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MUSCULOSKELETAL IMAGING

ORIGINAL ARTICLE

Comparison of ultrasonographic patellar tendon evaluation methods in elite junior female volleyball players: thickness versus cross-sectional area

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PURPOSE
The goal of the present study was to compare the patellar tendon cross-sectional area with the patellar tendon thickness and to determine the intra-observer compliance level in the cross-sectional area and thickness measurements. This comparison was used to describe the effects of playing volleyball on the patellar tendon.

MATERIALS AND METHODS
The patellar tendons of 60 volleyball players and 60 non-player female students, who were 11–16 years of age with similar physical characteristics, were examined using Doppler ultrasonography (US). Cross-sectional area and thickness measurements were conducted.

RESULTS
The proximal and distal thicknesses of the patellar tendon were similar, but the area was smaller for the distal portion. A correlation was observed between age and tendon thickness and between the thickness and area of the tendon. All of the measurements in the subjects with tendinosis were larger than those in the healthy controls. There were no pathological findings in the non-players. The intra-observer compliance was high.

CONCLUSION
The transverse plane area measurement was as reliable as the thickness measurement and exhibited a high level of intra-observer compliance. This measurement can be conducted during routine examinations. The patellar tendons in the athletes were observed to be widened and thickened, most likely because of overuse. Patellar tendinosis and Osgood-Schlatter Syndrome may be asymptomatic and incidentally detected. Therefore, routine US examinations may help prevent further injuries. Although the tendon thicknesses were observed to be the same in both extremities, any observed difference in the tendon areas may alert the physician to a risk factor for the development of tendinosis.

Key words: • tendinopathy • patella • volleyball • measurement • ultrasonography

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The patellar tendon (PT) is the most commonly injured anatomical region in athletes who are engaged in sports that require jumping, such as volleyball, basketball, or running (1). The diagnosis of PT injuries is often based on clinical findings; however, the use of imaging of the PT has increased, especially using ultrasonography (US) (2). Unfortunately, the results of imaging modalities (e.g., magnetic resonance imaging [MRI] and US) are ambiguous for PT injuries, but are often used during the examinations to exclude other causes and to assess the severity of the injury (1, 3). In addition to the other mechanisms that may explain these clinically inconsistent imaging findings, inaccuracies in the measurements of imaging and of pain may have contributed to these findings (1, 4).

During US, the tendon thickness, internal structure, and vascularization are often the examined parameters. The thickness measurements are performed in the transverse and longitudinal planes in the majority of studies (3, 5–7); however, this method does not take into account that the tendon has a variable, non-homogenous thickness throughout its length. The PT is conic proximally, with a wider and thinner shape, (7) and tapers distally to a narrower and thicker end, with a slight posterior bulge (8). In addition, variation in the tendon shape and thickness exists between individuals. Therefore, the institution of cross-sectional area measurements of the thickness during US exams may provide more information about the PT.

The present study aimed to examine the contribution of the PT cross-sectional area measurements using PT imaging in junior volleyball players and non-players compared with thickness alone. The present study also aimed to determine the intra-observer compliance level of reproducibility.

Materials and methods

Two separate groups of volunteers of the same age and gender were included in the present study. The first group consisted of 60 female volleyball players, and the second group consisted of 60 female sedentary individuals. Both of the groups of females were secondary school students. Written informed consent was obtained from all of the participants and their families. The ethics committee of the second author's institution approved the study design.

Selection of volunteers

The study group (Group 1) consisted of athletes (age range, 11–16 years) who played volleyball regularly for the previous two years on the school team. These athletes had no reported history of injuries of the knee within the previous year. The extremity that was used during landing while playing was labeled as the dominant lower extremity for comparison purposes because injuries tend to occur more often in the dominant extremity. However, measurements were taken for both tendons.

The control group (Group 2) consisted of healthy female subjects in the same age-range as Group 1, with no active participation in sports and no complaints of the knee joint. Similar to the first group, measurements were performed in both tendons of the participants in Group 2. To compare the results of Group 1 to Group 2, the dominant extremities of the Group 1 participants were chosen and compared with the right side of the Group 2 participants. Identification of the dominant extremity was irrelevant for the sedentary Group 2 subjects because these subjects did not engage in jumping activities. In addition, no statistical difference was demonstrated between the left and right measurements in the Group 2 subjects.

Medical history and physical examination

The age, height, and weight of all the participants were recorded, and the body mass indexes (BMI, kg/m²) were calculated. For each participant, a knee joint extensor provocative test was performed, and the lower pole of the patella and PT were palpated.

Ultrasonography

US examination was performed by a radiologist with five years of experience in musculoskeletal US. Care was taken to avoid radiologist bias; the radiologist was blinded to the dominant extremity and to the group for each subject. The volunteers were randomly assigned to the examinations and were asked to wear the same type of outfit (school uniforms) so that the radiologist could not determine the study group of the volunteers. Intra-observer compliance was evaluated one day later using an additional US exam. The examination was performed in both of the extremities in all of the participants; however, only the corresponding dominant extremities were compared.

