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Effect of a patellar strap on the joint position sense of the symptomatic knee in athletes with patellar tendinopathy

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Abstract

Objectives: The primary aim of this study was to investigate the effect of a patellar strap on the proprioception of the symptomatic leg in PT. Secondary aims were to investigate a possible difference in effectiveness between athletes with high and low proprioceptive acuity, and whether predictors of effectiveness could be found.

Design: Randomised cross-over pilot study

Methods: 24 athletes with PT (age 27.3±9.0, VISA-P 50.6±11.2) performed a joint position sense test with and without a patellar strap. The difference between both conditions was analysed using linear mixed-model analysis.

Results: No improvement in the joint position sense using the strap for the whole group was found, while those classified as having low proprioceptive acuity did improve using the strap ($p=0.015$, 17.2%). A larger knee girth, longer duration of symptoms and more tendon abnormalities were negatively associated with the strap's effectiveness.

Conclusions: The use of a patellar strap improves the knee joint proprioception - measured with joint position sense - of the symptomatic leg in athletes with poor proprioceptive acuity. Especially athletes with relatively small knee girth, short duration of symptoms and small tendon abnormalities might benefit from the strap. As proprioception plays an important role in motor control, and deficits in proprioception may put an athlete at risk for (re-)injury, these findings may be relevant for prevention as well as rehabilitation purposes in those PT athletes with low proprioceptive acuity.

Keywords: proprioception, jumper's knee, orthotic devices, secondary prevention, rehabilitation, athletic injuries

Introduction

Proprioception is considered an important protective mechanism, as it plays a role in optimising movements and reducing load to joint-related structures.[1] Proprioception is defined by Lönn as 'the perception of movement and position of body segments in relation to each other without the aid of vision'.[2] Injury of structures containing proprioceptive mechanoreceptors may lead to proprioceptive deficits, putting the athlete at risk for (re-)injury.[3]

External aids like tapes, braces and elastic bandages have proven to be beneficial for proprioception in several populations.[4-6] The effect of patellar strapping on knee joint proprioception of athletes with unilateral patellar tendinopathy (PT) and healthy participants was recently investigated.[7] In agreement with previous findings, a significant improvement in knee joint proprioception was found, especially among participants with low proprioceptive acuity. A new and notable finding was that no improvement in proprioception was found in the symptomatic leg of the participants with PT. This latter finding is of particular interest, as a patellar strap is commonly worn to reduce symptoms of patellar tendon pain.

A possible explanation for the lack of improvement in the symptomatic leg is that pain mechanisms have interfered with the effect of the patellar strap on knee joint proprioception, as symptoms were negatively associated with the effect of the strap.[7] Even though pain is the most important and limiting symptom in PT, it is very complex and not yet completely understood.[8] It is suggested that in addition to nociception, induced by damage or inflammation, peripheral and central sensitisation also play a role in PT-related pain.[8-10] Sensitisation is a process of generalised hypersensitivity of the somatosensory system, therefore proprioception might be enhanced. On the other hand, the presence of pain can influence proprioception negatively, as was found in several studies;[11 12] this negative association is not always demonstrated though.[13] Since the use of a patellar strap might influence both pain and proprioception,[7 14] this could explain why the proprioceptive effect of the strap in the painful knee joint is unclear.

In the previous study, the proprioceptive ability was measured passively using the threshold to detect passive motion (TTDPM), where subjects had to press a button as soon as they felt their leg moving.[7] Even though the TTDPM is used most often to measure proprioception and is considered as the most reliable,[15] it does not reflect the functional use of proprioception. Measuring joint position sense is believed to assess the afferent pathways more functionally[3 16] and can therefore provide additional information about the effect of using a strap on the proprioception of a symptomatic knee joint in PT.

The primary aim of this pilot study was to investigate the effect of the use of a patellar strap on the proprioception – using joint position sense – of the symptomatic knee joint in athletes with PT. Secondary aims are to investigate if there is a difference between participants with high and low proprioceptive acuity and whether possible predictors of the effect of the strap on knee joint proprioception can be identified.

Methods

This randomised cross-over pilot study was conducted between March and June 2015 among active athletes with PT. All tests were administered at the Center for Sports Medicine of University Medical Center Groningen (UMCG), the Netherlands. The study was approved by the medical ethical committee of UMCG (METc 2014/528), and all patients signed an informed consent before participating. For all aspects of the study the ethical guidelines according the Medical Research Involving Human Subjects Act were followed closely.

