Clinical Improvements Are Not Explained by Changes in Tendon Structure on Ultrasound Tissue Characterization After an Exercise Program for Patellar Tendinopathy

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Objectives: The aim of this study was to investigate the effects of a 4-wk in-season exercise program of isometric or isotonic exercises on tendon structure and dimensions as quantified by ultrasound tissue characterization (UTC).

Design: This was a randomized clinical trial. Volleyball and basketball players (16–31 yrs, $n = 29$) with clinically diagnosed patellar tendinopathy were randomized to a 4-wk isometric or isotonic exercise program. The programs were designed to decrease patellar tendon pain. A baseline and 4-wk UTC scan was used to evaluate change in tendon structure.

Results: No significant change in tendon structure or dimensions on UTC was detected after the exercise program despite patellar tendinopathy symptoms improving. The percentage and mean cross-sectional area of aligned fibrillar structure (echo types I + II) ($Z = -0.414$, $P = 0.679$) as well as disorganized structure (echo types III + IV) ($Z = -0.370$, $P = 0.711$) did not change over the 4-wk exercise program. Change in tendon structure and dimensions on UTC did not differ significantly between the groups.

Conclusion: Structural properties and dimensions of the patellar tendon on UTC did not change after a 4-wk isometric or isotonic exercise program for athletes with patellar tendinopathy in-season, despite an improvement in symptoms. It seems that structural improvements are not required for a positive clinical outcome.

Key Words: Tendinopathy, Patellar Ligament, Tendons, Ultrasonography

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Patellar tendinopathy (jumper's knee) is an overuse injury of the patellar tendon that impacts on sport and work participation.[1] The clinical diagnosis of patellar tendinopathy is often confirmed with ultrasound imaging, which has been shown to be relatively accurate in confirming patellar tendinopathy.[2] However, conventional grayscale ultrasound has limited ability to monitor intratendinous changes in response to load.[3] Only relatively gross measures such as cross-sectional area (CSA), anterior-posterior diameter, and height and width of a hypoechoic zone can be measured. It is not possible to quantify tendon structure with conventional ultrasound.

Higher-level analysis of ultrasound images has enabled quantification of tendon structure.[3,4] A relatively new imaging technique specifically designed for tendons is ultrasound tissue characterization (UTC; UTC imaging, Stein, the Netherlands). UTC provides a detailed view of a tendon in all planes and quantifies tendon structure by measuring the stability of pixel brightness over contiguous transverse grayscale images. UTC has been developed in veterinary medicine and tested against histomorphology of equine tissue.[5] It has also been found to reliably quantify the stability of the echo pattern in the human Achilles tendon and distinguish symptomatic from nonsymptomatic Achilles tendons.[6] UTC may be able to detect more subtle changes in tendon structure than conventional ultrasound.[7,8]

Exercise-based treatment has the most evidence in the management of patellar tendinopathy.[9] The impact of exercise on tendon structure has not yet been elucidated. However, molecular changes such as increased pro-peptide marker of type I collagen in the peritendon have been shown after a single bout of exercise (3 hrs of running)[10] as well as after a heavy resistance eccentric rehabilitation program of 12 wks.[11] Whether an increased type I collagen formation will lead to an adaptation in tendon structure is unclear, as tendon cells also have a

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capacity to prevent collagen fibrillogenesis within a cell.[12] Limited data are available on the effect of in vivo exercise programs on the structural appearance of the patellar tendon in people with patellar tendinopathy. Only one other study has investigated the effect of exercise on patellar tendon dimensions in people with patellar tendinopathy.[13] Doppler area and thickness of the patellar tendon decreased after a 12-wk heavy slow resistance exercise program but were not affected by a 12-wk isolated eccentric exercise program. The effect of exercise programs on patellar tendon structure has not been investigated so far. Therefore, the aim of this study was to investigate the effect of a 4-wk in-season exercise program on the structure and dimensions of the patellar tendon as quantified by UTC. This study investigated whether two exercise programs (isometric and isotonic exercises), designed to decrease patellar tendon pain, affected tendon structure or dimension on UTC. It is hypothesized that there will not be a change over time in tendon structure on UTC and no difference between the groups.