The examinations were conducted using a GE Logiq 9 scanner (General Electric Medical Systems, Milwaukee, Wisconsin, USA) and 12 MHz (10–14 MHz) linear probes. Gray scale and compound imaging, with an approximate 60 dB gain and 25-mm depth parameter, was used. The Doppler insonation was 6.7 MHz. For the color parameters, a low-wall filter (20–50) and a low-speed scale (pulse repetition frequency, PRF; 100–400 Hz) were selected. The color gain was maintained in a dynamic range, and in general, 40 to 60 dB were used.

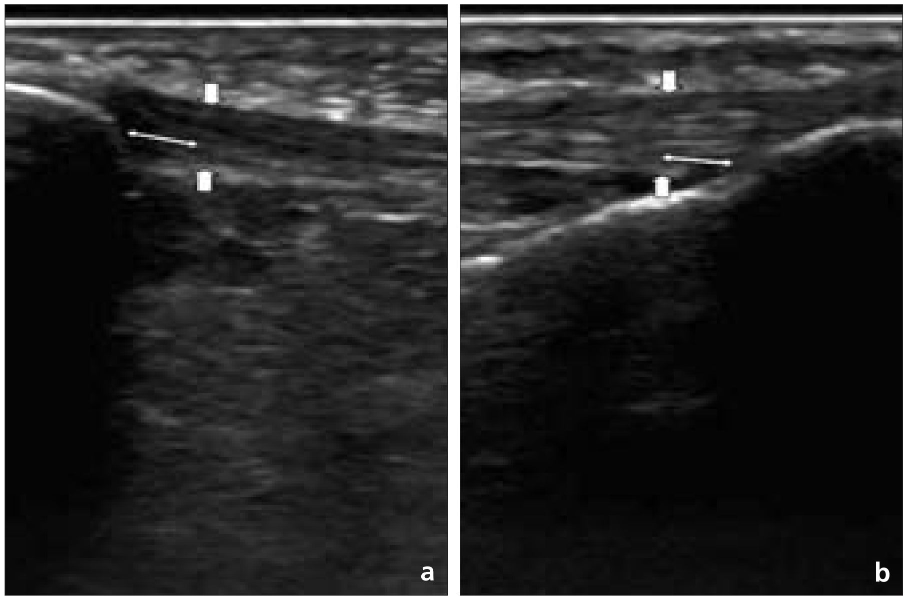

Figure 1. a, b. Patellar tendon thickness measurements. Measurements (*thick arrows*) were made in the longitudinal axis 6 mm away from the proximal insertions (*thin arrows*).

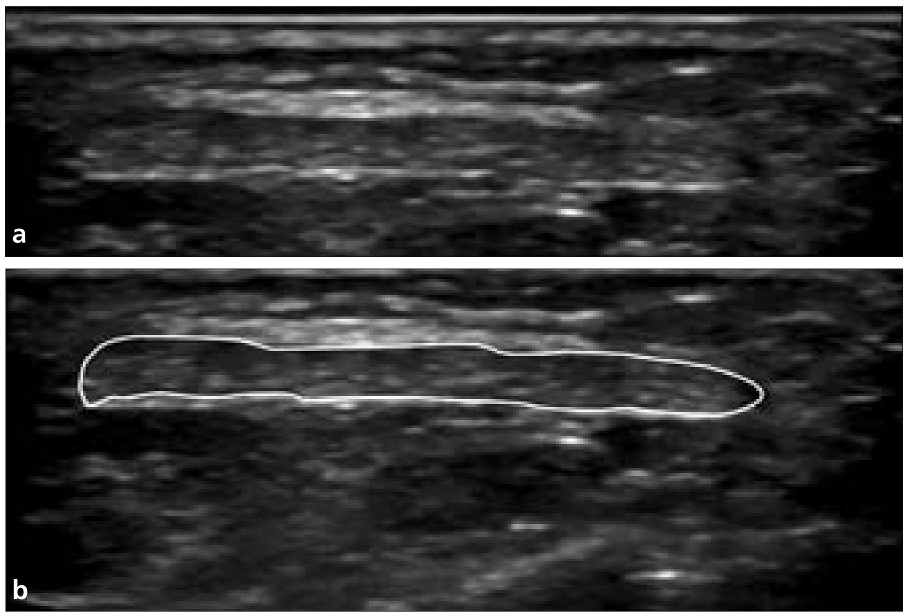

Figure 2. a, b. Patellar tendon area before measurement **(a)** and the transverse view of the measured tendon **(b)**.

The examination was performed on the longitudinal and transverse axis of both knees while the patient was in a supine position with the knees supported and flexed. The examination was performed at the most appropriate degree of knee flexion (approximately 45°) at which the tendon is taut with well-defined margins and is homogenous in fibrillar echotexture (9). The longitudinal slice thickness and transverse cross-sectional area measurements of the PT were made 6 mm distal to the patellar (proximal end) and 6 mm proximal to the tibial (distal end) tuberosity insertions (Figs. 1 and 2).

