Impact of Patellar Tendinopathy on Knee Proprioception: A Cross-Sectional Study

Rui Torres, PhD,† João Ferreira, BSc,‡ Diogo Silva, MSc,‡ Elisa Rodrigues, MSc,‡ Isabel M. Bessa, MSc,‡ and Fernando Ribeiro, PhD§*

Objective: To determine whether high-level athletes with patellar tendinopathy have diminished knee proprioceptive acuity.

Design: Cross-sectional study.

Setting: University research laboratory (institutional).

Participants: Twenty-one basketball and volleyball players with patellar tendinopathy (13 men and 8 women; mean age 24.5 ± 3.6; body mass index = 22.5 ± 2.0 kg/m^2) and an equal number of athletes without symptoms of patellar tendinopathy injury were included in this study.

Assessments: Participants underwent knee proprioception assessments on a single day. Furthermore, age, sex, height, weight, VISA-P (Victorian Institute of Sport Assessment) questionnaire sports participation, medical history, knee injuries, previous treatment, and medication were obtained.

Main Outcome Measures: Knee proprioception was evaluated by assessing sense of resistance, using a weight discrimination protocol, and joint position sense (JPS).

Results: No significant differences were observed in JPS at 30 and 60 degrees of knee flexion between groups (P = 0.165 and 0.481, respectively). In regard to the ability to discriminate weight, significant differences between the 2 groups were found with the tendinopathy group showing a higher percentage of error (P = 0.009), namely when the set of incremental weights varied by 10% from the standard weight.

Conclusions: Athletes with patellar tendinopathy have a diminished perception of force signals required for weight discrimination, whereas JPS remains unaffected in these athletes.

Key Words: proprioceptive acuity, weight perception, photogrammetry, anterior knee pain, tendinosis

INTRODUCTION

Patellar tendinopathy, also known as jumper's knee, is a common pathology in the athletic environment, with a particularly high incidence in sports that are characterized by recurrent explosive vertical jumps.[1–3] Its prevalence is especially high in volleyball players, both at the elite (44.6%)[4] and the recreational level (14.4%).[5]

In tendinopathy, the degenerated tendon tissue is described as disorganized and fibrous, with morphometric, histological, and biomechanical alterations.[3,6] The most frequent symptom of patellar tendinopathy is anterior knee pain, particularly confined to the patellar tendon at the inferior angle of the patella,[7,8] that is, especially exacerbated patellar tendon loading.[2,3,6,9] Despite major complaints, the pain mechanisms are not completely ascertained. It has been proposed that pain arises from biochemical stimulation of the nociceptors, increase in the ingrowth of free nerve endings, and/or higher concentrations of excitatory neurotransmitters.[10,11] It is important to refer that pain is not well correlated to structural changes; previous studies have shown painful tendons in subjects with and without tendon structural abnormalities.

The mechanical and material properties of the patellar tendon of athletes with tendinopathy were recently described, indicating a lower stiffness and Young's modulus.[12] The impact of patellar tendinopathy on flexibility and muscle strength is also documented[1]; nevertheless, little is known about its impact on joint proprioception.

Proprioception is defined as the afferent information from different areas of the body contributing to several conscious and unconscious sensations, automatic control of movement, balance, postural control, joint stability, and motor control.[13–15] The proprioceptive receptors are located in the joint capsules, ligaments, muscles, tendons, and skin. The Golgi tendon organ provides neural input related to the tension in the muscles and tendons, protecting them from injuries induced by excessive force production (by autogenic inhibition).[16] Classically, the information provided by the Golgi tendon organs has received little attention in the field of human movement control; nonetheless, its importance for the control of joint position and movement is presently recognized.[17,18] Visual, cognitive, and spatial abilities also contribute significantly to the construction of proprioception. Proprioception involves the perception of movement, resistance, and joint positions.[19] This study encompasses the assessment of 2 of them: sense of resistance and joint position sense (JPS).

In athletes, the proprioceptive function plays a relevant role both in injury prevention[20] and overall sport performance.[13]

Although there is no evidence about mechanoreceptors damage in the tendinopathy, it seems rational to admit that pain added to changes in the compliance of the tendon due to the alterations in its structure could result in a different neural activation and increase the error in the force sensations.