METHODS

Design and Participants

Volleyball and basketball players (16–31 yrs) presenting with patellar tendinopathy who were training or playing at least three times per week were eligible for this study. Participants were recruited by flyers that stated critical inclusion criteria and by talking to teams playing or training at least three times per week. All athletes with patellar tendinopathy were examined by the researchers, were assessed for eligibility, and consented to participate in the trial (Table 1). Patellar tendinopathy was clinically diagnosed by an experienced physiotherapist, based on an interview and physical examination. Focal, exercise-related pain at the inferior pole of the patella had to be present and it was ascertained that knee pain was not caused by other knee pathology (i.e., patellofemoral joint pain). The participants took part in a larger randomized clinical trial investigating the difference in effect on pain between an in-season 4-wk isometric and an in-season 4-wk isotonic exercise program.[14,15]

TABLE 1. Inclusion and exclusion criteria

Inclusion Criteria
Patellar tendinopathy diagnosed by an experienced physiotherapist
Focal/nonradiating pain at the inferior pole of the patella
Exercise (jumping/landing or change of direction activities)-associated knee pain
Training or playing sport at least three times per week
Exclusion Criteria
Other knee pathology
Previous patellar tendon rupture
Previous patellar tendon surgery
Inflammatory disorders
Metabolic bone diseases
Type II diabetes
Use of fluoroquinolone antibiotics or corticosteroids in the last 12 mos
Known familial hypercholesterolemia
Chronic pain conditions

Participants were randomized to an isometric or isotonic exercise group, and the programs were matched for time under tension and rest. Before and after the exercise program, UTC scans of the patellar tendon were made. Written informed consent of participants was obtained before inclusion in the study and rights of the participants were protected. The study was approved by the Monash University Human Research Ethics Committee, Australia (CF12/0230-2012000067), and it was registered in the Australian New Zealand Clinical Trial Registry (ACTRN12613000871741).

Exercise Programs

All exercises in both groups were performed on a leg extension machine. Five sets of 45-sec single-leg isometric holds (one repetition) were performed for each leg in the isometric exercise group during each session. The knee joint angle during the exercises was 60 degrees and contractions were executed at 80% of the maximal voluntary contraction weight. Before the start of the trial, the 45-sec maximal voluntary contraction in 60 degrees of knee flexion was measured on a leg extension machine to calculate the starting weight.

The participants in the isotonic exercise group had to perform four sets of eight repetitions of single-leg isotonic contractions for each leg per session. A repetition of an isotonic contraction started with a 3-sec concentric phase followed by a 4-sec eccentric phase. Exercises were performed in a pain-free range between 10 and 90 degrees of knee flexion at 80% of eight repetitions maximum. Testing for both groups was completed on the same leg extension machine that each participant used for the duration of the trial.

A set of exercises for both legs was followed by a rest interval of 15 secs (making the rest period for an individual leg approximately 1 min). Weights were increased by 2.5% every week when this weight was available on the leg extension machine, if the participant was pain-free and if no shaking of the muscles during the exercises took place. When participants experienced pain during an exercise or when their muscles started shaking, they were instructed to complete the session with a lower weight for the following repetitions. This ensured an equal time under tension for both groups. In addition to face-to-face explanation and instruction of the exercises by a physiotherapist at the gym, participants received an audio file with real-time instructions of the exercises, a metronome to pace the contraction, and rest intervals to listen to during their exercises. Participants were instructed to perform the exercises four times per week.

Outcome Measures

Ultrasound Tissue Characterization

A UTC scanner consists of an ultrasound probe (SmartProbe 10 L5, Terason 2000; Teratech) secured in a tracking device (UTC Tracker, UTC Imaging) to ensure a consistent transducer tilt angle in relation to the tendon. The tracker device moves the ultrasound probe automatically with a constant speed perpendicular along the tendon long axis. An ultrasound image of the transverse plane of the tendon is captured every 0.2 mm over the length of the patellar tendon. The UTC software (UTC 2011, UTC Imaging) constructs the sagittal and coronal planes from the transverse images, creating a three-dimensional ultrasound data-block.[6]

