



ConScientiae Saúde

ISSN: 1677-1028

conscientiaesaude@uninove.br

Universidade Nove de Julho

Brasil

Navarro Cyrillo, Fabio; Nunes Cabral, Cristina Maria
Patellofemoral pain syndrome alters joint position sense: a case-control study
ConScientiae Saúde, vol. 13, núm. 3, 2014, pp. 331-339
Universidade Nove de Julho
São Paulo, Brasil

Available in: <http://www.redalyc.org/articulo.oa?id=92932100002>

- How to cite
- Complete issue
- More information about this article
- Journal's homepage in redalyc.org

redalyc.org

Scientific Information System

Network of Scientific Journals from Latin America, the Caribbean, Spain and Portugal

Non-profit academic project, developed under the open access initiative

Patellofemoral pain syndrome alters joint position sense: a case-control study

A síndrome da dor patelofemoral altera a sensação de posição articular: estudo caso-controle

Fabio Navarro Cyrillo¹; Cristina Maria Nunes Cabral²

¹Mestre, Programa de Mestrado e Doutorado em Fisioterapia – Universidade Cidade de São Paulo – UNICID. São Paulo, SP – Brasil.

²Professora Doutora, Programa de Mestrado e Doutorado em Fisioterapia – Universidade Cidade de São Paulo – UNICID. São Paulo, SP – Brasil.

Postal address

Cristina Maria Nunes Cabral
R. Cesário Galeno 475
03071-000 – São Paulo – SP [Brasil]
cristina.cabral@unicid.edu.br

Abstract

Introduction: The evaluation of changes in joint position sense (JPS) of the knee may be crucial for the identification of disorders that could start during the development of patellofemoral pain syndrome (PFPS). **Objective:** To evaluate JPS of the knee in PFPS. **Methods:** Twenty nine women (15 healthy and 14 with PFPS) reproduced knee flexion angles of 45° and 60° during open kinetic chain exercises and of 45° during closed kinetic chain exercises. **Results:** The absolute error in the active reproduction of 45° in open kinetic chain exercises was significantly higher in the experimental group. There were significant differences in absolute and relative errors between the groups for active reproduction at 45° in open and closed kinetic chain exercises. **Conclusions:** This study suggests that PFPS alters JPS during active reproduction of the 45° angle in both open and closed kinetic chain exercises.

Key words: Knee; Patellofemoral pain syndrome; Proprioception.

Resumo

Introdução: A avaliação de alterações do senso de posição articular (SPA) do joelho é crucial para a identificação de desordens que ocorrem durante o desenvolvimento da síndrome da dor patelofemoral (SDPF). **Objetivo:** Avaliar o SPA do joelho na SDPF. **Métodos:** Vinte e nove mulheres (15 saudáveis e 14 com SDPF) reproduziram os ângulos de 45° e 60° de flexão do joelho em cadeia cinética aberta e de 45° em cadeia cinética fechada. **Resultados:** O erro absoluto na reprodução ativa do ângulo de 45° em cadeia cinética aberta foi significativamente maior no grupo experimental. Foi observada diferença significativa entre os grupos nos erros relativo e absoluto para a reprodução ativa do ângulo de 45° em cadeia cinética aberta e fechada. **Conclusões:** Este estudo sugere que a SDPF altera a SPA durante reprodução ativa do ângulo de 45°, tanto em cadeia cinética aberta quanto em fechada.

Descritores: Joelho; Propriocepção; Síndrome da dor patelofemoral.

Introduction

Patellofemoral pain syndrome (PFPS) is a disease with multifactorial causes that is characterized by diffuse pain in the anterior knee, usually with insidious onset and slow progression¹. PFPS is aggravated by activities that increase the compression forces in the patellofemoral joint, such as climbing and descending stairs, squatting, and sitting for long periods of time²⁻⁴. In PFPS, there is also a change in contact pressure between the articular surfaces of the femur and patella during movement, which, associated with the muscular imbalance, can lead to breakdown of the articular cartilage and possible alteration in proprioception because the features involved in knee proprioception are essential for proper musculoskeletal control⁵.