Thus, assuming the importance of the Golgi tendon organs to proprioceptive input and movement control, we hypothesize that the proprioception of the knee joint is impaired in athletes with patellar tendinopathy, increasing the injury risk. The confirmation of this hypothesis could drive new therapeutic approaches, because the malfunction of the normal protective inhibitory pathway of the musculotendinous unit, and also the biomechanical alterations observed in the degenerated tendon tissue, could dramatically increase the likelihood of tendon rupture.[21,22] To test this hypothesis, this study aims to analyze the knee joint proprioception of high-level competitive athletes with patellar tendinopathy compared with healthy subjects.

METHODS

Participants

A total of 124 (92 men and 32 women) athletes between the ages 18 and 35 from basketball and volleyball teams within our geographic area were invited to participate in the study.

To be included in the patellar tendinopathy group, the athletes had to meet the following criteria: a history of training-related and/or competition-related pain in the patellar tendon or its insertions; symptoms persisting for more than 3 months; pain and/or tenderness at palpation of the patellar tendon; and a score below 80 on the VISA-P (Victorian Institute of Sport Assessment) questionnaire.[23] To be included in the group without tendinopathy, an equal number of athletes from the same teams without a diagnosis of patellar tendinopathy were recruited. Participants were excluded according to the following criteria: a history of previous knee surgery or local injection therapy; any injury to the knee ligaments or cartilage; recovering from lower-limb injury other than patellar tendinopathy; metabolic, vestibular, or neuromuscular disorders; and being on medications. The exclusion criteria were applied to both groups.

Athletes diagnosed with patellar tendinopathy by the team physician and who met the inclusion and exclusion criteria were enrolled to participate in the study (tendinopathy group). Of the 124 athletes, 21 (13 males and 8 females) met the criteria to be included in the tendinopathy group. An equal number of athletes from the same teams without a diagnosis of patellar tendinopathy were randomly, by the method of minimization (minimization was based on team, player position, and sex), selected to participate in the control group without tendinopathy (13 males and 8 females). So, for every participant in the tendinopathy group, a participant from the same team, playing in the same position, was randomly selected to match the player with tendinopathy with a non-tendinopathy counterpart with the same competitive demands.

The participants were familiarized with the experimental protocol and apparatus. The assessment was conducted 48 hours after a game, to avoid the effects of intense or exhaustive exercise on proprioception, and before an exercise training session.

Procedures

First, participants were asked to complete the Brazilian Portuguese version of the VISA-P questionnaire. The Brazilian Portuguese version has high internal consistency, excellent reliability, and agreement [intraclass correlation coefficient (ICC) = 0.91; standard error of measurement, 5.2 points; minimal detectable change at the 90% confidence level, 12.2 points] and good construct validity (Pearson r = 0.60 compared with Lysholm).[24] Participants also completed a questionnaire about sports participation, medical history, knee injuries, previous treatment, and medication. Then, anthropometrics were measured in those who met the criteria to be included in the study. Height and weight were assessed using a standard wall-mounted stadiometer and a scale, respectively. Body mass index (kilograms per square meter) was calculated.

Proprioception Assessment

The submodalities of JPS and sense of resistance (weight discrimination) were assessed to characterize the proprioception of the knee. The order of the assessment was random. The protocol to assess the proprioception was always performed by the same examiner, who did not provide any feedback about the performance during the assessment. Moreover, this examiner was blinded to group allocation, and athletes were advised not to reveal their group allocation. The participants received instructions about the tests before their initiation, and they were allowed to familiarize themselves with them. The proprioceptive assessments were performed on the symptomatic leg. When both legs were symptomatic, the assessment was conducted on the dominant leg. In the group without tendinopathy, the assessments were made on the dominant leg.

Joint Position Sense Assessment

Joint position sense was assessed with an ipsilateral technique of active knee positioning of a passively determined position performed in open-kinetic chain without visual input as previously described.[25]

Before the assessment, 3 reflective markers were fixed with double-sided adhesive tape to the skin of the apex of the greater trochanter, the lateral femoral epicondyle, and the prominence of the lateral malleolus. Each set of markers (the greater trochanter–lateral femoral epicondyle and lateral femoral epicondyle–lateral malleolus) represents the axis of the thigh and the leg. A tripod-mounted digital camera, aligned and positioned as suggested,[25] was used to record (photograph) the joint positions.