The internal structural changes of the tendon were evaluated as follows: a tendon's natural fibrillar echo structure was recorded as "normal", the loss of fibrillar structure was recorded as "abnormal", and a hypoechoic focus in the tendon was recorded as "present" or "absent". The loss of fibrillar structure and/or the presence of a hypoechoic focus were used as the diagnostic criteria for tendinosis. Echogenic areas with an acoustic shadow in the tendon were diagnosed as a calcification. The color and power Doppler examinations were instituted in all of the participants in both of the groups to analyze the neovascularization in and around the tendon.

Statistics

The data analysis was performed using a commercially available software (Statistical Package for Social Sciences, version 18, SPSS Inc., Chicago, Illinois, USA).

Mean and standard deviation calculations of the participants' demographic data were performed. Because the tendon thickness and area measurements were not equally distributed, median, minimum and maximum values, and mean and standard deviation values were presented. Group relationships were evaluated using the non-parametric Spearman's rho test. The Wilcoxon test was used to determine the differences between the groups. If the P value was less than 0.05, the difference was considered statistically significant.

To evaluate the intra-observer compliance, an intra-class correlation coefficient was calculated. Two-way and random effect models were chosen for the evaluation.

Cut-off values for tendon thickness and area were evaluated. The evaluation of the parameter discriminative ability was conducted by calculating the area below the receiver operating characteristic curves.

Subjects who exhibited tenderness or pain during palpation or during knee-extensor provocative tests or who exhibited positive US findings were excluded from the continuous data analysis. These excluded patients were only included in the nominal data analysis.

Results

In the present study, the groups did not differ in age, height, weight, or BMI ($P > 0.05$) (Table 1). The right extremity of the volleyball players was dominant in 42 (70%) of the subjects, and the left extremity was dominant in 18 (30%) of the subjects.

The proximal and distal tendon thickness and area measurements and the statistical differences in these measurements are presented in Table 2.

Age and thickness correlations of the proximal and distal portions of the tendon were calculated. For the proximal

Table 1. Participants' demographic characteristics

Variables	Group 1 (n=60)	Group 2 (n=60)
Age (year)	13.72±1.32	13.71±1.31
Height (cm)	170.13±7.37	161±7.31
Weight (kg)	58.85±8.08	57.69±7.4
BMI (kg/m^2)	20.23±1.85	19.54±2.5

BMI, body mass index. $P > 0.05$ for comparisons between groups.

Table 2. US findings in study groups

	Group 1 dominant[a] (G1D)	Group 1 non-dominant[a] (G1ND)	Group 2[a] (G2)	*P* G1D vs. G1ND	*P* G1D vs. G2	*P* G1ND vs. G2
Continuous data (median [range], mean±standard deviation)						
Proximal thickness (mm)	4.8 (4–6.2)	4.1 (2.8–5)	4.0 (3.2–4.7)	< 0.0001	< 0.0001	0.72
	4.9±0.45	4.0±0.40	4.0±0.36			
Distal thickness (mm)	4.8 (4.1–5.9)	4.1 (2.9–5.5)	4.2 (3.2–4.7)	< 0.0001	< 0.0001	0.09
	4.9±0.38	4.0±0.50	4.0±0.39			
Proximal area (mm^2)	9.4 (7.1–13.9)	7.9 (5.1–10.4)	7.6 (5.2–9.2)	< 0.0001	< 0.0001	0.87
	9.8±1.3	7.9±0.90	7.5±0.9			
Distal area (mm^2)	7.8 (6.3–9.8)	7.1 (4.5–13)	7.3 (5.0–8.5)	< 0.001	< 0.0001	0.18
	7.8±0.89	7.4±1.1	7.1±0.8			
Nominal data (n [%])						
Proximal abnormal fibrillar structure	4 (6.7)	2 (3.3)	0 (0)			
Proximal hypoechoic focus	4 (6.7)	2 (3.3)	0 (0)			
Proximal abnormal fibrillar structure	3 (5.0)	1 (1.7)	0 (0)			
Proximal hypoechoic focus	3 (5.0)	1 (1.7)	0 (0)			
Tibial tuberosity abnormality	2 (3.3)	1 (1.7)	0 (0)			
Neovascularization	2 (3.3)	0 (0)	0 (0)			

[a]Measurements of dominant and non-dominant extremities of Group 1, and of Group 2 are given.

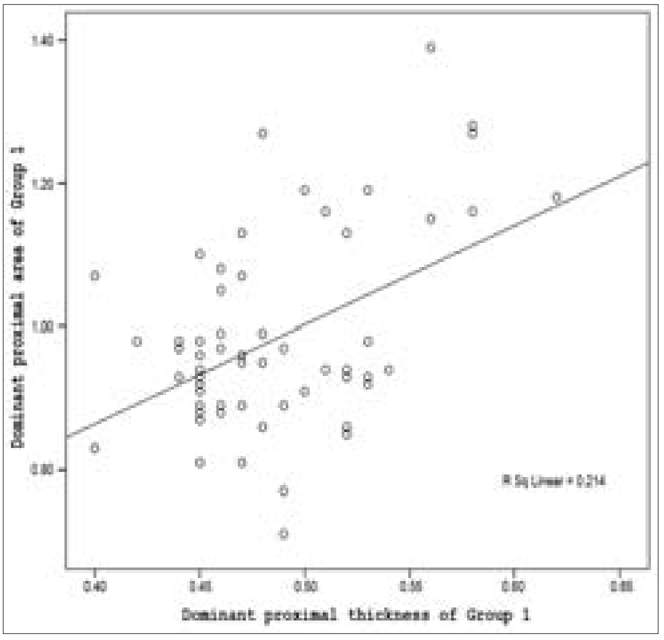

Figure 3. A correlation exists between the area and thickness of the tendon on the dominant side of the body in Group 1.