Proprioception comprises the sense of position and movement of the limbs and body without the use of vision. This concept can be defined as the sensory functions that let you feel the relative position of your body parts^{6,7}. Currently, research shows that proprioception is a complex phenomenon linked to two sub-modalities, the sense of stationary position of the limbs, or joint position sense (JPS), and perception of limb movement, or kinesthesia^{2,7,8}.

There are few studies that have assessed JPS in people with PFPS, with different conclusions. Two studies found no significant change in proprioception in individuals with PFPS compared to the control group^{2,5}. In five other studies^{4,9-12}, there seems to be evidence that the symptomatic knee of individuals with PFPS shows changes in JPS. Only Jerosch et al.⁹ and Baker et al.⁴ evaluated JPS of the knee during closed kinetic chain (CKC) exercises, where the patellofemoral joint receives a greater load. However, the studies failed to conduct these assessments while controlling for the speed of the repositioning of the limb, which may influence the perception of the target angle and act as a confounding factor. Other studies evaluate proprioception with a patellar bandage^{13,14}.

Considering the results of these studies, the issue of altering of the JPS of the knee in people with PFPS is not clear. One study shows that this change in JPS can occur because of pain and abnormal stress on the tissues involved with the alignment of the patella, which can initiate neuromuscular changes in control of the quadriceps muscle and joint structures involved in the patellofemoral region⁴. Thus, the purpose of this study was to evaluate knee JPS in participants with and without PFPS, comparing the symptomatic and asymptomatic knee of the participants with PFPS in open and closed kinetic chain exercises and active and passive reproduction.

Methods

Participants

Thirty-eight female participants were evaluated. Twenty-three of the participants had no musculoskeletal alteration, and 15 presented PFPS. The inclusion criteria were as follows: medical diagnosis of PFPS; reporting previous anterior or retropatellar knee pain for at least six months, during or after at least two activities including squatting, climbing or descending stairs, sitting for long periods, kneeling, running, and jumping; insidious onset of symptoms unrelated to a traumatic event; and showing positive results for patellar compression, scraping, Waldron's test, and instability during a descending 20 cm step test¹⁵⁻¹⁸. The exclusion criteria were ligamentous or meniscal injury, surgery or injury in the patellofemoral joint, patellar subluxation, persistent edema of the knee¹⁹ and practice of regular physical activity. Of the evaluated participants, eight considered healthy were excluded because patellar tests yielded positive results. One participant with PFPS was also excluded because of negative patellar tests. Thus, the control group was composed of 15 participants and the experimental group of 14. All participants signed a free and informed consent form ap-

proved by the Research Ethics Committee of the Universidade Cidade de São Paulo (protocol number 13319387).

The mean age of participants in the control group was 23.0 ± 1.0 years, mean weight was 58.2 ± 4.6 kg, mean height was 1.6 ± 0.1 m, and mean body mass index (BMI) was 21.6 ± 1.1 kg/m². For the experimental group, the mean age was 24.0 ± 1.0 years, mean weight was 57.7 ± 3.0 kg, mean height was 1.6 ± 0.1 m, and mean BMI was 21.8 ± 1.6 kg/m². There was no significant difference in these characteristics between groups. The right lower limb was dominant in all participants in the control group, and only one participant of the experimental group showed left limb dominance.

Evaluation

Both knees were evaluated in each group as follows: 1) with and without PFPS for the experimental group and 2) self-reported dominant and non-dominant leg for the control group. The sequences of tests and of the evaluated target angles were randomly chosen. The equipment used for the evaluation was an isokinetic dynamometer (Cybex Norm, CSMI, Stoughton, MA, USA) and an electrogoniometer, model GN360° with an accuracy of 0.5 degrees (Miotec Equipamentos Biomédicos Ltda., Porto Alegre, Brazil), and both were calibrated according to the manufacturer's instructions before each test. The participants were tested without visual information. The skin of the lower limb was cleansed with alcohol, and the electrogoniometer was positioned on the axis of the knee joint and secured with an elastic bandage (Kinesio Tex, KMS, Albuquerque, NM, USA) to capture the joint angle. In all situations, the angle was measured by the electrogoniometer. This is a valid procedure to reliably measure JPS¹⁹.