Participants were scanned by one trained researcher (S. Docking). The worst knee of participants (most pain on a numerical rating scale [NRS] from 0 to 10 during single leg decline squat [SLDS]) was scanned. Participants lay supine on a treatment bench; their knee was bent to approximately 100 degrees of knee flexion in which a clear image could be obtained with the ultrasound probe in the tracker perpendicular to the long axis of the tendon. Based on the consistency of intensity and distribution of gray levels of images over 4.8 mm (25 images), four echo types were calculated using computer algorithms. Echo type I indicated intact and aligned tendon bundles; echo type II, less integer and waving tendon bundles (less consistency in the contiguous transverse images than type I, therefore less continuous or more wavy fibers); echo type III, mainly fibrillar tissue; and echo type IV, a mainly amorphous matrix with loose fibrils, cells, or fluid.[4,6] A single ultrasound reflection that typically belongs to one continuous structure is displayed as echo type I or II (referred to as aligned fibrillar structure in this article).[8] Multiple reflections that interfere because of multiple interfaces are displayed as echo types III and IV (referred to as disorganized structure in this article).

Before analysis, the scans were deidentified to ensure that the researcher was blind to participant and date of measurement. The tendon was analyzed over 30 mm starting from the disappearance of the apex of the patella. This region was selected as it coincides with the most common area of pain and pathology and is similar to previous studies.[16] The tendon superficial to the inferior pole was not included in the analysis, as imaging artifact has been observed in this area negatively affecting reliability. This may underestimate change or affect sensitivity to changes, as a portion of pathology was not analyzed. Contours were manually selected around the border of the patellar tendon on the transverse images at regular intervals (no more than 5 mm apart) over the length of the tendon. A consensus on the placement of contours between two experienced researchers (M. van Ark and S. Docking) was reached. Based on these contours, the UTC software (UTC 2011, UTC Imaging) interpolated these defined contours to create a complete tendon volume where the proportions of each echo type and total number of pixels were calculated. The percentages of each echo type in the region of interest were calculated. The mean CSAs (mCSA) of aligned fibrillar structure (echo types I and II) and disorganized structure (echo types III and IV) were calculated as well. UTC software provides the number of pixels and percentage of each echo type for every transverse image. The CSA for each transverse image was calculated by multiplying the number of pixels by the area of the pixel (0.011 mm^2). The volume (mm^3) of aligned fibrillar structure, disorganized structure, and total tendon was calculated and divided by 30 mm to provide the mCSA (mm^2) for all parameters. This method has been described by Docking and Cook[16] and has been validated against an ultrasound phantom of known volume. Furthermore, maximum thickness (anterior-posterior diameter) of the patellar tendon was recorded.

Clinical Outcome Measures

The severity of patellar tendinopathy symptoms was quantified by pain measured with the 0 to 10 NRS during an SLDS and the Victorian Institute of Sport Assessment–Patella (VISA-P) questionnaire. The SLDS is a provocative clinical test that loads the patellar tendon to evaluate pain response of the patellar tendon. The VISA-P questionnaire is specifically designed to evaluate severity of symptoms, knee function, and ability to participate in physical activity in athletes with patellar tendinopathy. It provides a score between 0 and 100, with a score of 100 representing a pain-free and fully functioning athlete. Clinical outcome data—NRS pain (0–10) during the SLDS before and after the exercise program and VISA-P—are reported in a separate article describing the clinical outcomes of this trial.[14] Furthermore, the immediate effects of the exercises are reported in an article using the NRS pain score before and after every exercise session.[15] As the focus of the current article is on tendon structure and dimensions, clinical outcomes will only briefly be mentioned in the results. The effect of these exercise programs on tendon structure and dimensions is important for the understanding of adaptation of the patellar tendon in response to treatment of patellar tendinopathy and adds important information beyond the clinical outcome data.

Data Analysis

Outcome measures were not normally distributed, Wilcoxon signed-rank tests were used to test for differences in the UTC echo types, mCSA, thickness, NRS pain during SLDS, and VISA-P between baseline and follow-up measurements. A Mann-Whitney test was used to compare change in UTC outcome measures (UTC echo types, mCSA and thickness) between the isometric and isotonic groups.

