

Title

Isometric strength of the hip abductors and external rotators in athletes with and without patellar tendinopathy

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Abstract

Purpose

This study aims to compare the isometric strength of hip abductors and external rotators in male athletes with and without patellar tendinopathy (PT), and to examine the correlation between hip strength, pain, and functional scores.

Methods

Sixty male athletes (30 with PT and 30 controls) were recruited from local volleyball and basketball teams. The isometric strength of the hip abductors and external rotators was quantified using a belt-stabilized handheld dynamometer. This study used the visual analog scale (VAS) and the Victorian Institute of Sport Assessment-Patella (VISA-p) questionnaire to measure the intensity of pain and functional scores in athletes with PT, respectively.

Results

The normalized isometric strength of the hip abductors and external rotators was significantly less in the PT group compared with controls. In subjects with PT, the normalized isometric strength was decreased by 22.0% ($p = 0.000$) in the hip abductors and by 20.0% in the hip external rotators ($p = 0.004$), compared with controls. Significant correlations were found between the normalized isometric strength of the hip abductors and intensity of pain ($r = -0.70$; $p < 0.05$) and VISA-p score ($r = 0.63$; $p < 0.05$) in the affected leg in athletes with unilateral PT.

Conclusions

Athletes with PT have decreased isometric strength in their hip abductors and external rotators when compared with controls. In subjects with unilateral PT, decreased isometric strength in the hip abductors is associated with greater intensity of pain and lower functional scores. Results of this study implied that hip muscle assessment and strengthening should be included for reconditioning and rehabilitation in athletes with PT.

Introduction

Patellar tendinopathy (PT) is a common disorder in sports that involves running and jumping (Zwerver et al. 2011) with a prevalence rate higher in males than in females (Lian et al. 2005). Most importantly, about 53% of athletes with PT cease sports participation because of knee pain (Kettunen et al. 2002). Sporting activities involving jumping and landing place large loads on the patellar tendon and require the muscle–tendon units of the lower limb to dissipate kinetic energy on landing (Van der Worp et al. 2014). The function of the proximal muscle groups of the kinetic chain (e.g. hip musculature) might influence loading of the patellar tendon by playing a role in controlling trunk and limb kinematics during landing (Jacobs et al. 2007; Janssen et al. 2013; Malloy et al. 2016; Scattone Silva et al. 2017).

A review of the relationship between jump biomechanics and patellar tendinopathy suggests that employing a more flexible jumping pattern may reduce the development of PT (Van der Worp et al. 2014). During landing from vertical jump, an increase in trunk flexion (Scattone Silva et al. 2017) and decrease in trunk flexion velocity (Janssen et al. 2013) were found to significantly reduce the patellar tendon force. During horizontal landing, increases in hip adduction angle and knee internal rotation were observed in athletes with patellar tendon abnormalities compared with controls (Edwards et al. 2010). The authors speculated that the altered kinematics of the hip and knee joints may increase loading on the medial side of the proximal patellar tendon during horizontal landing. Hip muscle strength plays a major role in controlling hip and knee kinematics during vertical and horizontal landing. Decrease in isometric hip extensor strength was detected in subjects with PT compared with the healthy control (Scattone Silva et al. 2016). Whether

similar deficit would be found on the hip abductors and external rotators has not been explored. Understanding of the influence of trainable physical abilities, such as muscular strength in subjects with PT, might provide suggestions on reconditioning and rehabilitation in athletes with PT.

The present study aimed to compare the isometric strength of the hip abductors and external rotators in athletes with and without PT. Our secondary aim was to examine the possible association between hip strength, pain intensity, and symptom severity in athletes with PT. We hypothesized that athletes with PT would demonstrate decreased isometric strength of the hip abductors and external rotators compared with asymptomatic controls, and that decreased strength in the hip abductors or external rotators would be associated with greater intensity of pain and clinical symptoms in subjects with PT.