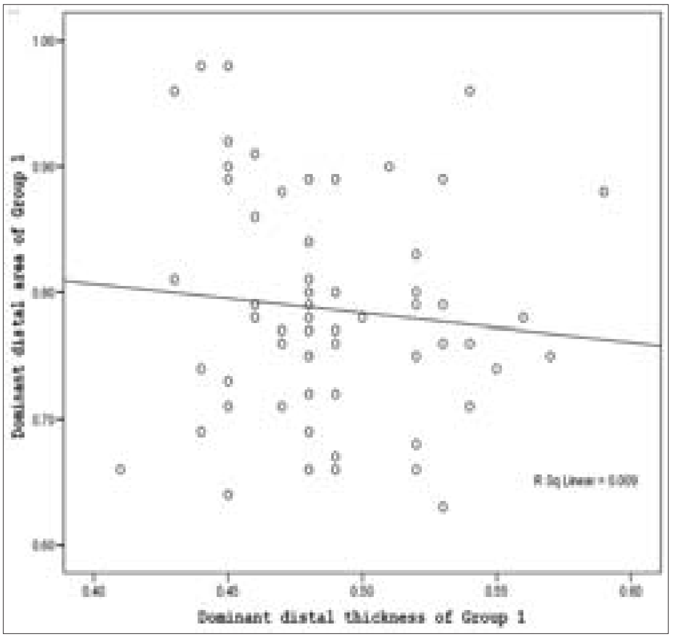

Figure 4. No correlation is detected between the area and the thickness of the tendon at the distal end of the dominant side of the body in Group 1.

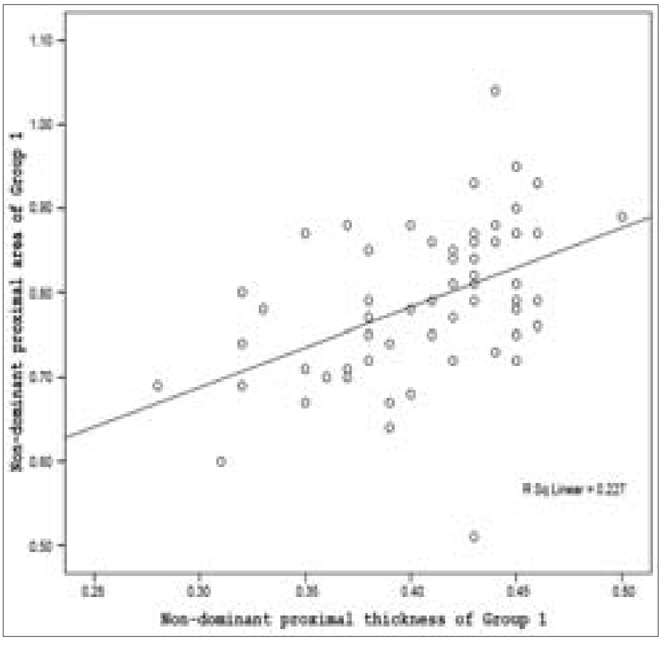

Figure 5. A thickness-area correlation exists in the proximal end of the tendon on the non-dominant side of the body in Group 1.

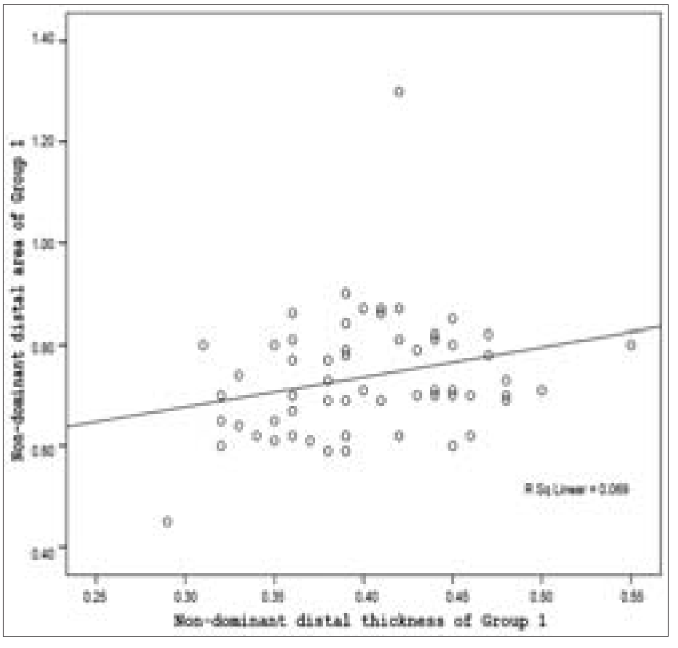

Figure 6. A thickness-area correlation is detected in the non-dominant side of the body in the distal end of the tendon in Group 1.

thickness, r=0.688, $P < 0.0001$, and for the distal thickness, r=0.281, $P = 0.015$. The relationships between the tendon thickness and area are shown in Figs. 3–8. The tendon thickness and area were correlated, except at the distal end of the tendon on the dominant side of the body (Fig. 4).