Participants were recruited via the UMCG Center for Sports Medicine; physiotherapy practices; posters; social media; and a mailing to volleyball and basketball clubs in Groningen. Participants had to meet all of the following criteria: 1) age between 18 and 50; 2) current symptoms of anterior knee pain in either one or both knees; 3) symptoms longer than three months; 4) clinical diagnosis of PT by a sports medicine physician or physiotherapist with several years of experience with patellar tendinopathy; 5) Victorian Institute Sports Assessment Patella (VISA-P) score <80 [17]; 6) active in sports; 7) ultrasound abnormalities performed with Ultrasound Tissue Characterisation (UTC) [18] (at least increased tendon thickness and a hypoechogenic zone judged by physiotherapist with extensive training and experience with UTC images). Patients were excluded if they had a chronic joint disease, other knee pathologies, a neurological disorder that may influence pain and proprioception, or injection therapy or knee surgery.

First the test procedure was explained to the participant, who completed the VISA-P questionnaire and a baseline questionnaire in which the athlete’s personal characteristics (age, height, weight), sport-related factors (playing level, hours of sports participation) and injury-related factors (duration of symptoms, bilateral/unilateral PT) were obtained. Knee girth was measured just below the patella and patellar tendon pain was assessed. This was done using a provocative test – performing ten single-leg decline squats (60 ° knee flexion) on a decline board with a slope of 20°.[19] Directly after the test participants were asked to indicate the experienced pain during the test on a Visual Analogue Scale (VAS) for pain (score varying between 0 indicating no pain and 100 indicating worst pain imaginable).

The patellar tendons of all participants were scanned using Ultrasound Tissue Characterisation (UTC). Participants were in supine lying position on a treatment bench and their knee was flexed to approximately 100° knee flexion. A UTC apparatus with an ultrasound probe (Smartprobe 12L5-V, Terason 2000+; Teratech, Burlington, MD, USA) was placed on the knee. This probe was fixed in a tracking device (UTC Tracker, UTC Imaging, Stein, The Netherlands) to ensure a consistent tilt angle in relation to the tendon. Next, the tracker moves the ultrasound probe along the tendon at a consistent speed. Data was collected every 0.2 mm. Three images were constructed by the UTC software: a sagittal, a coronal and a transversal image.[18] Based on the stability of the images, four echotypes were created, ranging from the best and most stable echo pattern (echo-type 1) to the worst and least stable (echo-type 4).[18]

Joint position sense was assessed using the MR Cube proprioception test (FysioRoadmap monitored rehab systems, Haarlem, The Netherlands). MR Cube is an analog linear position transducer - a box with a cable that can be pulled out (figure 1, top left). The reliability and validity of the linear position transducer is demonstrated in several other sports-specific tests [20 21] (all requiring positional accuracy, like the proprioception test in this study). The cable was attached to a leg extension apparatus (figure 1, top right) and MR Cube was connected via Bluetooth to a computer with MR System software. Via the attachment of the MR Cube cable and the connection with the software, movement of the bar of the leg extension apparatus resulted in a horizontal movement of the dot between the arrows (see Figure 1, bottom left) on the computer screen. Knee extension resulted in a movement of the dot to the right and knee flexion resulted in a movement to the left.

The purpose of the test is to replicate and maintain four times as precisely as possible the predetermined joint position: the right vertical line. The first two times with visual feedback (with dot and arrows) (Figure 1, bottom left), these efforts serve to familiarise the participant with the correct joint angle and measure the motor control. Thereafter the dot and the arrows disappear and the participant has to reproduce the predetermined joint position twice without visual feedback (Figure 1, bottom right). These efforts measure the proprioceptive ability of the participant. The MR Cube software presents the results as a deviation from the predetermined joint position in millimetres (linear displacement). The vertical line on the left side of the screen represents the rest period between the measurements.

The selected weight for the leg extension was 3 kg for women and 5 kg for men. The predetermined joint position was set at 50% of the range of motion, which was determined per individual before the first test. To avoid a possible effect of learning, attention level or fatigue, the order of conditions (with and without patellar strap) was balanced between participants, with half of the participants starting the test with the patellar strap and the other half without. The order of the conditions was dependent on the order of entrance in the study. The first patient started the tests without the strap, the second patient started with strap, after which the third patient started again without strap and so on. The patellar strap used in this study was a prototype of the Genupoint patellar brace (Bauerfeind AG, Zeulenroda-Triebes, Germany). The strap was positioned by the participants themselves, with the pressure point just below the patella, after receiving instructions from the researcher. In cases of bilateral PT, the knee with the most symptoms was used as the intervention leg. Each participant was allowed two test rounds for each leg in order to become familiar with the test protocol. After these test rounds the participant completed the proprioception test three times with the left leg and three times with the right leg. Next, the patellar strap was applied or removed and the participant repeated the exact same test, three times for each leg (first left, than right).

