IJSPT

ORIGINAL RESEARCH

COMPARISON OF FUNCTIONAL ACTIVITIES ON STRUCTURAL CHANGES OF THE INFERIOR PATELLAR POLE

Kelli McKinney, PT, DPT[1]
Harvey Wallmann, PT, DSc, SCS, ATC, CSCS[2]
Patrick Stalcup, PT, DPT[3]
Katie DiTommaso, PT, DPT[4]

ABSTRACT

Background: It is well known that eccentric and concentric exercise produce varied amounts of stress on the connective tissues. Diagnostic ultrasound has been used to measure these structural changes by observing fascicle length, angle, and thickness; however, there is a lack of evidence comparing the structural changes as it relates to eccentric, concentric, and stretching protocols.

Purpose: The purpose of this study was to compare the acute effects of static stretching, eccentric, concentric, and a combination of eccentric/concentric exercises on structural changes of the muscle tendon unit at the inferior patellar pole utilizing the diagnostic ultrasound.

Study Design: A repeated measures 2 x 4 within factorial study design with repeated measures on both factors was used to determine the differences in patellar tendon thickness within and between groups.

Methods: Forty-seven healthy subjects were screened for any lower extremity deficits or orthopaedic pathology. Forty-four ($N = 44$) subjects completed all four protocols; the attrition was due to injuries to the lower extremity, occurring unrelated to the study. A baseline measurement of the anterior inferior patellar tendon was performed with the diagnostic ultrasound prior to each participant completing one of the four interventions per week over a four-week period. Interventions completed by each participant included static stretching, concentric, eccentric, and combined concentric and eccentric exercises. Immediately following each intervention, a post-intervention inferior patellar tendon measurement was recorded using the diagnostic ultrasound.

Results: Significant differences in anterior to posterior tendon thickness of the inferior patellar tendon were observed between pre (4.983 ± 0.041mm) and post (5.198 ± 0.055mm) measurements ($p < 0.0005$) for the main effect of time. However, no differences in tendon thickness were noted comparing each intervention to one another ($p = 0.351$).

Conclusion: Differences in tendon thickness were noted acutely for pre- to post measurements across all interventions. Further research is needed to determine if differences in tendon thickness exist with a longer duration of exercise over time and with different types of intervention.

Keywords: Diagnostic ultrasound, inferior patellar pole, jumping, patellar tendon

[1] The Kid SpOt Center, Elizabethtown, KY, USA
[2] Department of Physical Therapy at Western Kentucky University, Bowling Green, KY, USA
[3] Medical Center-Albany, Albany, KY, USA
[4] Rehabsource, Oklahoma City, OK, USA

CORRESPONDING AUTHOR
Kelli McKinney
TheKid SpOt Center
529 Westport Rd
Elizabethtown, KY 42701
Phone: 270-763-8225
E-mail: Kelli.mckinney@thekidspotcenter.com

INTRODUCTION

As healthcare professionals, it is essential to understand how various forms of exercise impact the structure of contractile tissues that are involved in the performance of a specific movement. More specifically, investigating the impact of various exercises on the structure of the patellar tendon will help clinicians select an effective intervention in treating pathologies of the knee such as patellar tendinopathy or jumper's knee. Tendinopathies are commonly seen in sports medicine settings with more than 30% of upper and lower extremity sports related injuries being associated with this pathology.[1] Previous research has revealed that patellar tendinopathy creates activity-related anterior knee pain and jumping athletes can be at the greatest risk with repetitive loading to the knee.[2] Patellar tendinopathy may continue to cause problems for years if proper treatment or therapy is not conducted.[3]

Exercise-induced stress placed on connective tissue structures has been the topic of considerable research. It is well known that eccentric and concentric exercise produce altered amounts of stress on the connective tissues. As such, structural changes within the tendon have been shown to occur after exercise, especially after lengthy periods of time.[4–6] Other authors have revealed that significant changes in tendon structure do not occur during the treatment period.[7,8] These results, in addition to other research showing no correspondence to improvements in pain or function suggest that mechanism(s) other than structural adaptation may be responsible for clinical improvement during rehabilitation, although a discussion of these mechanisms is beyond the scope of this paper.[7]