For the evaluation in open kinetic chain (OKC) exercises, participants were blindfolded and positioned sitting in the chair of the isokinetic dynamometer with the spine supported

and secured by belts at the pelvis and shoulders according to the settings and recommendations in the manual from the manufacturer. The popliteal region was approximately 10 cm from the seat of the chair to eliminate possible skin interference. The knee joint was initially positioned at 90° of flexion as measured by the electrogoniometer, with the knee joint axis aligned with the axis of the dynamometer. A sphygmomanometer (Tycos, Welch Allyn Inc., Skaneateles Falls, NY, USA) inflated to 40 mmHg was placed on the anterior part of the tibia to reduce tactile feedback in the leg caused by the support of the dynamometer chair¹², as shown in Figure 1.

In the passive test, the arm of the dynamometer altered the position of the limb to be tested passively at a constant speed of 2°/s until reaching the target angle of 45° of knee flexion. This position was held for ten seconds to allow joint perception, and the joint was then returned to the starting position. This process was performed three times. After the procedure for joint perception, the dynamometer passively moved the leg from 90° to 30° of knee flexion three times, and the participant stopped the movement when she believed it was at 45°. At this point, the angle was recorded by an electrogoniometer. For the active test, a new perception procedure was performed with the prior parameters, and the participants actively reproduced the 45° angle of flexion three times².

After five minutes, the same procedure was performed with a target angle of 60° of knee flexion. The arm of the dynamometer passively positioned the limb at the target angle of 60° of knee flexion, and the range of free motion was 90° to 45° to reproduce the target angle².

The evaluation during the CKC exercise was performed only at a target angle of 45°. The participants were positioned standing while blindfolded in front of a backrest that they could use to stay balanced with the support of a finger⁴. Initially, they stayed in a bilateral squat at 45° of knee flexion for ten seconds three times to perceive the target angle. The participants were



Figure 1: A – Open kinetic chain exercises position; B – Detailed position of the sphygmomanometer and electrogoniometer

instructed to perform squats in the typical fashion (Figure 2). After these repetitions, they were instructed to actively reproduce the angle three times, and the values were controlled and stored by the electrogoniometer. Figure 3 shows the evaluations of the participants in terms of eligibility criteria, their distribution among groups, and type of assessment.

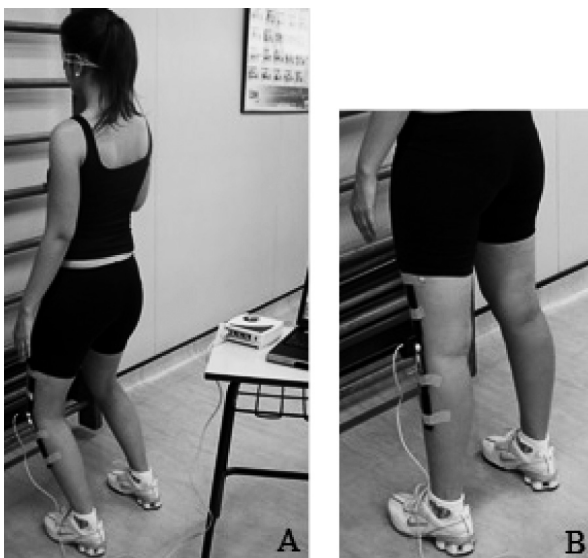


Figure 2: A – Closed kinetic chain exercises position; B – Detailed position of the electrogoniometer

Statistical analysis

We analyzed the angles reproduced by the participants relative to the target angles. The absolute error was defined as the difference between reproduction and target angle, ignoring sign. Relative error was defined as the difference between reproduction and target angles considering the value of the sign⁴. This design made it possible to establish the error value in degrees and determine whether the target was

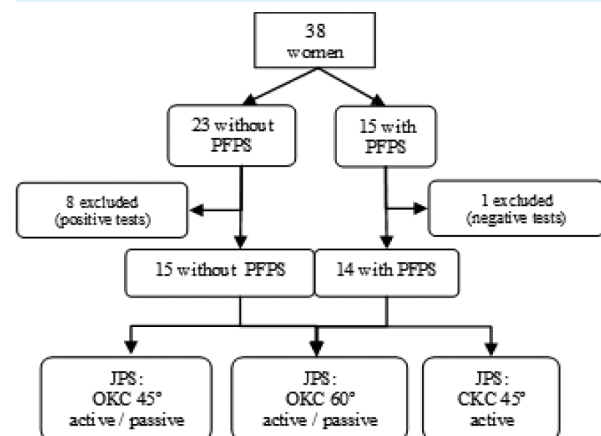


Figure 3: Diagram flow of the study. PFPS: patellofemoral pain syndrome, JPS: joint position sense, OKC: open kinetic chain. CKC: closed kinetic chain

exceeded (positive values), reached, or missed (negative values).