The ultrasound image of the patellar tendon obtained by UTC was analysed from the apex of the patella to 20 mm distally. In this area the percentages of the four echotypes were calculated. For a better comparison of the results between and among participants, the deviation in mm from the predetermined joint position obtained from the MR Cube was converted to a percentage deviation from the predetermined joint position. A two-level mixed-model analysis was used to analyse if there was a difference in the deviation (%) from the predetermined joint position (linear with square root correction) between the patellar strap and the control condition of the most symptomatic leg. The data was squared before presenting the data. In order to investigate possible differences in effectiveness of the patellar strap between athletes with high and low proprioceptive acuity, the participants were divided into two groups based on the median and analyzed separately. Those athletes who deviated less than median from the predetermined joint position were categorised as having high proprioceptive acuity, those who deviated more as having low proprioceptive acuity. To investigate possible predictors of the effect of the patellar strap on knee joint proprioception, univariate linear regression analyses were conducted. The difference in deviation from the predetermined joint position (%) between the intervention and the control condition was used as the dependent variable. Age, BMI, knee girth, VISA-P score, duration of PT (months), VAS pain score at baseline during 10x single-leg decline squats, hours of sports participation, playing level, deviation joint position no intervention (%) and echotypes I, II, III and IV (with square root correction to normalize the data) were included in the analysis as predictors. Because of the non-normal distribution of the duration of symptoms, this variable was spread over three categories (< 6 months, 6-12 months and > 12 months). All data were analysed using IBM SPPS version 20 (IBM Corp., Armonk, New York), and p-values below 0.05 were considered statistically significant.

Results

Thirty participants were screened for this study. One participant was excluded because it transpired that she had a past anterior cruciate ligament rupture, and five participants were excluded because they had no ultrasound abnormalities. Therefore 24 participants were included whose characteristics are in Table 1.

The results of the mixed-model analysis are presented in Table 2. For the symptomatic leg, no significant difference was found between the strapped and unstrapped conditions. The same holds for the group with high proprioceptive acuity. The group with low proprioceptive acuity improved significantly when wearing the strap compared to not wearing one. The absolute improvement was 4.0%, and the relative improvement (percentage from the unstrapped condition) was 17,2%.

The results of the linear regression analysis are presented in table 3 and show that having a larger knee girth is negatively associated with the effect of the patellar strap on knee joint proprioception. A negative association was also found for duration of PT and percentage of echotype IV. A trend towards a negative association with a difference in knee joint proprioception resulting from the strap was found for a higher BMI and percentage of echotype III. No association was found between symptoms (VISA-P or VAS) and effectiveness of the patellar strap.

Discussion

The aim of this pilot study was to investigate the effect of a patellar strap on the joint position sense in the symptomatic knee of athletes with PT. It was found that the knee joint proprioception of the symptomatic leg, measured with the joint position sense, did not improve with the use of a strap. However, those athletes who had low proprioceptive acuity were significantly more accurate when they wore the patellar strap compared to controls. New and notable findings in this study were that a bigger knee girth, longer duration of symptoms and more damage to the tendon all seem to negatively influence the effect of the patellar strap on knee joint proprioception.

The only previous study investigating the effect of a patellar strap on knee joint proprioception in PT athletes found no effect on knee joint proprioception of the symptomatic leg.[7] Looking at the entire group, the findings of the current study are in agreement with this previous finding, although those PT athletes who were classified as having low proprioceptive acuity did improve using a strap compared to controls. Different associated factors were also found, as in our previous study male gender and having more symptoms (higher VISA-P score) influenced the effect of the strap.