Successful results have been shown using eccentric exercise as treatment for chronic patellar tendon injuries with different protocols showing positive effects short-term and some long-term.[3,9] However, a systematic review by Malliaras et al suggested performance of eccentric-concentric loading in conjunction with or instead of eccentric loading for Achilles and patellar tendinopathies.[10]

Other research has investigated functional and symptomatic changes to connective tissues as a result of different modes of strengthening and stretching exercises. Diagnostic ultrasound has been used to measure these structural changes by observing fascicle length, angle, and thickness and allows for an immediate method to observe the effect of the intervention on the inferior pole of the patella.[11] Duclay et al concluded that tendinous structures and muscular architecture were affected by a seven-week eccentric training exercise program. After training, the fascicle angle and thickness increased during rest and type of contraction, whereas the fascicle length increased only during rest and not with contraction.[11] Visnes et al examined characteristics of jumper's knee and the inferior patellar pole in young athletes and found no difference in tendon thickness in athletes examined weekly following a 10 month training program.[12] In other studies looking at risk factors and treatment for jumper's knee, the researchers concluded that eccentric contraction exercises are a viable option for treating this pathology.[13,14] Biernat et al used ultrasonography to examine the structural changes of the patellar tendon during a rehabilitation protocol that consisted of eccentric exercise in competitive volleyball players and found that eccentric exercise can be effective when combined with functional exercises in treating patellar tendonapathy.[15] Although studies have been conducted using diagnostic ultrasound to evaluate structural changes in various tendons and muscle-tendon units (MTUs), these studies have not compared different types of exercise and/or stretching.[11,16–20] An increase in knowledge of structural changes is needed to aid healthcare professionals in rehabilitation of patients.

Though the effects of various types of exercise on connective tissue have been investigated, the effects of exercise comparing stretching as well as concentric and eccentric activities on the inferior patellar pole have yet to be clearly defined. The purpose of this study was to compare the acute effects of static stretching, eccentric, concentric, and a combination of eccentric /concentric exercises on structural changes of the MTU at the inferior patellar pole utilizing diagnostic ultrasound. The purpose of this study was to compare the acute effects of static stretching, eccentric, concentric, and a combination of eccentric/concentric exercises on structural changes of the muscle tendon unit at the inferior patellar pole utilizing the diagnostic ultrasound.

METHODS

Research Design

A quasi-experimental study with a 2 x 4 within factorial design with repeated measures on both factors was used to determine the differences of patellar tendon thickness within groups. The study received approval by Western Kentucky University's Institutional Review Board.

Subjects

A convenience sample of 47 healthy, generally active adults between the ages of 18 and 40 (21 males and 26 females) were recruited from Western Kentucky University's Doctor of Physical Therapy Program. Out of the 47 healthy subjects that began participation in the study, 44 completed all four interventions (N = 44) with a mean age of 25 and standard deviation of 3.4. The attrition was due to injuries to the lower extremity that occurred unrelated to the study.

Inclusion criteria included the ability to perform the required exercises, no musculoskeletal injuries, and the ability to speak English. Exclusion criteria included any previous lower extremity deficit or pathology. Pathologies included, but were not limited to, chronic tendinopathy, sprains or strains requiring orthopedic surgery, or any underlying chronic musculoskeletal impairment such as medically diagnosed osteoarthritis or active and tenderness to palpation Osgood Schlatter tibial tuberosities. All subjects were provided with an informed consent prior to participation in the study. The subjects were assigned de-identified case numbers and all documents were kept confidential.

During the study, participants were requested to avoid physical exercise including running, jumping, and lower extremity weight lifting for a period of 24 hours prior to the testing window, as well as during the testing procedure. Participants were also asked to avoid taking any nonsteroidal anti-inflammatory medication 48 hours before the testing period. Pre-measurements were taken before the intervention to focus on the effects of the intervention only, instead of possible external factors.