Two test positions (30 and 60 degrees) at the intermediate range of knee motion were used to evaluate JPS, with the subjects seated in a comfortable position with the legs hanging freely but not touching the ground. In brief, (1) the examiner slowly (at approximately 10 degrees/s) moved the leg from the 90 degrees of knee flexion (starting position) to the test positions (knee angle of 30 or 60 degrees of flexion),

(2) the subject kept the test position actively for 5 seconds, and (3) the subject actively returned the leg to the starting position and actively attempted to reproduce the test position.[25] The subjects performed 3 repetitions to reproduce each target angle. For each target and reposition angle, the examiner took 3 consecutive photographs to determine the knee angles by biophotogrammetry using the SAPO software. The SAPO software has excellent reliability (ICC = 0.96) when used to evaluate knee flexion angles.[26] Thus, the test and the 3 response positions were determined as the average of 3 consecutive photographs from each position. The knee joint position test is reported as the absolute angular error, calculated as the absolute difference between the test and the reproduced positions, which represents accuracy without directional bias.[27]

A previous study with soccer players showed an ICC = 0.910, a standard error of measurement = 0.42 degree, smallest real difference = 1.16 degrees for this method of JPS assessment.[28]

Sense of Resistance (Weight Discrimination)

The weight discrimination protocol was similar to that previously described by others.[29,30] In brief, the participants, blindfolded and wearing earplugs, were comfortably seated on the leg exercise table with the knees resting at 90 degrees. The participant could choose the lifting movement, the range of motion (from 90 degrees of knee flexion to full extension), and the speed he or she believed to be appropriate to estimate the weights. The standard weight (Sw) was the unloaded lever system (2.5 kg). The distance between the axis of the lever system and the leg pad (0.31 m) was the same for every subject, as the aim was to always have the same torque (0.775 kg·m). Four comparison weights (Cw) were used to gradually increase the mass of the standard weight; the comparison weights corresponded to increments of 14% (maximal torque = 0.350 kg × 0.31 m = 0.1085 kg·m), 12% (maximal torque = 0.300 kg × 0.31 m = 0.093 kg·m), 10% (maximal torque = 0.250 kg × 0.31 m = 0.0775 kg·m), and 8% (maximal torque = 0.200 kg × 0.31 m = 0.062 kg·m) from the standard weight. Before the protocol, the subjects were allowed to familiarize themselves with 5 easy (14%) and 5 more difficult discriminations (8%). The weight discrimination protocol consisted of trying to differentiate between the standard and the comparison weight. After receiving a tactile cue (a tap on the arm), participants lifted each weight successively and reported which was heavier, the first or the second weight. Fourteen trials were performed at each increment; the order of presentation (standard weight vs comparison weight) was random (block randomization), but both alternatives were equally probable within a block of 14 trials. The comparison weights were presented in 4 random blocks related to the weight discrimination difficulty. The lever arm was pulled away from the leg when loading and unloading the weights to prevent pressure cues. Proprioceptive acuity was determined for each group by plotting the median percentage and range interquartile of correct responses against each increment in weight.

Statistical Analysis

The analysis of the results was performed using the Statistical Package for Social Sciences (SPSS) version 21 (SPSS Inc, Chicago, Illinois) for Windows 7. The normal distribution of the measured parameters was determined using the Shapiro–Wilk test. Because the data do have not normal distribution, nonparametric tests were used. Therefore, the Mann–Whitney test was used to compare differences in weight discrimination and JPS between the 2 groups. The significance level was set at 0.05.

ETHICAL CONSIDERATIONS

The ethics committee of our institution approved the study (ESTSP/IPP-2092/2013). All participants provided written informed consent, and all procedures were conducted according to the Declaration of Helsinki.

RESULTS

The baseline characteristics of the participants are reported in Table 1. No statistical significant differences were found between groups regarding age, anthropometrics, proportion of males, and sport modality. The VISA-P questionnaire scores were constant in the group without tendinopathy (score = 100), whereas in the tendinopathy group, the score was between a minimum of 66 and a maximum of 79, the mean being 71.5 ± 4.6.

Table 2 presents the absolute errors in the JPS with the knee at 30 and 60 degrees of flexion. No differences were found between the 2 groups in JPS either at 30 or 60 degrees of knee flexion ($P > 0.05$).

Figure 1 shows the correct percentage values of the discrimination weight obtained at the different levels that comprised the protocol. Discrimination decreased in both groups when increments in weight represented smaller differences from the standard weight. Discrimination accuracy was significantly different between the groups, that is, the tendinopathy group showed a greater percentage of errors (P = 0.009) when the set of incremental weights varied 10% from the standard weight.