RESULTS

A total of 29 participants were included in the trial on clinical outcome measures, including participants with quadriceps tendinopathy at the superior pole of the patella. However, with current UTC techniques, it is not possible to obtain a scan with sufficient quality of the quadriceps tendon superior to the patella. Therefore, no UTC scans could be obtained from three participants, and these were excluded from all data and analyses presented in this article. Eighteen of the 26 participants with patellar tendinopathy completed the exercise program and baseline and follow-up UTC scan (Fig. 1). Participants were 16 men and 2 women with a mean (SD) age of 22.7 (4.7) yrs (range, 16–31 yrs). Baseline characteristics of the population are described in Table 2.

All outcome measures of the UTC scans did not show significant changes between baseline and follow-up measurements, with none of the changes greater than previously reported minimum detectable differences (Table 3).[16] There was no significant difference between the isometric and isotonic group for the change in percentage of echo type I (U = 28.0, P = 0.286), echo type II (U = 29.0, P = 0.328), echo type III (U = 33.0, P = 0.534), echo type IV (U = 39.0, P = 0.929), aligned fibrillar structure (U = 33.5, P = 0.563), and disorganized structure (U = 33.0, P = 0.534). Similarly, there was no significant change in the mCSA of the aligned fibrillar structure (U = 35.0, P = 0.657), mCSA of the disorganized structure (U = 34.0, P = 0.594), mCSA (U = 39.0, P = 0.929), and tendon thickness (U = 31.0,

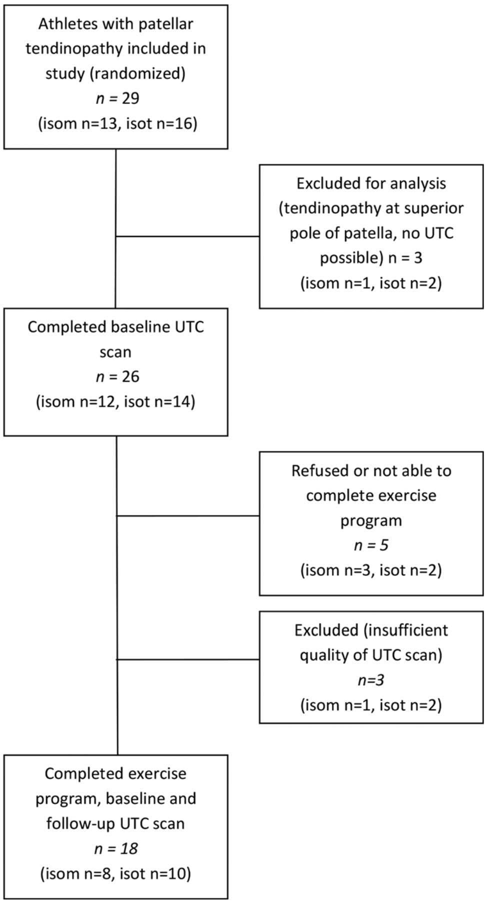

FIGURE 1. Flowchart of athletes with patellar tendinopathy participating in the study. isom indicates isometric group, isot, isotonic group).

$P = 0.421$) between groups. No difference in clinical outcomes between the groups after the 4-wk exercise programs was found as well.[14] A significant decrease in NRS pain during the SLDS of 6.0 (4.0–6.3) to 2.0 (1.5–3.5), median (interquartile range) (IQR), was found after the 4-wk exercise program compared to baseline ($Z = -3.634$, $P < 0.001$).[14] The VISA-P questionnaire showed a significant improvement after 4 wks, from (median [IQR]) 68 (57–76) to 82 (73–88) ($Z = -3.112$, $P = 0.002$).[14] Clinical outcomes of the participants are presented in Table 4.

DISCUSSION

Tendon structure, thickness, and mCSA on UTC were not altered after a 4-wk isometric or isotonic exercise program despite a significant decrease in pain. This is the first study to investigate the effects of a patellar tendinopathy treatment on patellar tendon structure with UTC.