Statistical analysis was performed with a 5% level of significance. The normality of the following variables was evaluated using the Shapiro-Wilk test: errors of the target angles (45° and 60° of knee flexion), age, height, weight, and BMI. After verifying normality, Bartlett's and Levene's tests were performed to verify homogeneity. Because normality and homogeneity were satisfactory for all variables, a two-way analysis of variance (ANOVA) with Tukey's *post hoc* test was used to compare the treatment groups, both in OKC and CKC exercises. A one-way Anova with Tukey's *post hoc* test was used for intragroup comparisons.

Results

In the evaluation of JPS in OKC, there was a significant difference between the knee of the dominant leg and non-dominant leg in all situations evaluated for the control group ($p<0.05$). For the experimental group, there was a significant difference only for the absolute error ($p=0.048$) between knees with and without PFPS at the tar-

get angle of 45° of knee flexion for active reproduction. At the target angle of 60° of knee flexion, we observed a significant difference only in the relative error for active reproduction ($p<0.033$) and passive reproduction ($p=0.003$). For both reproductions, the target angle was exceeded.

When comparing the knee of the dominant leg in the control group to the knee with PFPS in the experimental group, there were significant differences only for the target angle of 45° of knee flexion in active reproduction for both the absolute error ($p=0.029$) and relative error ($p=0.032$). For the relative error, the participants exceeded the target angle. There were no statistically significant differences in any of the reproductions and errors for the target angle of 60° of knee flexion ($p>0.05$).

A comparison of the active and passive reproductions of target angles of 45° and 60° degrees of flexion in the knee with PFPS in the experimental group revealed a statistically significant difference in active reproduction at 45° of knee flexion for both the absolute error ($p=0.001$) and the relative error ($p=0.001$). There was no statistically significant difference for the target angle of 60° of knee flexion ($p>0.05$). The participants exceeded the target angle in all situations (Table 1).

Table 1: Absolute and relative errors, in degrees, evaluated in open kinetic chain (45° and 60° of knee flexion) for the control group (dominant leg and non-dominant leg) and experimental group (knee with and without patellofemoral pain syndrome)

Target angle	Type of error	Reproduction	Control group (n=15)		Experimental group (n=14)	
			Dominant leg	Non-dominant leg	Knee without PFPS	Knee with PFPS
45°	Absolute	Active	1.0 ± 0.7	1.4 ± 0.7 ¹	1.3 ± 1.1	2.8 ± 2.9 ^{9,12}
		Passive	0.8 ± 0.7	1.3 ± 0.6 ²	1.0 ± 0.9	2.2 ± 2.5 ¹⁴
	Relative	Active	0.9 ± 0.7	1.4 ± 0.7 ³	1.3 ± 1.1	2.8 ± 2.0 ¹³
		Passive	0.8 ± 0.6	1.3 ± 0.6 ⁴	1.0 ± 0.9	2.1 ± 1.9 ¹⁵
60°	Absolute	Active	0.1 ± 0.8	1.2 ± 0.7 ⁵	1.2 ± 1.5	1.7 ± 4.1
		Passive	0.6 ± 0.5	1.0 ± 0.6 ⁶	0.8 ± 1.0	1.3 ± 3.4
	Relative	Active	0.8 ± 0.7	1.2 ± 0.7 ⁷	3.9 ± 2.1	1.7 ± 4.0 ¹⁰
		Passive	0.6 ± 0.5	1.0 ± 0.6 ⁸	0.8 ± 1.1	1.3 ± 3.0 ¹¹