Instrumentation

Ultrasonographic images (UI) were captured using the MyLab25 Gold (Esaote, Indianapolis, IN). An inter-rater reliability value of 96.4% has been found when measuring the tendons attachment site at the bone.[12] A single operator received a one-on-one course training from a certified operator from Easote using a linear array transducer functioning at a frequency of 10 MHz. An intra-rater reliability study was performed for the single operator resulting in an intraclass coefficient single of 0.725, which is representative of good reliability.[21] Images were recorded under specific case numbers to blind the evaluator to the participant's images. The ultrasound operator evaluated images with software-based measurements from the MyLab25 Gold system for musculoskeletal images. The inferior patellar pole was used as a standard reference point for all images (approximately center of image, 2 cm of structure on each side) as this is a common site for repetitive micro-trauma to occur at the patellar tendon during activities that involve prolonged running or repetitive jumping.

Procedure

Testing was conducted in the University Medical Center Health Complex exercise lab with each participant having a 10-minute testing window. Each participant was asked to return each week at approximately the same time on the same day of the week as their initial session. Prior to beginning testing and interventions, each participant was screened for inclusion/exclusion criteria and demographic information (gender, height, weight, BMI) was obtained, along with informed consent. Baseline testing consisted of three measurements of the infrapatellar tendon using diagnostic ultrasound to produce UI. The baseline UI was taken with the participant in a supine position and the knee flexed to approximately 30 degrees. Images were taken of the tendon insertion point of the inferior patellar pole approximately 4 cm in length (2 cm of inferior patella, 2 cm of patellar tendon). The average of the three images was used as the baseline measurement for each participant.

After baseline UI measurements were conducted, the participant performed the randomized exercise intervention (stretching, concentric, eccentric, combination concentric/eccentric) depending on the phase of the study. Each researcher was assigned a specific role that was maintained throughout the study: intervention specialist, ultrasound operator, and recorder. The ultrasound operator was blinded to the assignment of interventions each participant performed.

Exercise Protocol

The exercise protocol consisted of one intervention per week targeting the right patellar tendon for a total of four weeks. Each week the participants randomly selected an intervention from the pool of uncompleted interventions until all had been completed. The interventions were listed on different pieces of paper and turned face down for participants to draw from. After an intervention was drawn it was eliminated from the choices during the next selection. The stretching intervention (Protocol A) consisted of three static stretches: standing quadriceps stretch, reclining quadriceps stretch, and kneeling quadriceps stretch (Figure 1). Each stretch was held for 30 seconds for three repetitions.[22] The second intervention was a concentric exercise intervention (Protocol B): the participant was asked to jump to a maximum height off the right leg and land on the left leg. The participant was instructed to jump at maximal exertion for one minute. The third intervention was an eccentric intervention (Protocol C): the participant was instructed to jump to a maximum height off the left leg and land on the right leg at maximal exertion for one minute. The fourth and final intervention was a combination concentric/eccentric intervention (Protocol D): the participant was asked to jump to a maximum height off both legs and to land on both legs at maximal exertion for one minute. See Figure 2 for the flight phase of Protocols B-D.

Immediately following each exercise intervention, UI of the same tendon was performed as previously described for the baseline UI. Exercise protocol and UI were performed in the same location to ensure no delay in imaging for extraneous control. Baseline and post-exercise images were then evaluated for any structural changes that may have been produced by the exercise protocol (see Figures 3 and 4). A total of six images (three baseline, three post-intervention) were captured for each intervention to ensure accurate readings of the structural changes.