The effect of treatments on patellar tendon structure and dimensions is still unclear. Although the presence of ultrasound abnormalities increases the risk of developing patellar tendinopathy,[17] pain and ultrasound abnormalities do not have a clear relationship.[18] The results of previous studies are inconclusive regarding the relationship between clinical outcomes and ultrasound changes in lower limb tendinopathies.[13,19–21] Only one in vivo study on the effects of treatments on patellar tendon dimensions has been conducted in patients with patellar tendinopathy. This was a randomized controlled trial conducted by Kongsgaard et al.,[13] which compared corticosteroid injections and isolated eccentric training and heavy slow resistance training in 52 recreational athletes with patellar tendinopathy. They found a decrease in anterior-posterior tendon diameter and color Doppler area in the heavy slow resistance and corticosteroid group, but not the eccentric group, after 12 wks compared with baseline, despite a similar decrease in pain between all groups. Patellar tendon CSA was increased only in the eccentric training group.

This study's results are in line with those of a prospective observational study of 23 chronic Achilles tendinopathy patients undertaking an eccentric training program.[22] UTC echo types did not change from baseline over the course of the 24 wk training program, despite clinical improvement observed. They concluded that there was no short-term (24 wks) increase in organized tendon structure after eccentric exercises.[22] In contrast, an improvement in tendon structure on UTC in combination with an improvement in pain and function was observed in 54 Achilles tendinopathy patients receiving either platelet-rich plasma injection or placebo (saline) injection both combined with eccentric exercises. Tendon structure on UTC showed improvements in echo types I + II and coincided with a significant decrease of echo type III and IV after 24 wks.[23] However, the change in UTC echo pattern was no different between the two groups.[24] The previous two UTC studies show contradictory evidence on the relation between clinical outcome and tendon structure on UTC. Results from this study support the theory that a decrease in pain does not necessarily mean a coinciding improvement in patellar tendon structure as examined using UTC in the short-term.

There are several possible explanations for the absence of an effect on structure in this study. One of the explanations is that changes in tendon structure take longer than 4 wks to occur. Markers of anabolic and catabolic processes in the peritendon are in balance for the first 4 wks of physical training, whereas after 4 wks, a net collagen synthesis occurs.[25] However, changes to the tendon structure may not follow; tendon structure might take many months to improve[24,26] if structure changes at all.[21] This is confirmed by Heinemeier et al.,[27] who investigated forensic samples of people who had lived in regions where nuclear bomb testing occurred. They demonstrated that levels of the radioisotope ^{14}C in the core of Achilles tendons corresponded to atmospheric ^{14}C levels during their first two decades of life; in contrast, hardly any ^{14}C was present in muscle samples.[27] The authors therefore concluded

TABLE 2. Characteristics of the population

Characteristics	Total (n = 18)
Age, years, mean ± SD (range)	22.7 ± 4.7 (16–31)
Sex (male/female)	16/2
Duration of symptoms, months, mean ± SD (range)	34.2 ± 36.0 (1–120)
BMI, kg/m^2, mean ± SD (range)	24.7 ± 3.1 (20.4–34.7)
Unilateral/bilateral symptoms	7/11

TABLE 3. Tendon structure and dimensions measured on UTC before and after a 4-wk isometric or isotonic exercise program in athletes with patellar tendinopathy ($n = 18$)