Materials and methods

Subject recruitment

Sixty male recreational athletes (PT group: 30; control group: 30) were recruited from local volleyball and basketball teams. Thirty athletes with PT participated in this study (unilateral PT = 12; bilateral PT = 18). The criteria for participation were: (1) age 18–35 years; (2) pain in the inferior pole of the patella or the proximal patellar tendon, with aggravation during single leg squatting and jumping (Lian et al. 1996); (3) pain duration > 3 months; (4) maximum intensity of pain in the previous week > 3 using a visual analog scale (VAS), with 0 as no pain and 10 as the

worst pain; (5) Victorian Institute of Sport Assessment-patella Questionnaire (VISA-p) < 80 (Zwerver et al. 2011); (6) no history of corticosteroid injection or surgery of the lower limb; (7) thickening of the proximal patellar tendon with areas of hypoechoic signals (Kulig et al. 2013). Thirty age-matched subjects from the same teams with no history of knee trauma or surgery and no anterior knee pain, tendon abnormality, or inflammation were recruited as controls. The subjects were assessed by an experienced physical therapist (WCL) and both control and PT underwent ultrasonographic examination by another physical therapist (ZJZ). For subjects with bilateral PT, measurements were taken on the most painful leg (Bolgla et al. 2008).

Ethics statement

This study was approved by the Human Subject Ethics Subcommittee of the Department of Rehabilitation Sciences, the Hong Kong Polytechnic University. The experimental procedures were conducted in accordance with the Declaration of Helsinki. The procedures of the study were fully explained to the participants, who provided written informed consent before testing.

Isometric strength measurements

Isometric strength was measured using a belt-stabilized handheld dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) by one examiner (ZJZ). This method has been proven valid (Martins et al. 2017) and has excellent reliability for the abductors (Martins et al. 2017; Thorborg et al. 2013) and external rotators (Martins et al. 2017). The intraclass correlation coefficient and standard error of measurement ranged from 0.80 to 0.99 and 2.7–3.1 kg (or 7.9–

9.2%), respectively, for the hip abductors (Martins et al. 2017; Thorborg et al. 2013); the intraclass correlation coefficient and standard error of measurement ranged from 0.80 to 0.90 and 3.6–4.4 kg (or 5.2–7.3%) for the external rotators (Martins et al. 2017). For all measurements, subjects were instructed to give maximal effort and maintained it for 5 s. One submaximal trial was practiced and three test repetitions were performed, with 15 s of rest between trials (Ireland et al. 2003). The peak values from the three measurements were recorded. The average peak isometric strength values of the hip abductors and external rotators were normalized by body mass and height for each subject (Tate et al. 2017).

Isometric strength of the hip abductors was measured with subjects in side-lying position on an examination table (Ireland et al. 2003). A pillow was placed between the legs, such that the leg to be tested was placed in 0° of hip flexion and 10° of hip abduction with the knee fully extended. The centre of the force pad of the handheld dynamometer was placed over a mark located 5 cm proximal to the lateral knee joint line. A strap was placed just proximal to the iliac crest and attached to the underside of the examination table to stabilize the trunk, and a second strap was wrapped around the dynamometer, the thighs, and the underside of the examination table. The subject was instructed to push the tested leg upwards (abduction).

Hip external rotator isometric strength testing was performed with subjects sitting on an examination table, with the hips and knees flexed to 90° (Ireland et al. 2003). A strap was placed on the thigh of the tested leg to minimize hip adduction. The centre of the force pad of the dynamometer was placed 5 cm above the medial malleolus and secured by a second strap around

the base of a stationary object. The subject was instructed to move the leg inwards (external rotation).

Clinical severity of symptoms

Intensity of pain and functional scores were assessed before strength measurement. Pain intensity was assessed by the maximum VAS score during functional activities in the previous 7 days. The VAS is scored from 0 to 10, with 0 indicating no pain and 10 indicating the worst pain during testing. The VAS is reliable and valid for the evaluation of patients with anterior knee pain (Crossley et al. 2007). The VISA-p questionnaire is used to assess the severity of symptoms and functional ability in subjects with PT (Visentini et al. 1998). The eight-item questionnaire includes four questions on self-perceived pain associated with functional activity, two on ability to perform functional activities, and two on the ability to play a sport. Self-perceived abilities are rated on a 10-point Likert scale, with 0 as lowest and 10 as highest ability. The total possible score of the questionnaire is 100, and the final score is used to quantify the clinical symptoms and functional level.

Statistical analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analyses. Normality of variables was assessed using the Shapiro–Wilk test. Continuous variables were expressed as means and standard deviations. Chi square tests were used to examine the differences in sports activities performed by the PT and control groups. Independent t tests were

performed to compare demographic data between players with and without PT. Paired t tests were used for side-by-side comparisons of the variables in the controls. If there were no significant side-by-side differences, a coin toss would be used to decide which side would be used for further analysis. Multivariate analysis of covariance (MANCOVA) was used to compare the normalized isometric strength of hip abductors and external rotators between the painful side in athletes with PT and the controls with variables, with significant group difference as covariates. Pearson's correlations were used to examine the relationships between hip strength (abductors and external rotators), pain, and functional ability in athletes with unilateral PT and bilateral PT. P values < 0.05 were considered statistically significant.