Physical examination revealed a total of 13 (21.7%) participants with positive findings. The sonographically-detected abnormalities are summarized in Table 2, showing that the thickness of both ends of the same tendon was similar in all of the participants, of whether or not they play volleyball. However, the proximal ends of the tendons were larger (i.e., with an increased surface area). The tendons on the dominant side of the athletes were the thickest and the largest (Figs. 9 and 10). No statistical differences were observed in tendon thickness or area in Group 1's non-dominant extremities compared with those of Group 2. The tendinosis findings are presented as nominal data in Table 2. The term "tibial tuberosity abnormality" refers to chondral edema and fragmentation (i.e., Osgood-Schlatter Syndrome). In Group 2, no cases with an abnormal US or positive physical findings were noted.

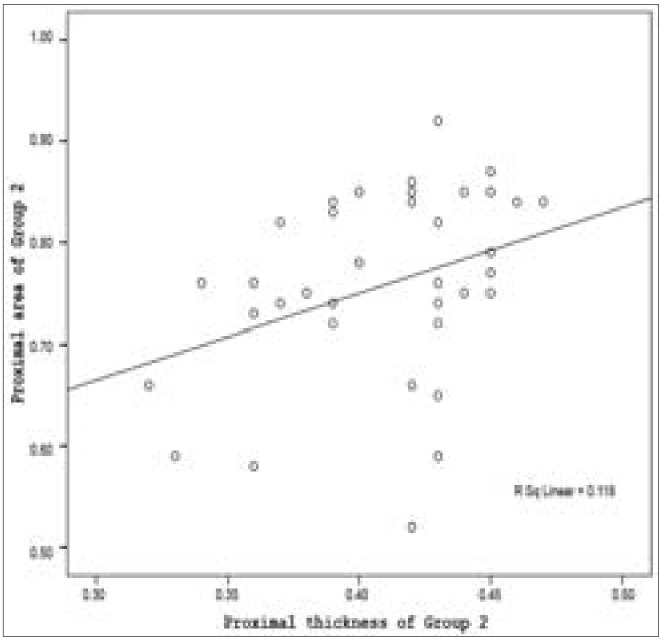

Figure 7. A thickness-area correlation is present in the proximal end of the tendon in Group 2.

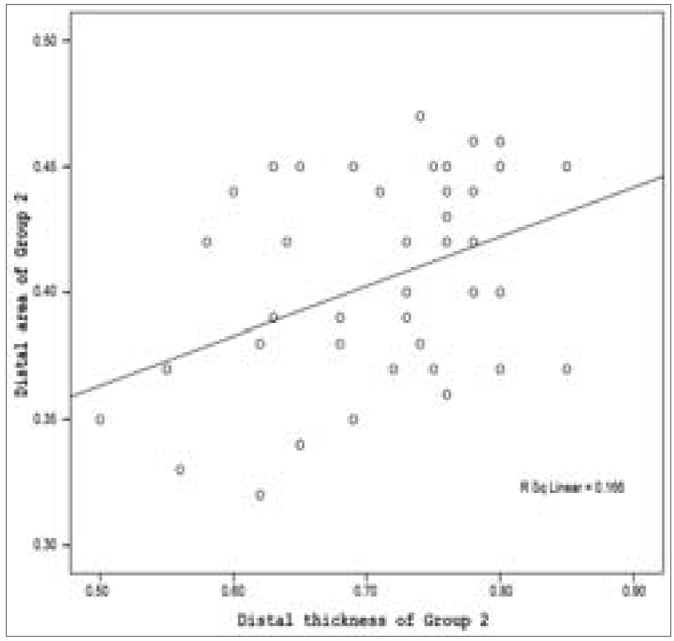

Figure 8. A correlation exists between the thickness and area of the distal end of the tendon in Group 2.