The results showed that there is a significant decrease in the capacity to discriminate weight in the tendinopathy group, that is, the difference between groups is reflected in the differential threshold, whose median in the group without tendinopathy is approximately 0.24 kg, whereas in the tendinopathy condition, it is 0.31 kg.

TABLE 1. Baseline Characteristics of the Participants

	Tendinopathy Group (N = 21)	Without Tendinopathy Group (N = 21)
Males/females (N)	13/8	13/8
Age (yrs)	24.5 ± 3.6	25.7 ± 2.9
BMI (kg/m^2)	22.5 ± 2.0	23.6 ± 1.1
VISA-P (points)	71.5 ± 4.6	100
Number of basketball players (%)	12 (57)	12 (57)
Number of volleyball players (%)	9 (43)	9 (43)

BMI, body mass index; VISA-P, Victorian Institute of Sport Assessment.

TABLE 2. Median and Interquartile Range (IQR) of Knee Joint Position Sense (JPS) at 30 and 60 Degrees of the Knee Flexion Between Tendinopathy and Without Tendinopathy Groups

Groups		JPS at 30 Degrees	JPS at 60 Degrees
Tendinopathy	Median (IQR), degrees	4.4 (3.8)	6.6 (4.1)
Without tendinopathy	Median (IQR), degrees	5.5 (3.9)	6.8 (4.4)
	P	0.165	0.481

DISCUSSION

This study aimed to test the hypothesis that high-level competitive athletes with patellar tendinopathy have impaired knee joint proprioception. Our findings confirm our hypothesis, at least partially, as we could demonstrate that there is a decrease in the sense of resistance of those athletes with patellar tendinopathy. In fact, those suffering from this condition had a reduced ability to discriminate weight in comparison to "noninjured" athletes. Nevertheless, patellar tendinopathy had no influence on knee JPS.

Little is known about the impact of patellar tendinopathy on knee proprioception; to the best of our knowledge, this is the first study relating patellar tendinopathy to knee proprioception. Our results are similar to those reported in previous studies investigating proprioception in other injuries. Maenhout et al[31] evaluated subjects with rotator cuff tendinopathy, who also showed a decrease in proprioception, an overestimation of the target force during force-reproduction tests, related to less ability to discriminate weight. Likewise, Juul-Kristensen et al[32] reported worse JPS and threshold to detect passive motion in patients with lateral elbow epicondylitis. However, a study of runners both with and without a history of knee overuse injury observed that knee flexion and hip adduction JPS was similar in runners with and without a history of knee overuse injury.[33]

Keeping in mind that Golgi tendon organs are located in the tendon of the skeletal muscle, it seems logical to attribute the dysfunction of Golgi tendon organs as the explanation for our results. In fact, as tendinopathy is characterized by degeneration, regeneration, and micro tears of the tendinous tissue, it seems logical that abnormal afferent inputs from the sensorial system related to these structures could be present. Indeed, the presence of morphological alterations such as disrupted collagen, thinner-than-normal collagen fibers, and neovascularization and fibrosis are well documented.[3] Nonetheless, it is unclear if the tendon mechanoreceptors are damaged in the tendinopathy and/or if their dysfunction is related to changes in the tendon tissues.

Another potential explanation for the results observed in the weight discrimination protocol could be the presence of pain. Patellar tendinopathy is characterized by local tendon pain. Therefore, the nociceptive afferent nerve endings, such as Meissner corpuscles, Pacinian corpuscles, Ruffini corpuscles, and muscle spindles, among others, could be sensitized and this could, in turn, maintain the painful condition. This fact could be seen as a negative influence on the quality of sensory information related to a sensory mismatch from the sensory endings and could have a negative influence on knee proprioception.[32] However, our data do not fully agree with this explanation because we did not observe changes in JPS. Thus, one can theorize that the lack of changes in JPS could be related with a preserved input from muscle spindles in those athletes with tendinopathy because muscle spindle is the major contributor to the JPS,