The difference in results between the two studies on the effect of a patellar strap on the symptomatic leg might partly be explained by differences in the research population. In the current study the PT patients had more severe symptoms of shorter duration, and the clinical diagnosis of PT was supported by ultrasound, making this diagnosis more likely.[22] Also another brand patellar strap was used. Considering that various braces, elastic bandages and tapes have previously shown to improve proprioception,[4 6 23] the latter does not seem to be a plausible explanation for the differences we found. Given that the associated factors for effectiveness were also entirely different between the two studies, the use of another type of test (active joint position sense test instead of the passive motion sense test used before) seems to be the most plausible reason for the different outcomes. This is not surprising, as it is shown that the different types of tests are weakly related [24 25] and the tests rely on different receptors – with a more important role of the muscle spindles in the active joint position sense test.[16 26] Which test provides the best information for the sports field is debatable. The most frequently used and reliable test to assess proprioception is considered to be the threshold to detect passive motion,[15] yet considering the passive nature and slow angular speed of this test it seems a rather poor reflection of the knee joint proprioception requirements for the sports field.[15] The joint position sense test reflects the functional use of proprioception better – through active movement-finding positions in space.[16] One could therefore argue that this test is more relevant for practice than a more passive test. Validity remains however an issue in all currently available proprioception tests and a combination of different types of tests to assess proprioception would probably provide the best information.[25] The improvement of 17%, as found for athletes with low proprioceptive acuity, is comparable to previous studies that found improvements ranging between 10–25% [5 6 27] and might be substantial enough to be noticeable to the athlete.

As for predictors of the effect of the strap on knee joint proprioception, the association between pain and the effect of the patellar strap on proprioception could not be confirmed in the current study. Several 'new' factors were found to be associated with the effect of a patellar strap on knee joint proprioception: a longer duration of symptoms, more tendon abnormalities (echotypes III and IV), a higher BMI and a larger knee girth all have a negative influence on the effectiveness of the patellar strap. Positive correlations were found between echotypes III and IV and duration of symptoms (data not shown), indicating that athletes with longer duration of symptoms had tendons with more abnormalities. It has been suggested that use of an orthosis causes additional cutaneous stimulation, which improves proprioception.[1] The findings of the current study suggest however that other proprioceptors may also play a role in the beneficial effect of a patellar strap on knee joint proprioception. For instance, the fact that more tendon abnormalities were associated with less effectiveness might indicate that not only cutaneous mechanoreceptors are stimulated, but also the proprioceptors in tendon tissue – the Golgi tendon organs.[3 16] The findings that having a larger knee girth and a higher BMI both negatively influence the effect of a patellar strap support this suggestion. In addition, we hypothesize that the muscle spindles of the quadriceps muscle could be involved. As was shown by Lavagnino et al the pressure of the patellar strap can lead to an increased patella – patellar tendon angle,[28] resulting in a slightly stretched quadriceps muscle. As the muscle spindles are sensitive to changes in muscle length,[26 29] they may be more activated with the use of a patellar strap. Since muscle spindles provide the most proprioceptive information, especially mid-range of motion,[16 26] this activation caused by the strap could be responsible for the improvement in knee joint proprioception.

This study has some limitations that should be mentioned. First of all, as in all studies measuring proprioception, the cut-off point to classify patients with high and low proprioceptive acuity was chosen quite arbitrarily. In this study participants were split by the median, to get an idea about the (possibly different) effectiveness of the strap in those performing best on the MR Cube proprioception test and those performing less accurate. One should be aware that it does not necessarily mean that patients classified as having low proprioceptive acuity do in fact have poor proprioception. Second, given that our study was setup as a pilot study we included only 24 subjects. Clearly, the study power to find a difference between the two conditions was very low (a post-hoc power analysis showed a power of 20%). However, even with this low power we did find a difference in the subgroup with low acuity, indicating a real effect of the patellar strap in this subgroup. Third, participants were allowed to apply the patellar strap to their knee on their own. Even though the position was checked by the researchers, the pressure exerted by the patellar strap depended on the athlete’s preference and was not standardised. This might have influenced the results.[30] On the other hand, in practice athletes also apply the strap to their knee by themselves, hence differences in exerted pressure are a proper reflection of normal use. Third, we used an open kinetic chain exercise – where the foot of the participant is free to move in the open space – which might have caused a stronger effect of the patellar strap compared to closed kinetic chain exercise. During closed kinetic chain exercise (e.g. standing squat), additional input from other muscles of the lower limb and cutaneous sensors of the foot is available. This additional information, not present in open kinetic chain exercise, makes the effect of the patellar strap less important.[4]

Conclusion

The use of a patellar strap improves the knee joint proprioception of the symptomatic leg in PT patients with low proprioceptive acuity. Especially athletes with relatively small knee girth, short duration of symptoms and small tendon abnormalities are more likely to benefit from the strap in terms of their proprioceptive acuity. Since poor proprioceptive acuity is suggested to be a risk factor for injuries and reinjuries[3], these findings might be very interesting for practice.