	Total Population			Isometric Exercise Group			Isotonic Exercise Group		
	Baseline, Median (IQR)	4 wks, Median (IQR)	Wilcoxon Signed Rank Test, Z and P	Baseline, Median (IQR)	4 wks, Median (IQR)	Wilcoxon Signed Rank Test, Z and P	Baseline, Median (IQR)	4 wks, Median (IQR)	Wilcoxon Signed Rank Test, Z and P
Echo type I, %	73.1 (64.1–83.5)	75.8 (64.4–79.0)	$Z = -0.893$ $P = 0.372$	72.7 (65.2–83.6)	74.8 (60.9–79.7)	$Z = -1.540$ $P = 0.123$	73.1 (63.9–83.8)	75.8 (68.8–78.9)	$Z = -0.153$ $P = 0.878$
Echo type II, %	16.3 (11.2–20.9)	17.4 (15.5–18.9)	$Z = -1.459$ $P = 0.145$	18.1 (11.4–23.3)	18.6 (17.0–26.9)	$Z = -1.540$ $P = 0.123$	14.0 (10.6–20.2)	15.7 (13.4–18.3)	$Z = -0.561$ $P = 0.575$
Echo type III, %	4.3 (2.4–7.3)	4.2 (2.9–6.6)	$Z = -0.142$ $P = 0.887$	4.6 (1.6–4.7)	3.4 (1.4–7.5)	$Z = -0.338$ $P = 0.735$	3.8 (2.7–8.2)	4.9 (3.0–6.6)	$Z = -0.375$ $P = 0.721$
Echo type IV, %	4.4 (2.5–6.5)	3.7 (2.1–5.9)	$Z = -1.570$ $P = 0.116$	2.7 (2.1–6.2)	3.2 (1.1–4.8)	$Z = -1.260$ $P = 0.208$	4.5 (3.3–7.5)	3.8 (3.0–7.3)	$Z = -0.971$ $P = 0.332$
Aligned fibrillar structure (echo type I + II), %	92.4 (86.9–95.0)	92.4 (87.7–95.0)	$Z = -0.981$ $P = 0.327$	92.7 (89.1–96.5)	93.5 (87.8–97.4)	$Z = -0.491$ $P = 0.624$	91.8 (85.2–93.7)	91.3 (87.0–94.2)	$Z = -0.968$ $P = 0.333$
Disorganized structure (echo type III + IV), %	7.7(5.0–13.2)	7.7 (5.0–12.4)	$Z = -0.980$ $P = 0.327$	7.3 (3.5–10.9)	6.6 (2.7–12.3)	$Z = -0.491$ $P = 0.624$	8.2 (6.3–14.7)	8.8 (5.8–13.0)	$Z = -0.968$ $P = 0.333$
mCSA of aligned fibrillar structure, mm^2	121.5 (110.2–133.1)	124.3 (112.2–136.1)	$Z = -0.414$ $P = 0.679$	122.5 (112.1–131.5)	119.1 (112.1–128.6)	$Z = -0.560$ $P = 0.575$	121.5 (108.1–133.4)	124.9 (116.9–139.2)	$Z = -0.357$ $P = 0.721$
mCSA of disorganized structure, mm^2	10.9 (7.3–20.7)	11.4 (6.4–21.9)	$Z = -0.370$ $P = 0.711$	9.9 (4.9–19.1)	9.6 (3.0–21.1)	$Z = 0.0$ $P = 1.0$	11.9 (8.4–22.8)	12.4 (7.4–21.9)	$Z = -0.357$ $P = 0.721$
mCSA, mm^2	138.3 (126.3–145.9)	140.7 (117.3–153.5)	$Z = -0.414$ $P = 0.679$	137.1 (121.6–145.4)	128.4 (116.2–154.5)	$Z = -0.280$ $P = 0.779$	140.5 (128.7–145.9)	145.1 (127.0–154.7)	$Z = -0.459$ $P = 0.646$
Thickness: anterior-posterior diameter, mm	7.8 (6.9–8.6)	7.5 (6.5–9.1)	$Z = -0.131$ $P = 0.896$	8.1 (7.3–9.0)	8.9 (6.6–9.6)	$Z = -0.422$ $P = 0.673$	7.4 (6.4–8.4)	7.4 (6.4–8.0)	$Z = -0.102$ $P = 0.919$

Significant difference from baseline ($P < 0.05$).

TABLE 4. Clinical outcome measures at baseline and follow-up of the participants

Measurements	Total (n = 16)
NRS pain SLDS—baseline	6.0 (4.3–6.4)
NRS pain SLDS—4 wks	2.3 (1.3–3.8)[a]
VISA-P—baseline	67.5 (56.8–75.8)
VISA-P —4 wks	81.5 (72.8–87.5)

Data are presented as median (IQR).

[a]Originally these data were included in the study on clinical outcomes (van Ark et al, 2016)[14].

that renewal of adult core tendon tissue is extremely limited.[27] Because it was end of the season, participants have not been followed up over a longer period. Future research should investigate the effects over a longer period and the effects of longer exercise programs.