Figure 1. *Protocol A. Image 1 - kneeling quad stretch, image 2 - reclining quad stretch, image 3 - standing quad stretch.*

Figure 2. *Image 1- flight phase of Protocol B, image 2 - flight phase of Protocol C, image 3 – flight phase of Protocol D.*

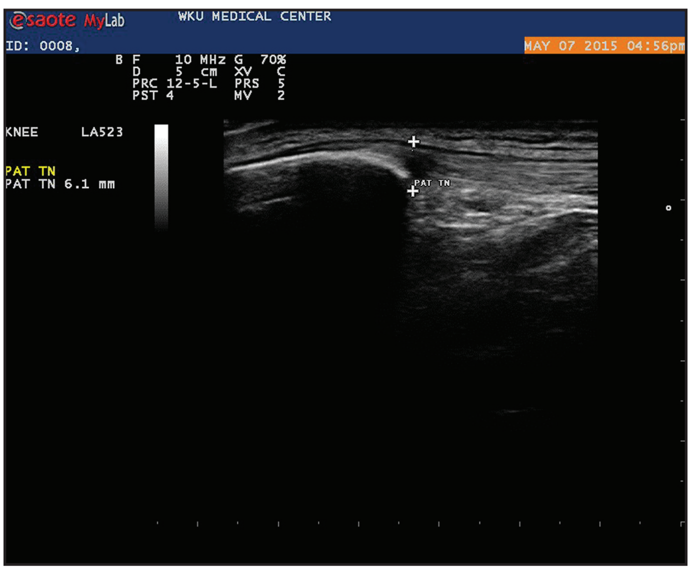

Figure 3. *Ultrasound image of the pre-measured inferior pole of the patella.*

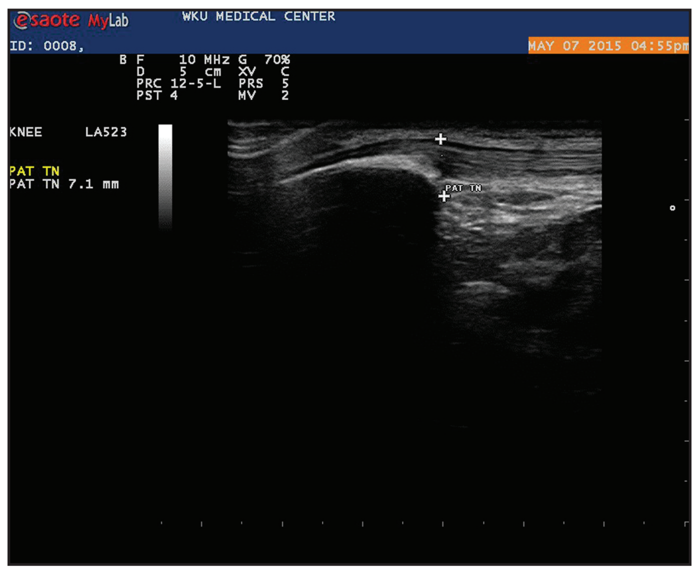

Figure 4. *Ultrasound image of the post-measured inferior pole of the patella.*

Averages were then taken from each of the three sets of images and used for the results.

STATISTICAL ANALYSIS

A 2 x 4 repeated measures ANOVA within factorial study design with repeated measures on both factors was used to determine the differences of the infrapatellar MTU thickness within and between groups utilizing the IBM SPSS version 22.0 (SPSS, Inc., Chicago, IL). Tendon thickness measurements were classified as ratio data. Mean demographic characteristics such as age, height, weight, and BMI were documented and summarized. All images recorded from the ultrasound machine were saved and stored onto a flash drive with each individual case file. Any missing data/images excluded the participant from the study.

RESULTS

Significant differences in anterior to posterior tendon thickness of the inferior patellar tendon between pre and post measurements $F(1,43)=34.435$, $p<0.0005$ were found for the main effect of time. The tendon thickness was greater at post measurements (mean = 5.19 ± 0.055mm) than at pre-measurements (mean = 4.983 ± 0.041 mm) with an effect size of 0.895, as displayed in Table 1. However, no significant differences in tendon thickness were noted when comparing each intervention ($p=0.351$). Table 2 compares the results of pre- and post-measurements of stretching, concentric/eccentric, concentric, and eccentric exercise protocols. Protocol A (stretching) had a pre-measurement average of 5.02 ± 1.047mm and a post measurement average of 5.106 ± 0.968mm. Protocol B (concentric exercise) resulted in a pre-measurement average of 5.01 ± 0.999mm and post measurement average of 5.27 ± 0.955mm. Protocol C (eccentric exercise) produced a pre-measurement average of 4.97 ± 0.928mm and post measurement average of 5.15 ± 1.096mm. Protocol D (combination of concentric and eccentric exercise) resulted in a pre-measurement average of 4.93 ± 0.903mm and post measurement average of 5.21 ± 1.007mm.