Data presented as mean ± SD

PFPS= patellofemoral pain syndrome

¹ $p=0.004$ versus dominant leg; ² $p<0.001$ versus dominant leg; ³ $p=0.003$ versus dominant leg; ⁴ $p=0.002$ versus dominant leg; ⁵ $p<0.001$ versus dominant leg; ⁶ $p=0.003$ versus dominant leg; ⁷ $p=0.001$ versus dominant leg;

⁸ $p=0.030$ versus dominant leg; ⁹ $p=0.048$ versus knee without PFPS; ¹⁰ $p=0.033$ versus knee without PFPS;

¹¹ $p=0.003$ versus knee without PFPS; ¹² $p=0.029$ versus dominant leg; ¹³ $p=0.032$ versus dominant leg; ¹⁴ $p=0.001$ versus passive reproduction; ¹⁵ $p=0.001$ versus passive reproduction.

Table 2 shows the comparison of the reproduction of JPS in CKC exercises between the knee of the dominant leg in the control group and the knee with PFPS in the experimental group for a target angle of 45° of knee flexion. There was a statistically significant difference for both the absolute error ($p=0.002$) and relative error ($p=0.002$), with the experimental group producing greater errors and underestimating the target angle.

Table 2: Absolute and relative errors, in degrees, evaluated in closed kinetic chain for the control group (dominant leg) and experimental group (knee with PFPS)

Target angle	Type of error	Control group	Experimental group
45°	Absolute	1.5 ± 6.9	3.6 ± 0.5 ¹
	Relative	3.5 ± 0.6	-1.6 ± 0.2 ²

Data expressed as mean ± SD

PFPS= patellofemoral pain syndrome

¹ $p=0.002$ versus control group; ² $p=0.002$ versus control group.

Discussion

Two systems for assessing JPS of the knee stand out among those found in the literature: the isokinetic dynamometer, for passive reproduction of movement, and the electrogoniometer, for measuring joint angle¹⁸. According to Lephart and Fu²⁰, the use of continuous passive motion in the isokinetic dynamometer was validated and recognized as one of the best methods for this type of evaluation; however, it was not an available resource for the evaluation conducted in this study.

Although some authors have used angles measured by an isokinetic dynamometer^{9,11,12,21}, in this study we chose measurement by an electrogoniometer. This measurement was accomplished by positioning the arm of the dynamometer relative to the subject's leg such that the angles obtained by the dynamometer system were not the exact values of the joint position of the limb. The reason for this was that the sphyg-

manometer that was used to reduce tactile feedback changed the initial angle of the knee.

We observed that, for most reproductions, there were no statistically significant differences in JPS between the knee with and without PFPS in the experimental group, as measured by the absolute and relative errors. This result shows that even the asymptomatic knee of PFPS patients may exhibit alteration of the JPS. The data found in a study by Kramer et al.⁵ also showed no significant difference between the affected and unaffected knees of patients with PPS, although they evaluated reproduction of angles in different situations (sitting and standing). Jerosh et al.⁹ observed a change in the JPS of the asymptomatic knee in patients with PFPS compared to a control group, which suggests that the unaffected knee also shows altered proprioception. Similar results were also found in a study by Baker et al.⁴, which observed that the asymptomatic knee of patients with unilateral PFPS showed altered proprioception.

All participants with PFPS had symptoms in the dominant leg, except one subject whose symptoms were in the non-dominant leg. Thus, one of the factors that might have influenced the observed errors in the asymptomatic knee may have been the actual characteristic of the PFPS, which can be present bilaterally, as well as possible compensation that may occur due to the pain of the syndrome⁴. This factor is reflected in the result that more errors were made with the non-dominant leg than with the dominant leg in the control group for both the 45° and 60° target angles of knee flexion during active and passive reproductions. It can be suggested that the dominant leg has more accuracy in the repositioning of an angle.

It is noteworthy that a very large variability and high standard deviation were observed in the group with PFPS. This result can be explained by the nature of the disease, which is characterized by multifactorial causes. For this syndrome, etiological differences are difficult to control, and few studies have evaluated the causal effects. However, the differences were

significant for active reproduction and the absolute error at the target angle of 45° as well as for active and passive reproduction and the relative error at the target angle of 60°.