Results

Subject characteristics

The age, height, body mass, BMI, and training intensity of subjects in both groups are shown in Table 1. There were no significant differences in age, height, body mass, and distribution of sports type ($p > 0.05$) (Table 1). However, significant differences were found in BMI ($p = 0.021$) and weekly practice hour ($p = 0.008$) between the groups. BMI and weekly practice hour were used as covariates for further analysis.

Isometric strength of hip abductors and external rotators

Side-by-side differences in the isometric strength of the hip abductors ($p = 0.53$) and hip external rotators ($p = 0.55$) in the controls were not significant. A limb of the control group was chosen at random for comparison with the tendinopathy group.

Athletes with PT had significantly less isometric strength in their hip abductors (by 22%) and external rotators (by 20%) compared with the controls. The normalized isometric strengths of the hip abductors were 0.85 (95% CI = 0.78–0.93) N kg⁻¹m⁻¹ and 1.09 (95% CI = 1.02–1.18) N kg⁻¹m⁻¹ in the PT and control subjects, respectively ($p = 0.002$). The normalized isometric strengths of the hip external rotators were 0.12 (95% CI = 0.11–0.13) N kg⁻¹m⁻¹ and 0.15 (95% CI = 0.13–0.16) N kg⁻¹m⁻¹ in the PT and control subjects, respectively ($p = 0.024$).

Relationships between isometric muscle strength, intensity of pain, and functional ability

Significant correlations were found between normalized isometric strength of hip abductors and intensity of pain scores ($r = -0.70$; $p = 0.01$) (Fig. 1a) and VISA-p scores ($r = 0.63$; $p = 0.03$) (Fig. 1b) in athletes with unilateral PT, i.e. lower isometric strength of hip abductors, increased intensity of pain, and decreased functional ability. However, no significant correlation was found between normalized hip strength and intensity of pain as well as VISA-p score in subjects with bilateral PT. There was no significant correlation between external rotator strength and pain intensity or symptoms severity in both athletes with unilateral and bilateral PT (Table 2).

Discussion

The findings from this study indicated that the isometric strength of hip abductors and external rotators was significantly less in athletes with PT than in controls. This study also established correlations between isometric strength of the hip abductors, pain, and functional ability in athletes with unilateral PT.

Significantly less isometric strength of the hip abductors and external rotators was detected in basketball and volleyball players with PT compared to their asymptomatic counterparts. The normalized isometric strength was reduced by 20–22% in the hip abductors and hip external rotators, which is larger than the measurement errors (less than 10%) found for isometric measurements of these two muscles using a handheld dynamometer (Martins et al. 2017). To our knowledge, no similar studies have been performed to examine the isometric strength of the hip abductors and external rotators in athletes with PT. Therefore, direct comparison with other studies is not possible. In this connection, Scattone Silva et al. (2016) observed a reduction in the hip extensor strength (by 27%) in subjects with PT than control. The gluteus maximus is the main hip extensor and external rotator (Neumann 2010) and its superior fibres are also hip abductors (Shoja 2008). The reduction in hip abduction strength might associate with weakness in different heads of the glutei muscles, including the gluteus maximus and medius. Similarly, significantly less isometric strength in these three muscles was detected in middle-aged recreational athletes with mid-Achilles tendinopathy (Habets et al. 2017). The strength deficits ranged from 29 to 34%. Thus, significantly less isometric strength of the proximal muscle group (the hip muscles) in the kinetic chain was detected in subjects with tendinopathy.

The present cross-sectional observation study could not establish a cause-and-effect relationship between hip muscle strength and the development of PT. The significantly less isometric muscle strength in the affected side might reflect less activity in the affected leg, or weakened hip muscles might affect lower limb biomechanics and thereby increase stress on the medial side of

the patellar tendon, leading to tendinopathy. However, findings from this study support the notion that rehabilitation for athletes with PT should include the proximal hip muscles (Rudavsky and Cook 2014). In this connection, a case study reported that an 8-week intervention of hip extensor strengthening and jumping-landing modification for one male athlete with PT could reduce pain and improved jump-landing biomechanics (Scattone Silva et al. 2015).