DISCUSSION

The purpose of this study was to compare the effects of static stretching, eccentric, concentric, and a combination of eccentric/concentric exercises on acute structural changes of the muscle tendon unit (MTU) at the inferior patellar pole utilizing diagnostic ultrasound. The results suggest that there were no significant differences in tendon thickness when comparing each intervention. The findings agree with Kubo et al when comparing dynamic versus static training who found no differences obtained when observing the cross sectional area of the patellar tendon after dynamic and static training utilizing MRI.[23] A study completed by Malliaras et al had similar results with change in patellar tendon stiffness and modulus being significantly greater when comparing all exercise groups to the control. However, no significant changes were found comparing eccentric training and concentric training.[24]

Previous research has been performed using diagnostic ultrasound to compare structural changes in tendons. Utilizing diagnostic ultrasound, Visnes et al discovered that there was an increase in tendon thickness of the quadriceps and patella tendons of male athletes that went on to develop jumper's knee.[12]

Although previous studies looked at the differences of structural changes between stretching or a specific exercise protocol, there are no studies that have compared eccentric, concentric, and stretching. Samukawa et al showed no structural changes in tissues while investigating the effects of dynamic stretching on the muscle-tendon properties of the plantar flexors after stretching.[17] Frizziero et al looked at the role of eccentric exercise as a treatment option to common sports injuries in the Achilles tendon. They found that, although there was no change to the thickness of the tendon, possible remodeling was taking place resulting in tendon healing.[25] This conclusion was reached based on the premise that the use of eccentric contractions to treat the impairment and the length of time between interventions and tendon measures was sufficient to overcome the acute phase of tendon enlargement. McCreesh examined the vascular changes associated with an eccentric exercise program in a case report and determined that a reduction of vascularization and

Table 1. *Significant outcome measures via 2x4 repeated measures ANOVA for the main effect of time.*

Meausres	Pre Mean	Post Mean	Effect Size	p value
Tendon Thickness (mm)	4.983	5.19	0.895	<0.0005

Table 2. *Pre and post measurements of tendon thickness for each intervention.*

	Protocol A-Stretch		Protocol B-CON		Protocol C -ECC		Protocol D-ECC/CON	
Tendon Thickness	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Mean (mm)	5.015909	5.156818	5.006818	5.268182	4.972727	5.15	4.934091	5.206818
Standard Deviation (mm)	1.047021	0.968191	0.999627	0.955224	0.928455	1.096188	0.902694	1.007506

accompanying nerve fibers actually improved the patient's function.[26]

In an orthopedic physical therapy setting, the impact of concentric and eccentric exercise on tendon physiology can guide therapy choices for patient populations such as muscle strengthening using concentric exercises or treating tendonitis using high force eccentric exercises. In a sports or training setting it is also important to understand tendon response as it relates to muscle performance and exercise to determine appropriate protocol. Understanding the physiological effects of the connective tissues can provide a basis for conservative treatment that would benefit the individual the most. These physiological changes were addressed in the study conducted by Yin et al when looking at the microcirculation of the patellar tendon following eccentric exercise and how that circulation impacted tendon stiffness. They concluded that, following four rounds of eccentric exercise, microcirculation improved resulting in increased tendon flexibility.[27]