In comparing JPS between the dominant knee in the control group and the knee with PFPS in the experimental group, there was a statistically significant difference in both the absolute and relative errors for active reproduction at 45°, which is considered a critical angle in functional motion of the knee joint. At this angle, which is commonly used in daily activities, the pressure between the patella and the femoral groove increases²². Nevertheless, in the passive reproduction at 45° and active and passive reproduction at 60° assessments, there was no statistically significant difference for either absolute or relative error. Lobato et al.² observed no change in knee proprioception in patients with PFPS compared to a control group without PFPS in assessing JPS using the passive movement of the isokinetic dynamometer at target angles of 30°, 45°, and 60°.

However, Baker et al.⁴ and Hazneci et al.¹¹ observed a significant difference between the errors of participants with PFPS compared with a control group without injury. The first study evaluated reproductions at angles of 20° and 60°, and the second study at angles of 40° and 50°, using an isokinetic dynamometer for limb positioning.

The comparative analysis of the active and passive reproductions at 45° and 60° of knee flexion showed that both absolute and relative error were significantly higher in the active reproductions compared with the control group for the target angle of 45°. In the literature, all studies, with the exception of three^{4,5,12}, used passive movement for active and passive perception of the target angle, which may have favored larger errors for active reproduction. Indeed, Kramer et al.⁵ and Selfe et al.¹² found no difference in the comparisons. The fact that perception of the angle was achieved with passive movement may have influenced the errors found during active reproduction because the physiological

characteristics and activation of receptors and mechanoreceptors are different⁷. Thus, because the physiological characteristics of perception are different, continuous passive motion seems to be the best resource for perception only for passive reproduction and not for active reproduction, as proposed by the literature and the present study^{10,22}.

The present study shows that for the CKC exercise, the experimental group showed greater relative and absolute error for the target angle of 45°. Moreover, the subjects had a tendency not to reach the target angle. This result was most likely caused by their concern regarding increased joint compression that usually occurs during daily activities²³. This trend was not observed in the OKC recordings, in which the participants generally exceeded the target angle. A study that evaluated JPS during a horizontal squat did not find difference between PFPS patients and a control group²⁴.

The target angle of 60° was not used for CKC comparisons. During a series of pilot studies, participants showed a high level of instability and could not stay in place during the time required for perception. In this situation, the greater the flexion of the knee, the greater the compression of the patellofemoral joint.

Major differences in the definition of proprioception and its sub-modalities were found in our survey of the literature. These differences may have even favored the methodological distinction found in related studies because the positioning and angle analysis systems used were different. In this study, we opted for positioning and angular capture systems that had been validated and were better represented in the literature^{2,11,12,21}. The methodology proposed in this study permits the assessment of JPS of the knee joint – which is considered an important stage and sub-modality of proprioception – but not all its proprioceptive responses. Thus, this study did not assess kinesthesia or motion detection, which are important features of a complete proprioceptive evaluation.

Misalignment of the patella, which is triggered by multifactorial mechanisms such as im-

balance of the vastus medialis and vastus lateralis muscles, alteration of the Q angle, muscle shortening of the quadriceps and iliotibial tract, and altered proprioception, could be the beginning of major knee injuries^{21,23}. Thus, identifying JPS changes in individuals with PFPS is critical for determining intervention programs and preventing future deficits.

Conclusion

For the methodological conditions used, this study suggests that patients with PFPS have changes in JPS compared to the control group only in active reproductions at the target angle of 45° in both OKC and CKC exercises, normally exceeding the target angles. Furthermore, it was observed that the asymptomatic knee of patients with PFPS demonstrated an alteration of JPS when compared with the affected knee.