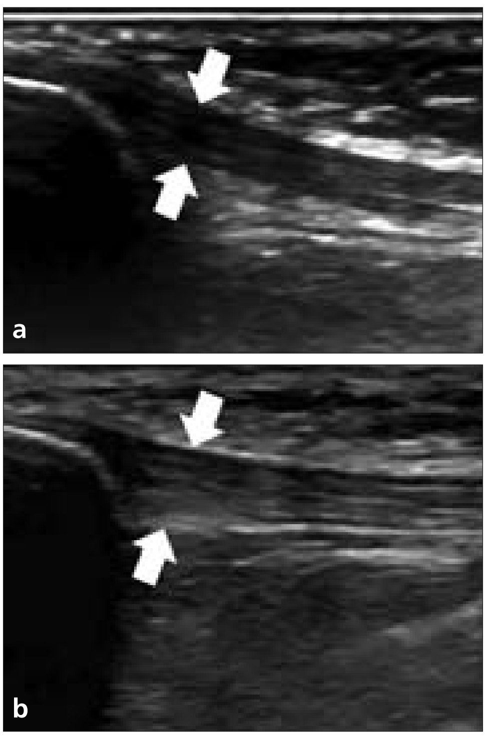

Figure 9. a, b. The thickness of the proximal end of the tendon in the non-dominant side **(a)** and the dominant side **(b)** of the body. The tendon on the dominant side is thicker *(arrows)*.

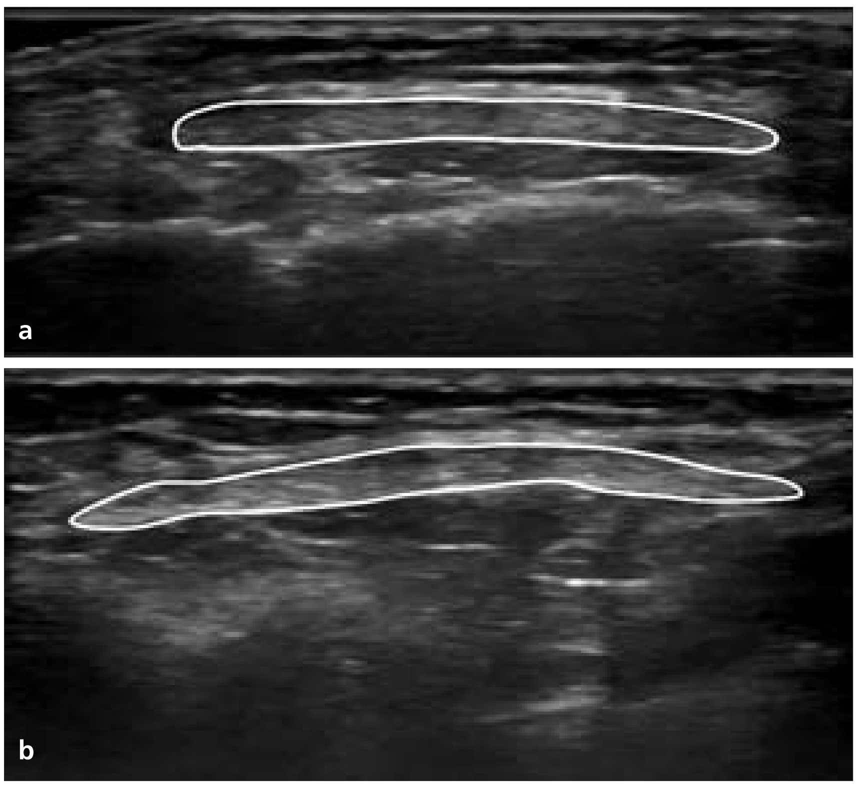

Figure 10. a, b. Proximal tendon areas in the non-dominant **(a)** and dominant **(b)** extremities. The tendon area on the dominant side body is larger.

The measurements from Group 1's normal and tendinosis cases are shown in Table 3. The thickness and area of the tendon was significantly increased in the tendinosis cases. The cut-off values on the dominant side of the body for the tendon thickness and area were 6.6 mm and 14.65 mm², respectively, at the proximal end; and were 6.25 mm and 12.55 mm², respectively, at the distal end of the tendon (sensitivity and specificity of 100% in all cases). No cut-off value was calculated for the non-dominant side in the Group 2 participants because of the insufficient number of pathological cases.

The intra-observer compliance in the proximal area of the non-dominant side of the body was not adequate ($P > 0.05$). However, the compliance for all of the other measurements was adequate. The coefficients and P values are presented in Table 4.

Discussion

Repetitive and impetuous landings on hard surfaces during jumping subjects the PT to stress injury by overloading the knee extensors. This process may lead to chronic patellar tendinosis (Jumper's knee), which affects more than 40% of sports players (6). Approximately 10% of the athlete population becomes symptomatic at one time in their life (10). The occurrence of patellar tendinosis in adolescent athletes has been observed in a wide range of between 7% and 36% (5, 11, 12), which is in agreement with the results of the present study (21.7%).

Unfortunately, these overuse-related tendinopathies are often affiliated with professional and elite athletes who are at the peak of their careers. These tendinopathies may force these athletes to reduce the frequency and intensity of their activities or to retire because of the chronicity of the symptoms (1). Therefore, the health of the PT has attracted increased attention in sports medicine research.