There are several limitations to the present study, one being the small sample size (N = 44). Further study would need to be completed with a larger and more diverse sample size to generalize the results to a larger population. Another limitation that may have involved tendon properties may be that the sample size was too homogenous. This could have resulted in a potential ceiling effect, since only normal subjects were observed in the study. The ultrasound operator may have had measurement errors as well. Another limitation may involve the procedure itself. Several factors are important when determining successful performance. For example, it was expected that subjects gave a maximal effort for each jump. Participants with previous training may be more experienced at the activities and perform at an optimal level compared to an individual with no athletic training or experience. It is likely that the subjects may not have felt prepared or skilled enough in the exercise to give a maximal effort or that there were individual differences in motivation levels and perspective to obtain maximal effort. This limitation is magnified by looking at the study conducted by Earp et al due to the change in tendon structure. Researchers examined the force conducting properties of tendons during different phases of the stretch shortening cycle (SCC) and how the tendon changed with varying loads. They concluded that with larger amplitude forces the tendons changed from a power amplifier at light loads to a rigid force transducer at higher loads.[28] Also when dealing with participants' maximum effort, it is important to understand the buffering principle of the patellar tendon in relation to the eccentric control of the quadriceps. Hicks et al concluded that during a low-intensity jump the muscular fascicles undergo greater lengthening than during a maximal jump in which the fascicles and tendons become stiffer.[29] This change in tendon performance could possibly impact tendon structural integrity and should be investigated further.

Contrary to previous research involving numerous forms of concentric, eccentric, and stretching interventions in isolation, the current study compared various forms of exercise as they relate to an increase in tendon thickness. Although no significance differences were determined between the different interventions, this study provides a baseline for future research to further investigate the structural effects on tendon from stretching, concentric, eccentric, and a combination of concentric and eccentric exercises with chronic exercise over time and with different types of intervention. This is only a comparative study of four different interventions. The authors speculate that, since the duration of the study was only four weeks, there may be a potential increase in collagen overlay during this time, resulting in an increase thickness size of the MTU

CONCLUSION

This study compared the effects of static stretching, eccentric, concentric, and a combination of eccentric/concentric exercises on structural changes at the MTU of the inferior patellar pole utilizing diagnostic ultrasound. Although there were no differences noted between exercise types, findings revealed acute, statistically significant changes in the thickness of the inferior patellar pole pre- to post exercise. This finding is clinically important for those individuals who engage in impact activities and for clinicians treating adverse conditions related to overuse. Further research is needed to determine the duration of acute effects of the various contractions and the chronic effects of structural changes of the inferior patellar pole.

