at the time there was no tradition of systematic weight training (eccentric strength training) to treat patellar tendinopathy. In fact, most of the players had received no treatment for their symptoms. We did find that the prevalence of patellar tendinopathy was significantly higher among outside hitters and middle blockers compared with utility players and setters. This is not surprising because outside hitters and middle blockers perform a much higher number of maximal jumps than do setters as a result of their function on the team.

The players with patellar tendinopathy reportedly trained more with weights than the others did. This additional weight training by itself indicates a higher total loading of the extensor apparatus, and the anticipated effect of this training would also increase muscle mass and jumping ability. This indication is supported by the fact that the players with patellar tendinopathy had a greater body weight than those without patellar tendinopathy. We did not examine body composition, but it is unlikely that the body weight difference observed was due to differences in body fat in such a well-trained population of players.

The right knee was affected twice as often as the left knee in the patients in the present study. The majority of the players used a right-left step-close takeoff technique, and only one player reportedly preferred the right leg when landing after the attack. In fact, 20 of the 22 players with current jumper's knee on the right side used a right-left takeoff technique. This finding suggests that a relationship may exist between the takeoff technique and patellar tendinopathy and that the forces sustained during takeoff may be of considerable importance. For a right-handed player to obtain proper alignment of the upper body for an effective spike, the preferred technique involves placing the right foot first in a position of about 45° of external rotation[27] (Fig. 2). When using this takeoff technique, the deceleration work is done mostly with the right leg, subjecting it to higher eccentric-concentric loading than the left leg. Also, when these high loads are imposed, the right leg may be in a state of functional malalignment. The preferred takeoff technique results in

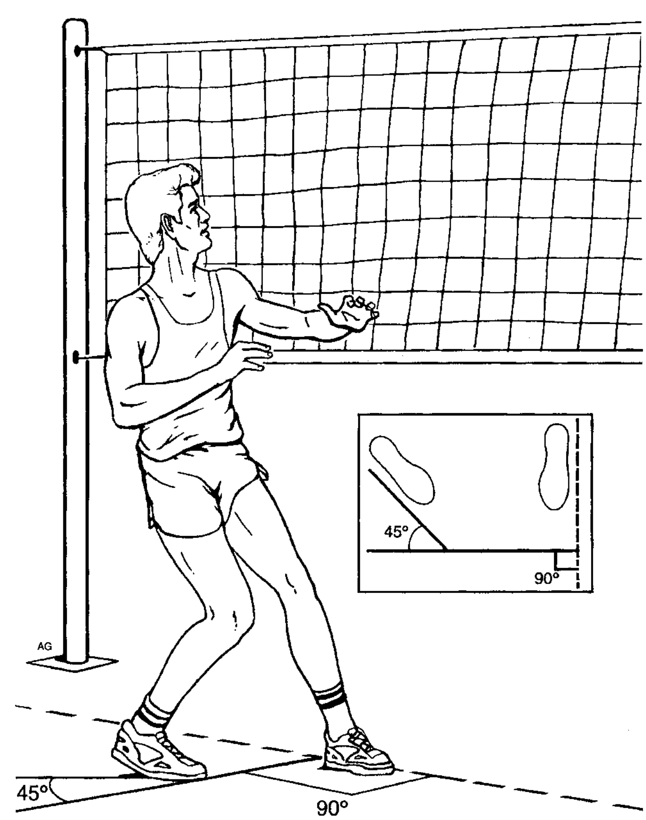

Figure 2. Takeoff technique during spike jumps in volleyball. Note how the typical foot placement pattern results in external rotation of the tibia in relation to the femur, increased knee flexion, and valgus stress on the right side.

a valgus position of the right leg, a greater flexion angle of the knee, and greater external rotation of the tibia relative to the femur (Fig. 2). It is possible that these factors result in a more unfavorable loading pattern of the right knee with respect to development of patellar tendinopathy. Motion analysis and direct force measurements are necessary to study this phenomenon in more detail.

It is tempting to speculate that the particular takeoff technique used in volleyball may cause loading patterns that are more likely to cause jumper's knee than those observed in many other sports. An exception may be high jumping, where the takeoff leg is loaded in valgus and external rotation, similar to the position in volleyball. However, the prevalence of jumper's knee in other sports is not known, although clinical studies indicate that jumper's knee may also be a problem among athletes in soccer and athletics.[13,20,23,24] The high prevalence of jumper's knee among high-level volleyball players detected in the present study is similar to that reported by others,[6,8,18] but further epidemiologic studies are necessary to compare the prevalence in other sports.

CONCLUSIONS

The overall results from the jump-testing program showed an increased performance ability of the leg extensors among players with a current diagnosis of jumper's knee compared with players without a history of jumper's knee. The body weight of the players with jumper's knee was also greater, and they reportedly did more weight training than the group without symptoms. All of these factors will tend to increase the loading of the extensor apparatus and thereby increase the susceptibility to partial tendon ruptures.

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