Because of the high prevalence of PT in sports involving jumping and landing, several researchers have conducted studies to identify jump-landing biomechanics associated with the injury (Bisseling et al. 2007; Edwards et al. 2010; Rosen et al. 2015; Siegmund et al. 2008). During vertical landing, higher hip internal rotation at initial contact (Edwards et al. 2010), decreased maximal flexion and angular displacement in the sagittal plane of the hip and knee (Rosen et al. 2015), and less ankle plantar flexion and excursion (Bisseling et al. 2007) were observed in subjects with PT or patellar tendon abnormalities compared with controls. Significant differences in landing kinematics, such as increased hip adduction and knee internal rotation, were detected during horizontal landing between subjects with a patellar tendon abnormality and controls (Edwards et al. 2010). As mentioned in the above paragraph, the jump-landing kinematic could be improved after an 8-week intervention of hip extensor strengthening and jumping-landing modification (Scattone Silva et al. 2015). The findings shed light on the importance of including proximal hip muscle strengthening exercises and jumping-landing skill for athletes with PT. Further study is suggested to explore the independent and combined effects of hip muscle strengthening and jumping-landing modification for athletes with PT.

The present findings also provide evidence that in athletes with unilateral PT, decreased isometric strength in the hip abductors was associated with greater intensity of self-perceived pain and a lower functional score. Since the hip abductor muscle group is important for controlling lower limb kinematics during landing, the weakness of these muscles might induce greater loading and thereby greater intensity of pain in the patellar tendon. Accordingly, athletes with greater intensity of pain or decreased functional ability may avoid/reduce loading on the affected leg, eventually leading to disuse atrophy. We were unable to identify correlations between isometric hip strength, intensity of self-perceived pain, and functional scores in athletes with bilateral PT. The findings in this study are comparable to those reported by Gaida et al. (2004), who stated that unilateral and bilateral PT have distinct aetiologies.

When compared with asymptomatic controls, the PT group had significantly greater BMI and training hours per week. Overloading of the patellar tendon may be associated with intrinsic factors, such as body weight, BMI (van der Worp et al. 2011), and muscle flexibility (Morton et al. 2017; Witvrouw et al. 2001). Our subjects with PT had significantly higher BMI, but no significant differences in body mass. On the other hand, Tiemessen et al. (2009) reported that playing and training for 12 h per week in basketball and volleyball led to an increased risk of PT. In this study, more percentage of subjects in the control (17%) than PT (6.7%) groups had sports training for ≥ 12 h/week. Contrary to our expectation, the mean training hours per week were significantly greater in the controls (mean = 8.7 h/week) than in the PT group (mean = 6.0 h/week). We postulated that subjects with PT might have reduced their training hours because of pain.

Limitations

Although weakness of the hip abductor and external rotator muscles was detected in players with PT, a causal relationship could not be established. A prospective study is needed to ascertain the cause and effect relationship between hip muscle strength and development/recovery of PT. In this study, only male basketball and volleyball players were assessed. The findings could not be generalized to female athletes or other sports. Moreover, the isometric strength of the hip muscles was assessed using a handheld dynamometer. Examiner influence was minimized using external straps for fixation of the dynamometer. However, we did not measure limb length and this may be a confounding variable affecting strength measurement. This bias was minimized by reporting strength measurements in units of force normalized by body mass and height.

Conclusions

The study showed that recreational male athletes with PT demonstrate significant weakness in the hip abductors and external rotators. In athletes with unilateral PT, decreased isometric strength of the hip abductors is associated with greater intensity of pain and a decreased functional score. Based on these findings, assessment and rehabilitation of hip muscle strength should be included in an intervention programme for athletes with PT.

Abbreviations

PT: Patellar tendinopathy

VAS: Visual analog scale

VISA-p: Victorian Institute of Sport Assessment-patella

MANCOVA: Multivariate analysis of covariance

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Table 1 Characteristics of PT and control groups

Variables	PT group (<i>n</i> = 30)	Control group (<i>n</i> = 30)	<i>p</i>
Age (year)	22.9 ± 4.4	23.5 ± 4.6	0.628
Body mass (kg)	74.7 ± 6.7	72.5 ± 8.4	0.271
Height (m)	1.81 ± 0.6	1.80 ± 0.6	0.250
BMI (kg/m ²)	23.0 ± 1.9	21.8 ± 1.9	0.021
Weekly hours of sports practice	6.0 ± 3.3	8.6 ± 4.0	0.008
Time of participation in sports (years)	8.8 ± 3.6	8.6 ± 4.5	0.886
Sports (volleyball/basketball)	14/16	15/15	0.509
Pain duration (years)	1.3 ± 2.1		
Unilateral/bilateral PT	12/18		