References

1. Frye JL, Ramey LN, Hart JM. The effects of exercise on decreasing pain and increasing function in patients with patellofemoral pain syndrome. A systematic review. *Sports Health*. 2012;4(3):205-10.
2. Lobato DFM, Santos GM, Coqueiro KRR, Mattiello-Rosa SMG, Terruggi-Junior A, Bevilacqua-Grossi D, et al. Evaluation of proprioception of the knee among individuals with patellofemoral dysfunction. *Rev Bras Fisioter*. 2005;9:57-62.
3. Thomeé R, Augustsson J, Karlsson J. Patellofemoral pain syndrome – a review of current issues. *Sports Med*. 1999;28:245-62.
4. Baker V, Bennell K, Stillman B, Cowan S, Crossley K. Abnormal knee joint position sense in individuals with patellofemoral pain syndrome. *J Orthop Res*. 2002;20:208-14.
5. Kramer J, Handfield T, Kiefer G, Forwell L, Birmingham T. Comparisons of weight-bearing and non-weight-bearing tests of knee proprioception performed by patients with patellofemoral pain syndrome and asymptomatic individuals. *Clin J Sports Med*. 1997;7:113-8.
6. Buchalla CM (ed). International classification of functioning, disability and health. São Paulo: Editora da Universidade de São Paulo; 2003.
7. Kandel ER, Schwartz JH, Jessell T (eds). Principles of neural science. Barueri: Manole; 2003.
8. Hewett TE, Paterno MV, Myer GD. Strategies for enhancing proprioception and neuromuscular control of the knee. *Clin Orthop Relat Res*. 2002;402:76-94.
9. Jerosch J, Schmidt K, Prymka M. Proprioceptive abilities of patients with a patellar pain syndrome with special reference to the effect of an elastic knee bandage. *Der Unfallchirurg*. 1997;100:719-23.
10. Bennell KL, Wee E, Crossley K, Stillman B, Hodges P. Effects of experimentally-induced anterior knee pain on knee joint position sense in healthy individuals. *J Orthop Res*. 2005;23:46-53.
11. Hazneci B, Yildiz Y, Sekir U, Aydin T, Kalyon TA. Efficacy of isokinetic exercise on joint position sense and muscle strength in patellofemoral pain syndrome. *Am J Phys Med Rehabil*. 2005;84:521-7.
12. Selfe J, Callaghan M, McHenry A, Richards J, Oldham J. An investigation into the effect of number of trials during proprioceptive testing in patients with patellofemoral pain syndrome. *J Orthop Res*. 2006;24:1218-24.
13. Callaghan MJ, McKie S, Richardson P, Oldham JA. Effects of patellar taping on brain activity during knee proprioception tests using functional magnetic resonance imaging. *Phys Ther*. 2012;92:821-30.
14. Felicio LR, Masullo CL, Saad MC, Bevilacqua-Grossi D. The effect of a patellar bandage on the postural control of individuals with patellofemoral pain syndrome. *J Phys Ther Sci*. 2014;26:461-4.
15. Cowan SM, Bennell KL, Hodges PW, Crossley KM, McConnell J. Delayed onset of electromyographic activity of *vastus medialis obliquus* relative to *vastus lateralis* in subjects with patellofemoral pain syndrome. *Arch Phys Med Rehabil*. 2001;82:183-9.
16. Crossley KM, Cowan SM, Bennell KL, McConnell J. Knee flexion during stair ambulation is altered in individuals with patellofemoral pain. *J Orthop Res*. 2004;22:267-74.
17. Magee DJ (ed). Orthopedic physical assessment. Barueri: Manole; 2005.
18. Powers C. Conservative treatment of patellofemoral pain syndrome. *Physiotherapy*. 2007;93(Suppl 1):S18.

19. Thomeé R. A comprehensive treatment approach for patellofemoral pain syndrome in young women. *Phys Ther.* 1997;77:1690-703.
20. Beynnon BD, Renström PA, Konradsen L, Elmqvist L, Gottlieb D, Dirks M. Validation of techniques to measure knee proprioception. In: Lephart SM, Fu FH (eds). *Proprioception and neuromuscular control in joint stability*. Champaign: Human Kinetics; 2000.
21. Lephart SM, Fu FH (eds). *Proprioception and neuromuscular control in joint stability*. Champaign: Human Kinetics; 2000.
22. Callaghan MJ, Selfe J, McHenry A, Oldham JA. Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Man Ther.* 2008;13:192-9.
23. Andrews RJ, Harrelson GL, Wilk KE (eds). *Physical rehabilitation of the injured athlete*. Rio de Janeiro: Guanabara-Koogan; 2005.
24. Yosmaoqlu HB, Kaya D, Guney H, Nyland J, Baltaci G, Yuksel I, et al. Is there a relationship between tracking ability, point position sense, and functional level in patellofemoral pain syndrome? *Knee Surg Sports Traumatol Arthrosc.* 2013;21:2564-71.