The mechanisms involved in tendinosis and the clinically-irrelevant imaging findings are subjects of debate among researchers in this field (8). Positive imaging findings are reported in asymptomatic patients, but upon vigorous exercise in a fixed time course, these patients revert to being symptomatic. In some cases, symptomatic patients present with no imaging abnormalities. The pathology of tendinosis is also very difficult to treat and is chronic and recurrent in nature. These factors increase the challenge in treating tendinosis in combination with the fact that imaging findings and symptoms, such as pain, are not correlated and may have different causes (8). Therefore, an understanding of the anatomy and the mechanics of the patellar joint are needed. Because the PT is not an anatomically homogenous structure, imagers should attempt to view the tendon as a three-dimensional structure instead of only measuring its thickness. However, area measurements should also be included in the assessment.

In the present study, all of the participants were asymptomatic; however, positive imaging findings of tendinosis were detected in 21.7% of the players. These results suggest that, regardless of the mechanism of injury, the jumping activity itself is involved in the development of tendinosis. This finding may be related to an overload on the dominant knee during jumping activity or may be attributed to the frequent vigorous training programs. However, the common finding in our participants with positive imaging findings was an increase in the thickness of the PT that may have caused a change in the anatomy and alignment of the patellar joint.

Impingement-related causes of tendinosis have been suggested, such as a long inferior pole of the patella that causes an impingement on the posterior proximal surface of a taut, thickened PT or the impingement of the Hoffa fat pad (8). A previous study by Lian et al. (12) revealed that a greater body weight, an increase in weight training and a better jumping performance may increase the susceptibility to patellar tendinopathy in volleyball players. This finding is supported by the absence of imaging abnormalities or symptoms in the sedentary group, as compared with the volleyball players, and the presence of fewer imaging findings in the non-dominant extremity compared with the dominant extremity. In a study by Pfirrmann et al. (6) on adult beach volleyball players, the occurrence of tendon thickness and tendinopathy were similar in the dominant and non-dominant side. This result is contradictory to our findings of significant differences in the thickness and area of the tendon. Pfirrmann et al. (6) stated that beach volleyball causes the same amount of force on each leg, which equally loads both extremities. This equal amount of loading is in contrast to volleyball or other jumping activities on hard surfaces in which one extremity bears

Table 3. Measurements (mean) of tendinosis and non-tendinosis participants' in Group 1

		Thickness (mm)		Area (mm^2)	
Part	Extremity	Tendinosis	Normal	Tendinosis	Normal
Proximal	Dominant	7.6	4.9	16	9.4
Proximal	Non-dominant	6.4	4.1	14.6	7.8
Distal	Dominant	6.8	4.8	16.5	7.8
Distal	Non-dominant	5.6	4.0	15.4	7.1

Table 4. Intra-class correlation coefficients obtained from intra-observer compliance evaluation

Variable	Correlation coefficient	P
Group 1 dominant proximal thickness	0.865	< 0.0001
Group 1 dominant distal thickness	0.881	< 0.0001
Group 1 dominant proximal area	0.991	< 0.0001
Group 1 dominant distal area	0.994	< 0.0001
Group 1 non-dominant proximal thickness	0.912	< 0.0001
Group 1 non-dominant distal thickness	0.945	< 0.0001
Group 1 non-dominant proximal area	0.018	> 0.05
Group 1 non-dominant distal area	0.981	< 0.0001
Group 2 proximal thickness	0.856	< 0.0001
Group 2 distal thickness	0.876	< 0.0001
Group 2 proximal area	0.986	< 0.0001
Group 2 distal area	0.972	< 0.0001

the majority of the impetus, which suggests an effect of loading on the development of tendinosis. Discordance between this study and ours may also result from demographic dissimilarities and the differences in the training programs of the participants.

According to the present study, the distal and proximal portions of the PT were of similar thickness in all of the participants; however, the proximal portions of the PT were much wider in all groups. This finding is in agreement with the anatomical fact that the PT is a cone shaped structure that tapers towards its distal end (7, 8). The PTs were thickest and widest in volleyball players' dominant extremities compared with the non-dominant side of these players and to the tendons of Group 2. No statistically significant differences were observed in the thickness and area of the tendon in the non-dominant extremities and the Group 2 subjects. As the tendon thickens, the tendon area widens. This relationship indicates a correlation between the thickness and area of the dominant tendon, except in the cases with negative US findings, in which this correlation failed at the distal end. The increase in the tendon area was less than expected, which signified a deviation from the expected tendon shape. Interestingly, three participants that were diagnosed with tendinosis exhibited a tendon thickness and area that were approximately double compared with the normal values on the distal side. It is unclear whether this result correlated with tendinosis because this group had too few subjects to allow for statistical generalization. Larger scale studies with a larger number of participants are needed to validate this finding.

A positive correlation between age and thickness was noted in the present study. In several studies, although an increase in thickness was detected, no definitive numerical value was presented (2, 3, 5). In another study with a similar age range to the present article, tendon thickness was measured using MRI, and a positive correlation was reported. This result is in agreement with that of the present study, but no numerical results were reported in the previous study (13). In the present study, no correlation between age and tendon area was observed. Measurements of the tendon area have not been conducted in this specific age group previously. This finding may result from an adjustment in the tendon's shape that is related to aging. Additional studies in adults of both sexes are needed to determine how this age-related finding of tendon thickness and area relates to tendinosis.