Another possible reason for the limited change in tendon structure observed in this study is that the tendon adapts to pathology by ensuring that sufficient levels of load-bearing aligned fibrillar structure is present.[16] Docking and Cook[16] compared the mCSA of aligned fibrillar structure on UTC (echo types I and II) in the pathologic and structurally normal patellar tendon. Interestingly, an increased mCSA of aligned fibrillar structure was observed in the pathologic patellar tendon. The mCSA of aligned fibrillar structure in this study is similar to that reported in the structurally normal tendon.[16] It was proposed that as the pathologic patellar tendon contains sufficient levels of aligned fibrillar structure, remodeling of tendon structure is not required to obtain a positive clinical outcome. Moreover, Docking and Cook[16] suggested that exercise-based interventions may be efficacious by building load tolerance in the already present aligned fibrillar structure, improving muscular strength and capacity and/or changes to the central nervous system.[28] The findings of the current study seem to support the hypothesis that structural improvements are not required for a positive clinical outcome,[29] as the tendon may already have sufficient levels of load-bearing aligned fibrillar structure. Future interventions may therefore need to focus on addressing load capacity in the surrounding aligned fibrillar structure, rather than normalizing tendon structure.

The total mCSA of the patellar tendons in this study was smaller (138.3 mm^2) compared with previous reported mCSA of pathologic tendons (154.9 mm^2).[16] Docking and Cook[16] reported a relationship between the mCSA of disorganized tissue (echo type III + IV) and total tendon mCSA. This may explain the difference in mCSA, because they reported a higher amount of disorganized structure compared with this study (median of 17.1 mm^2 compared with 10.9 mm^2 at baseline in this study).[16] The difference in population of the studies may potentially have caused these differences; this study included an active sporting population with patellar tendinopathy, whereas the previous study was a clinical cohort.

The UTC technique has some limitations. First, different versions of the UTC (with a different ultrasound probe: SmartProbe 12 L5-V or SmartProbe 10 L5) and differences in study populations and designs of the studies make it hard to compare absolute values between studies. This study is one of the first studies presenting UTC characteristics of patellar tendinopathy patients. Only recently, the first results of UTC data in patellar tendons were presented.[16,29] It is important to realize that differences in features of UTC scans may influence the results. Therefore, characteristics of UTC scans should always be reported in research as well as clinical practice. A second limitation of the UTC technique is that its sensitivity to change over time is not available. Although it has been found reliable and repeatable in Achilles[6] and patellar[30] tendons, the exact ability to detect change is still unclear. It would be necessary to compare UTC scans with in vitro human biopsies to calculate sensitivity. Although the true sensitivity of UTC to detect change in the context of the current study is unknown, a previous study has demonstrated that minimum detectable change of a UTC scan in patellar tendons is 1.7% for aligned fibrillar structure as well as disorganized structure.[16] Because the reported changes in the current study are smaller than the minimum detectable change, it can be stated that there no change in tendon characteristics on UTC was observed. However, the possibility that changes in tissue structure have occurred beyond the resolution of UTC cannot be ruled out. Based on the current findings, improvement in the UTC echo pattern does not appear to be a mechanism that explains short-term clinical improvements. Furthermore, while the participant numbers are relatively small, power analysis based on this study's findings suggests that over ~1600 participants would be needed to find a potential effect.

This study contributes to the discussion on the relationship between clinical outcomes and tendon structure in patellar tendinopathy. However, many issues around this subject are still not elucidated. For a better understanding of patellar tendinopathy, studies on the long-term effects of treatments on tendon structure should be conducted. More research has to be conducted in this field to be able to make grounded statements on this topic. The current study provides some rationale as to why positive clinical outcomes are possible with limited tissue regeneration. Future studies may also need to investigate other parameters (i.e., muscle strength and endurance and corticospinal changes) to explain potential positive clinical findings following load-based interventions.

CONCLUSION

A 4-wk isometric or isotonic exercise program for patellar tendinopathy does not have an effect on tendon structure and dimensions quantified by UTC. Despite an improvement in patellar tendinopathy symptoms after the exercise program, tendon characteristics on UTC did not change accordingly within a 4-wk timespan. Structural change and pathology in tendon do not have a clear relation with pain. Although many treatment interventions are directed at improving tendon pathology, this study shows that pain can improve without a change in structure. This study quantified intratendinous structure, rather than measuring external tendon dimensions, suggesting that tendon structure may be stable even when exercise-based interventions improve pain. Structural improvement in tendon is not necessary for a change in pain. The outcomes of treatments for patellar tendinopathy need to be based on clinical findings rather than imaging. More research is needed to determine the effect of treatments on tendon structure. The effects of exercise programs of a longer duration and with longer follow-up periods need to be investigated.

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