Practical implications

- The use of a patellar strap may improve the knee joint proprioception in the symptomatic leg of athletes with patellar tendinopathy
- Especially PT athletes with relatively small knee girth, short duration of symptoms and small tendon abnormalities might benefit from the use of a patellar strap
- The use of a patellar strap may be relevant for (re-)injury prevention as well as rehabilitation purposes, especially in those athletes with poor proprioceptive acuity.

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Figure legends:

Figure 1: MR Cube with a slightly pulled out cable (top left). MR Cube connected to a knee extension apparatus (top right). MR Cube proprioception test screen (bottom figures). Bottom left: with visual feedback; the dot between the arrows represents the current knee joint position. Bottom right: without visual feedback. The left vertical line represents the rest position, the right vertical line represents the predetermined joint position (50% Range of Motion).

Figure 2: The deviation in percentage from the predetermined joint position in the control and patellar strap condition for the whole group and for the participants with low and high acuity separately. The absolute and relative differences between both conditions are presented.

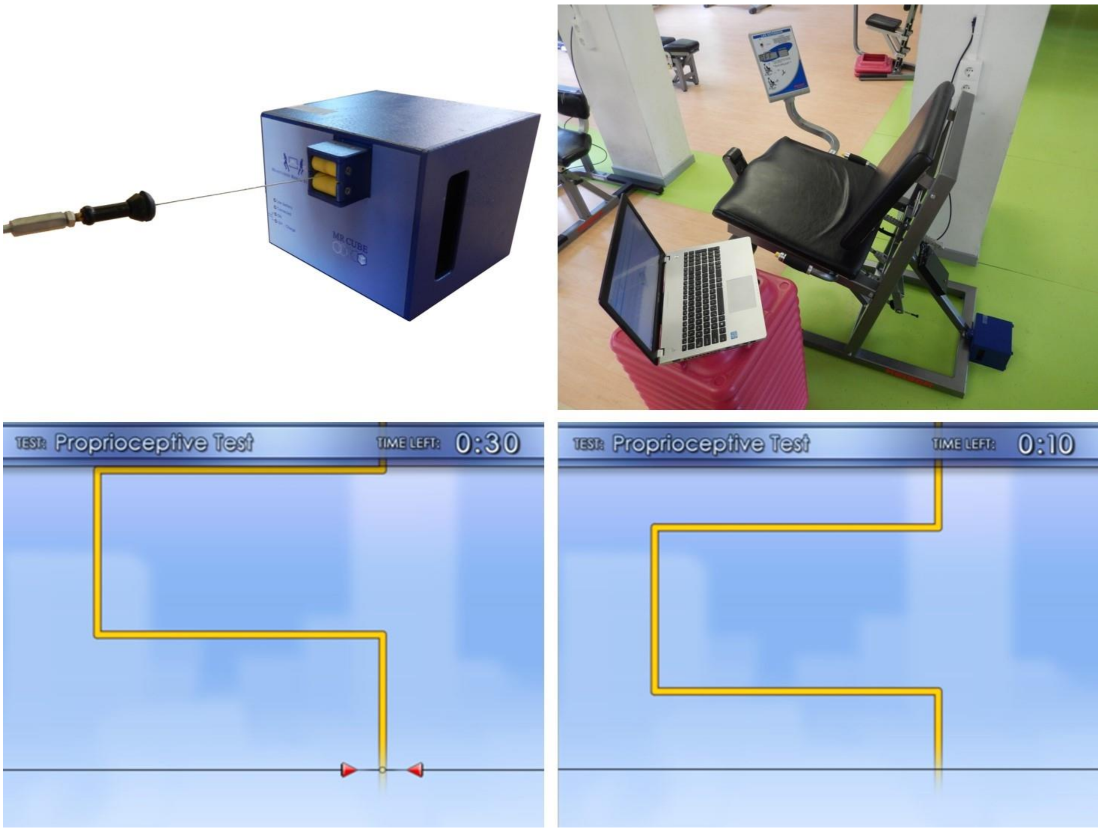
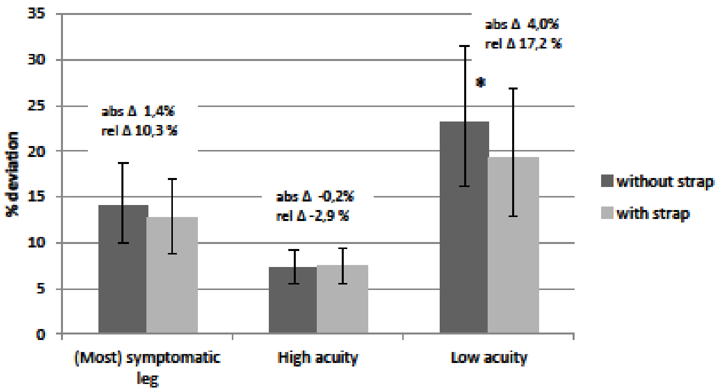