REFERENCES

1. Murtaugh B, Ihm JM. Eccentric training for the treatment of tendinopathies. *Curr Sports Med Rep*. 2013;12(3):175-182.
2. Wilson JJ, Best TM. Common overuse tendon problems: A review and recommendations for treatment. *Am Fam Physician*. 2005;72(5):811-818.
3. Childress MA, Beutler A. Management of chronic tendon injuries. *Am Fam Physician*. 2013;87(7):486-490.4. Gärdin A, Movin T, Svensson L, Shalabi A. The long-term clinical and MRI results following eccentric calf muscle training in chronic Achilles tendinosis. *Skelet Radiol*. 2010;39(5):435-442.
5. van der Plas A, de Jonge S, de Vos RJ, et al. A 5-year follow-up study of alfredson's heel-drop exercise programme in chronic midportion Achilles tendinopathy. *Br J Sports Med*. 2012;46(3):214-218.
6. Shalabi A. Magnetic resonance imaging in chronic Achilles tendinopathy. *Acta Radiol Suppl Stockh*. 2004;Supplement(432):1-45.
7. Drew B, Smith T, Littlewood C, Sturrock B. Do structural changes (e.g., collagen/matrix) explain the response to therapeutic exercises in tendinopathy: A systematic review. *Br J Sports Med*. 2012;0:1-8.
8. de Vos RJ, Heijboer MP, Weinans H, Verhaar JA, van Schie HT. Tendon structure's lack of relation to clinical outcome after eccentric exercises in chronic midportion Achilles tendinopathy. *J Sport Rehab*. 2012;21(1):34.
9. Frohm, Eccentric treatment for patellar tendinopathy a prospective randomised short-term pilot study of two rehabilitation protocols.pdf.
10. Malliaras P, Barton CJ, Reeves ND, et al. Achilles and patellar tendinopathy loading programmes : a systematic review comparing clinical outcomes and identifying potential mechanisms for effectiveness. *Sports Med Auckl NZ*. 2013;43(4):267-286.
11. Duclay J, Martin A, Duclay A, et al. Behavior of fascicles and the myotendinous junction of human medial gastrocnemius following eccentric strength training. *Muscle Nerve*. 2009;39(6):819-827.
12. Visnes H, Tegnander A, Bahr R. Ultrasound characteristics of the patellar and quadriceps tendons among young elite athletes. *Scand J Med Sci Sports*. 2015;25(2):205-215.
13. Visnes H, Aandahl HÅ, Bahr R. Jumper's knee paradox--jumping ability is a risk factor for developing jumper's knee: a 5-year prospective study. *Br J Sports Med*. 2013;47(8):503-507.
14. Visnes H, Bahr R. The evolution of eccentric training as treatment for patellar tendinopathy (jumper's knee): a critical review of exercise programmes. *Br J Sports Med*. 2007;41(4):217-223.
15. Biernat R, Trzaskoma Z, Trzaskoma L, et al. Rehabilitation protocol for patellar tendinopathy applied among 16- to 19-year old volleyball players. *J Strength Cond Res Natl Strength Cond Assoc*. 2014;28(1):43-52.
16. Parr JJ, Yarrow JF, Garbo CM, et al. Symptomatic and functional responses to concentric-eccentric isokinetic versus eccentric-only isotonic exercise. *J Athl Train*. 2009;44(5):462-468.
17. Samukawa M, Hattori M, Sugama N, et al. The effects of dynamic stretching on plantar flexor muscle-tendon tissue properties. *Man Ther*. 2011;16(6):618-622.
18. Shaikh Z, Perry M, Morrissey D, et al. Achilles tendinopathy in club runners. *Int J Sports Med*. 2012;33(5):390-394.
19. Grigg NL, Wearing SC, Smeathers JE. Eccentric calf muscle exercise produces a greater acute reduction in Achilles tendon thickness than concentric exercise. *Br J Sports Med*. 2009;43(4):280-283.
20. Romero-Rodriguez D, Gual G, Tesch PA. Efficacy of an inertial resistance training paradigm in the treatment of patellar tendinopathy in athletes: a case-series study. *Phys Ther Sport Off J Assoc Chart Physiother Sports Med*. 2011;12(1):43-48.
21. Cicchetti, Domenic V. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychol Assess*. 1994;6(4):284-290.
22. Bandy W, Irion J. The effect of time on static stretch on the flexibility of the hamstring muscles. *Phys Ther*. 1994;74:845-850.
23. Kubo K, Ikebukuro T, Yaeshima K, et al. Effects of static and dynamic training on the stiffness and blood volume of tendon in vivo. *J Appl Physiol Bethesda Md 1985*. 2009;106(2):412-417.
24. Malliaras P, Kamal B, Nowell A, et al. Patellar tendon adaptation in relation to load-intensity and contraction type. *J Biomech*. 2013;46(11):1893-1899.
25. Frizziero A, Trainito S, Oliva F, et al. The role of eccentric exercise in sport injuries rehabilitation. *Br Med Bull*. 2014;110(1):47-75.
26. McCreesh KM, Riley SJ, Crotty JM. Neovascularity in patellar tendinopathy and the response to eccentric training: a case report using Power Doppler ultrasound. *Man Ther*. 2013;18(6):602-605.
27. Yin N-H, Chen W-S, Wu Y-T, et al. Increased patellar tendon microcirculation and reduction of tendon stiffness following knee extension eccentric exercises. *J Orthop Sports Phys Ther*. 2014;44(4):304-312.
28. Earp JE, Newton RU, Cormie P, et al. The influence of loading intensity on muscle-tendon unit behavior during maximal knee extensor stretch shortening cycle exercise. *Eur J Appl Physiol*. 2014;114(1):59-69.
29. Hicks KM, Onambele-Pearson GL, Winwood K, et al. Gender differences in fascicular lengthening during eccentric contractions: the role of the patella tendon stiffness. *Acta Physiol Oxf Engl*. 2013;209(3):235-244.