Values shown are means ± standard deviations

PT patellar tendinopathy, BMI body mass index

Table 2 Pearson product–moment correlation coefficients (r) between normalized isometric strength of the hip abductors and external rotators and intensity of pain as well as VISA-p scores in the affected sides in athletes with unilateral and bilateral PT

	Unilateral PT (<i>n</i> = 12)		Bilateral PT (<i>n</i> = 18)	
	Abductors	External rotators	Abductors	External rotators
VAS	– 0.70*	– 0.05	– 0.05	0.11
VISA-p	0.63*	0.07	– 0.05	– 0.16

PT patellar tendinopathy, VAS visual analog scale, VISA-p Victorian Institute of Sport Assessment-patellar Questionnaire

*Significant correlation ($p < 0.05$)

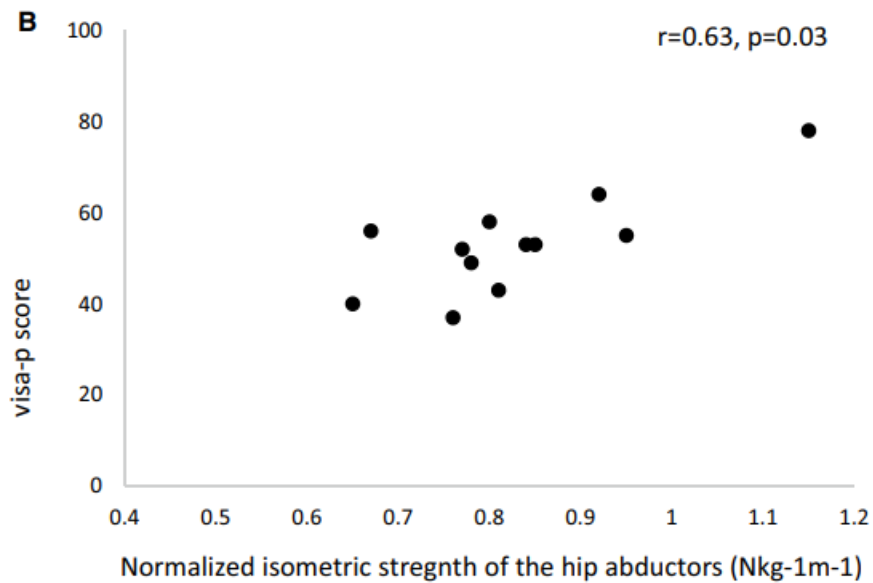
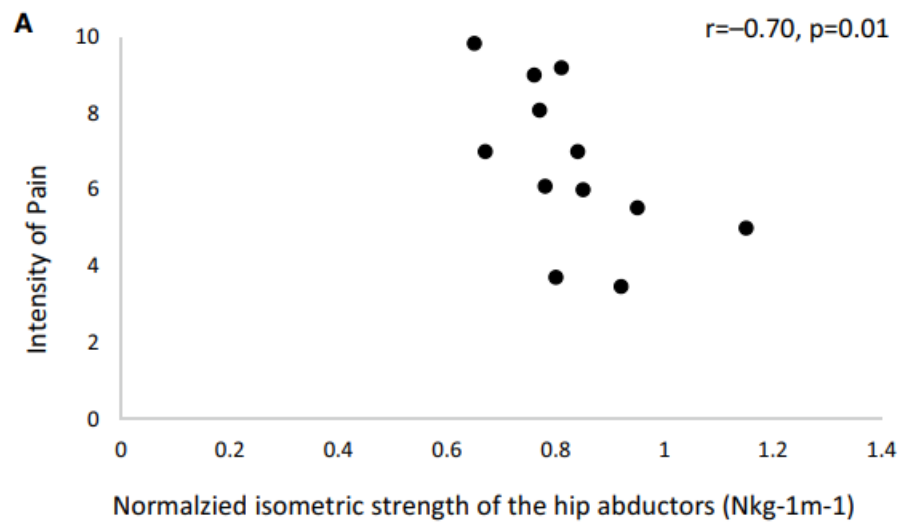


Figure 1 Correlation between normalized isometric strength of the hip abductors and a intensity of pain; b VISA-p score