Fig 1



35
30
25
20
15
10
5
0
% deviation
abs Δ 1,4%
rel Δ 10,3 %
abs Δ -0,2%
rel Δ -2,9 %
abs Δ 4,0%
rel Δ 17,2 %
*
without strap
with strap
(Most) symptomatic leg
High acuity
Low acuity

Fig 2

Table 1: Descriptive statistics of the participants

n	24
General characteristics	
Age (years)	27.3 (9.0)
Gender (male/female)	18 / 6
BMI[a] (kg/m^2)	24.1 (3.8)
Knee girth (cm)	34.5 (3.3)
Injury-related factors	
Knee PT (left/right/both)	8 / 5 / 11
VISA-P (0-100)	50.6 (11.2)
VAS baseline 10x SLDS	42.1 (19.1)
PT duration (months)	14.0 (48.8)
UTC echotype (%) most symptomatic knee [b]	
I	53.2 (1.4)
II	35.3 (0.9)
III	8.3 (0.8)
IV	3.2 (0.4)
Sports-related factors	
Playing level (recreational/regional/national)[c]	8 / 11 / 5
Sport (hours per week) [c]	5.0 (4.4)

Displayed values are frequencies and (mean (SD) except for PT duration and sport (hours per week) (medians (interquartile range)). [a] *Body Mass Index,* [b] *Ultrasound Tissue Characterisation, n = 23 because of one poor quality scan* [c] *primary sports.*

Table 2: Results from the mixed-model analysis. The deviation in percentage from the predetermined joint position of both conditions and the absolute and relative (% from the without strap condition (between brackets)) difference between the two is presented.

% deviation	Without strap Mean (95% CI)	With strap Mean (95% CI)	Difference (%[a])	p- value
(Most) symptomatic leg	14.0 (10.0-18.7)	12.6 (8.8-17.0)	1.4 (10.3)	0.098
High acuity	7.2 (5.4-9.2)	7.4 (5.5-9.4)	-0.2 (-2.9)	0.812
Low acuity	23.2 (16.2-31.5)	19.2 (12.9-26.8)	4.0 (17.2)	0.015*

** p<0.05 significant difference between % deviation without and with strap* [a] *difference expressed as a percentage from the without strap condition.*

Table 3: Results from the univariate regression analysis. The association of general characteristics, injury-related factors and sports-related factors with the effectiveness of a patellar strap on the knee joint proprioception are presented.

	B	SE	p-value
General characteristics			
Age (years)	-0.151	0.151	0.33
BMI[a] (kg/m^2)	-0.632	0.341	0.08#
Knee girth (cm)	-0.842	0.428	0.04*
Injury-related factors			
VISA-P (0-100)	-0.024	0.041	0.85
Duration PT (< 6 months / 6-12 months / > 12 months)	-3.252	1.475	0.04*
VAS baseline 10x SLDS	0.012	0.067	0.86
UTC echotype (%) most symptomatic knee[b]			
I	0.270	0.217	0.23
II	0.078	0.332	0.82
III	-0.632	0.373	0.10#
IV[c]	-5.417	2.483	0.04*
Sports-related factors			
Sports participation (hours)[d]	-0.182	0.439	0.68
Playing level	-0.862	-0.096	0.66
Other			
Deviation joint position no strap (%)	3.152	1.879	0.11

*Dependent variable: % deviation correct joint position no intervention - % deviation correct joint position intervention. * p<0.05 significant association with effectiveness of patellar strap on joint position sense # p<0.10 trend towards associaion with effectiveness of patellar strap on joint position sense [a] Body Mass Index, [b] Ultrasound Tissue Characterisation, n = 23 because of one poor quality scan [c] analysis with square root correction [d] primary sports*