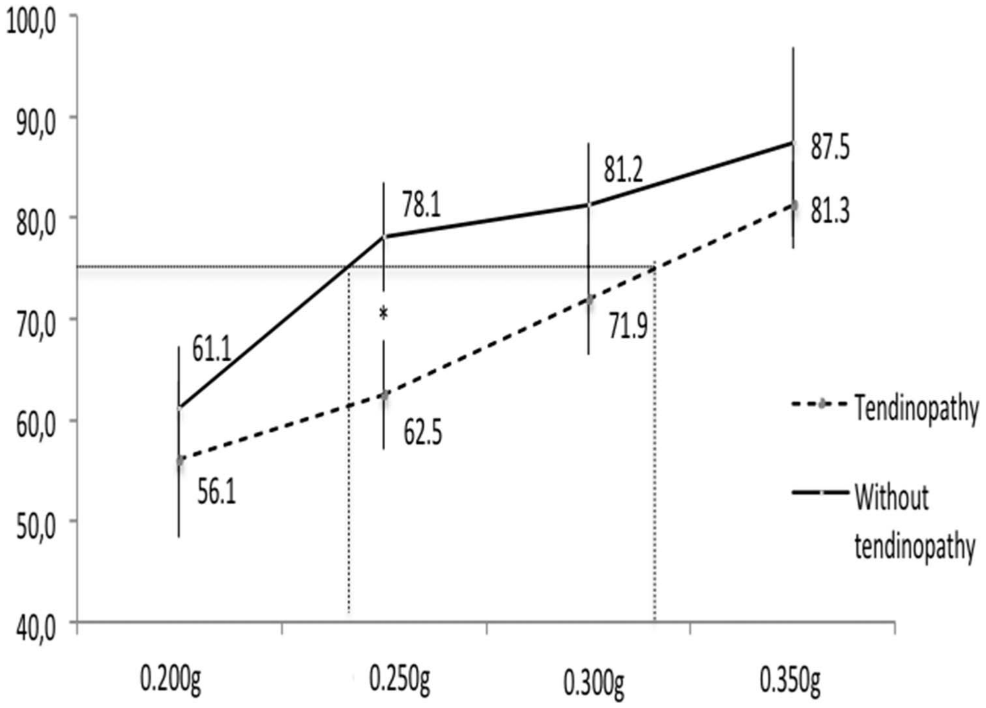

FIGURE 1. Performance in the weight discrimination task between groups. Values are expressed as median and interquartile interval. The dotted line indicates the 75% correct discrimination level. Mann–Whitney *U* test showed significant differences between tendinopathy and without tendinopathy groups ($P < 0.05$).

particularly at midrange,[34] which was the position used to assess JPS.

The different results observed in the proprioceptive submodalities could be at least partially explained by the different primary sources of proprioceptive input (the Golgi tendon organs or muscle spindles). That is, the tendinopathy could induce some degree of dysfunction in the Golgi tendon organs without having an impact on muscle spindles, as suggested by our results.

Although our results are not consistent with the idea of a generalized reduction in all the proprioceptive modalities, they need to be taken into consideration in the management of patellar tendinopathy. The results of this study seem to suggest that proprioceptive exercises aiming to improve proprioception could be a part of treatment routine of patellar tendinopathy.

Some study limitations should be recognized. First, the lack of a medical imaging technique to detect tendon imaging abnormalities/degenerative changes is a limitation. Owing to this fact, we cannot completely exclude the possibility of some of athletes of the group without tendinopathy having degenerative tendon changes without the presence of pain. Second, there was a lack of assessment of pain, which could have enabled us to correlate pain with proprioceptive deficits. Third, the target knee angles were defined passively (while repositioning was active), which was previously shown to be less accurate than the active positioning for position sense assessment.[35] Future studies are needed to determine whether the sense of resistance returns to normal after patellar tendinopathy has been successfully treated (for instance, with a rehabilitation program incorporating eccentric exercise and proprioceptive training, or ultrasound-guided injections of hyperosmolar dextrose). Further studies should also investigate whether the structural changes in the tendon are responsible for the poor sense of resistance. Longitudinal studies would also be useful to establish whether a poorer sense of resistance is a risk factor for patellar tendon rupture.

CONCLUSIONS

In conclusion, athletes with patellar tendinopathy showed impaired proprioception, namely, sense of resistance. We believe that our results deserve a close look because a poor sense of resistance could lead to a malfunction of the normal protective inhibitory pathway of the musculotendinous unit.

ACKNOWLEDGMENTS

iBiMED is a research unit supported by the Portuguese foundation for Science and Technology (REF: UID/BIM/04501/2013) and FEDER/Compete2020 funds.

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