A Doppler evaluation revealed neovascularization in two cases of tendinosis. Despite the previous reports that have related neovascularization to pain (5, 14), in the present study, the patients were asymptomatic, and pain was only reported during deep palpation of the tendon.

In the present study, Osgood-Schlatter Syndrome was the second pathology that was observed in addition to tendinosis. Apophysial chondral thickening was detected in these subjects. Osgood-Schlatter Syndrome often occurs in children who are active in sports (15), and the presence of this syndrome is not an unusual finding given the age range of the present study group.

The study had some limitations. The study group consisted of only adolescent women volleyball players. Measurements in other sports participants, male and adult athletes, and people of the same age group who are not actively engaged in sports are needed. Although the intra-observer compliance of the area measurements exhibited a reproducibility and reliability that was similar to those of the thickness measurements, the inter-observer compliance values are unknown for the thickness measurements because only one radiologist conducted these measurements. Multi-centered studies are needed to fully evaluate the area, shape, and age-related changes of the PT.

In conclusion, the PT in athletes thickens and widens because of overuse. This process leads to an anatomical deviation from the normal thickness and wideness of this tendon. Larger scale studies may help determine whether differences in tendon thickness, area, the ratio of thickness and area, and age are factors in the risk of developing tendinosis. Osgood-Schlatter Syndrome and patellar tendinosis in athletes may remain asymptomatic and were incidentally diagnosed in the present study. Therefore, US examinations may prevent further injuries. Transverse cross-sectional area measurements are as reliable as thickness measurements and can be instituted in US examination practice. In addition, both of these types of measurements have a high intraobserver correlation. The thickness/area ratio of the PT and comparative examinations can be performed in both extremities. Despite similarities in thickness, any difference in tendon area measurements or ratios may alert the physician to the risk of tendinosis. As a result, additional follow-up and exercise programs may be initiated. The findings of the present study suggest that cut-off values for the thickness and area of the PT need to be determined using a comparison of the measurements of normal and tendinosis cases in multi-centered studies of a large series of participants. These cut-off scales would allow for the determination of risk projections for tendinosis using thickness/area ratios.

Conflicts of interest disclosure

The authors declared no conflicts of interest.

References

1. Lorbach O, Diamantopoulos A, Kammerer KP, Paessler HH. The influence of the lower patellar pole in the pathogenesis of chronic patellar tendinopathy. Knee Surg Sports Traumatol Arthrosc 2008; 16:348–452.
2. Gisslèn K, Gyulai C, Söderman K, Alfredson H. High prevalence of jumper's knee and sonographic changes in Swedish elite junior volleyball players compared to matched controls. Br J Sports Med 2005; 39:298–301.
3. Gisslén K, Gyulai C, Nordström P, Alfredson H. 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. Br J Sports Med 2007; 41:253–258.
4. Malliaras P, Cook J, Ptasznik R, Thomas S. Prospective study of change in patellar tendon abnormality on imaging and pain over a volleyball season. Br J Sports Med 2006; 40:272–274.
5. Gisslén K, Alfredson H. Neovascularisation and pain in jumper's knee: a prospective clinical and sonographic study in elite junior volleyball players. Br J Sports Med 2005; 39:423–428.
6. Pfirrmann CW, Jost B, Pirkl C, Aitzetmüller G, Lajtai G. Quadriceps tendinosis and patellar tendinosis in professional beach volleyball players: sonographic findings in correlation with clinical symptoms. Eur Radiol 2008; 18:1703–1709.
7. Fredberg U, Bolvig L, Andersen NT, Stengaard-Pedersen K. Ultrasonography in evaluation of Achilles and patella tendon thickness. Ultraschall Med 2008; 29:60–65.
8. Basso O, Johnson DP, Amis AA. The anatomy of the patellar tendon. Knee Surg Sports Traumatol Arthrosc 2001; 9:2–5.

9. Bianchi S, Martinoli C. Ultrasound of the musculoskeletal system. 1st ed. Heidelberg: Springer-Verlag, 2007; 659.
10. Ogon P, Maier D, Jaeger A, Suedkamp NP. Arthroscopic patellar release for the treatment of chronic patellar tendinopathy. Arthroscopy 2006; 22:462.
11. Cook JL, Khan KM, Kiss ZS, Griffiths L. Patellar tendinopathy in junior basketball players: a controlled clinical and ultrasonographic study of 268 patellar tendons in players aged 14–18 years. Scand J Med Sci Sports 2000; 10:216–220.
12. Lian O, Holen KJ, 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.
13. Schweitzer ME, Mitchell DG, Ehrlich SM. The patellar tendon: thickening, internal signal buckling, and other MR variants. Skeletal Radiol 1993; 22:411–416.
14. Terslev L, Qvistgaard E, Torp-Pedersen S, et al. Ultrasound and Power Doppler findings in jumper's knee—preliminary observations. Eur J Ultrasound 2001; 13:183–189.
15. Blankstein A, Cohen I, Heim M, et al. Ultrasonography as a diagnostic modality in Osgood-Schlatter disease. A clinical study and review of the literature. Arch Orthop Trauma Surg 2001; 121:536–539.