

# EFFECT OF ADDITIONAL SENSORY INFORMATION IN THE PROPRIOCEPTION AND POSTURAL CONTROL OF INDIVIDUALS WITH ACL LESION

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## ABSTRACT

**Objective:** The purpose of this study was to examine the effect of additional sensory information in proprioception and postural balance of individuals with ACL lesion. **Methods:** Participated in this study 28 individuals with ACL unilateral lesion and 28 individuals with healthy knee. Proprioception was evaluated through the threshold to detection of passive knee motion from 15 and 45 degrees, for flexion and extension directions. Postural balance was evaluated in single leg stance without vision, on a plate force and investigated through the mean sway amplitude, mean sway velocity of the center of pressure. The conditions of sensory information used were: normal information, infrapatellar adhesive tape

and infrapatellar strap. **Results:** Individuals with ACL lesion show a deficit in proprioception and postural balance when compared with individuals with healthy knee ( $p < 0.05$ ). However, with the use of additional sensory information, proprioception and postural control performance in individuals with ACL lesion improve ( $p < 0.05$ ). Individuals with healthy knee did not show any benefit with the use of additional sensory information ( $p > 0.05$ ). **Conclusion:** ACL lesion causes damage in the proprioception and postural control system. However, these effects are minimized with the use of additional sensory information.

**Keywords:** Anterior cruciate ligament. Proprioception musculoskeletal equilibrium. Knee.

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## INTRODUCTION

Individuals bearing anterior cruciate ligament (ACL) injuries show changes on motor control, since after an injury, there is usually damage on sensory information as a result of the compromised mechanoreceptors present on ACL. Diminished sensory information following an ACL injury causes a change on the correlation between sensory information and motor activity, which can cause other changes and an inferior performance on these individuals' motor control.

Many authors have investigated several aspects of the sensory and motor behavior of individuals with ACL injuries, such as, for example, proprioception and stance control.<sup>1-9</sup> However, although these aspects involving proprioception and stance control have been studied in individuals with ACL injuries for at least 20 years, many controversies and contradictions still remain. A critical point is the real sensory limitation resulting from ACL injuries and its consequences on motor behavior. Hence, one of the challenges faced by professional involved in the rehabilitation of these individuals is to find a way to offset this potential sensory limitation resulting from ACL injuries, thus favoring an appropriate motor behavior.

In the last decades, some studies have investigated the effect of somatosensory information on stance control using the technique of smooth touch on a rigid surface.<sup>10,11</sup> In these studies, adult individuals showed a significant reduction of body oscillation when standing up and touching the tip of index finger on a rigid and stationary surface. As the strength applied on the surface wasn't enough to provide significant mechanical support<sup>12</sup>, the improved stance control performance has been suggested to be a result of the additional sensory stimulus provided by the finger touching a stationary surface.<sup>10,11</sup> These studies indicate that sensory information and motor activity are correlated in terms of maintaining the body at a given position and that an additional sensory information can be continuously used, causing a reduced body oscillation.

This indicates the potential for using these assumptions in rehabilitation, once an additional sensory stimulus can improve motor control, as seen on body oscillation. However, it seems reasonable to investigate the addition of other sensory information sources, since the touch bar indicates a favorable direction, but this is an experimental condition that cannot be replicated in dynamic environments. In this sense, some orthoses may

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indicate an additional and more functional sensory stimulation alternative for individuals with ACL injuries. Some studies point out to a positive effect in using functional knee orthoses and straps on the proprioceptive ability of individuals with healthy knees, with ACL injury, and with femoropatellar syndromes.<sup>13-16</sup> However, there is no correlation between this improved sensory afference and some motor behaviors, such as stance control. Taking these aspects into account, the objective of this study was to investigate the effect of using additional threshold sensory information for detecting passive movements of knee joint and on stance control of individuals with ACL injury and with healthy knees.

## MATERIALS AND METHODS

### Subjects

Twenty-eight young adult individuals with unilateral ACL injury participated on this study (Age:  $23 \pm 4$  years; Height:  $1.71 \pm 0.08$  m; Mass:  $70 \pm 10$  Kg), constituting the injured group (IG) and 28 young adult individuals with healthy knees (Age:  $22 \pm 2$  years; Height:  $1.73 \pm 0.08$  m; Mass:  $72 \pm 11$  Kg), with no neurological, musculoskeletal and/or vestibular system conditions, constituting the control group (CG). Individuals presenting any symptom or injury on lower limbs as well as with previous history of surgery on the feet, ankle, knee and hip have been excluded from this group. The groups were paired for gender, age, height and mass for subsequent comparison.

Individuals included on the CG were selected from the Orthopaedics Outpatient Facility of Hospital das Clínicas, University of São Paulo's Ribeirão Preto Medical School (HCFMRP – USP). In order to standardize IG, the same exclusion criteria used for selecting the CG were adopted, while the inclusion criteria included: 1) diagnosis of unilateral ACL injury confirmed by Magnetic Resonance imaging test for no longer than three years; 2) no history of collateral and posterior ligament injuries, fractures or neurological deficit; 3) full range of motion of the knee joint, no joint edema, and no pain when ambulating. Individuals with meniscal and chondral injuries have not been excluded.

Os the subjects included on IG, fourteen had ACL injury on the right knee and 14 on the left side, with mean injury time, i.e., the period between trauma and assessment, of 20 months ( $\pm 10$  months). Of these, 14 had associated meniscal injuries, while 10 had medial meniscus injury only and 4 had medial and lateral meniscus injuries, and 14 with simple ACL injury.

### PROCEDURES

The subjects were allowed to participate on the study since they signed a free and informed consent term as approved by the Committee of Ethics of the UNESP Biosciences Institute - Rio Claro campus. Each participant was assessed at the Orthopaedics Outpatient Facility of HCFMRP – USP and submitted to two specific experiments. Previously to the tests, a brief evaluation was conducted to assure that the inclusion and exclusion criteria were met. In all experiments, the subjects were wearing shorts and T-shirts, with bare feet, when both knees were assessed and classified as injured knee (IK) and non-injured knee (NIK), in the case of IG, and as right knee (RK) and left knee (LK) in the case of CG.

Evaluation of the threshold for detecting knee joint passive movement: In order to evaluate the subjects, a continuous passive

motion - CPM system (Model Leg Exerciser – Stryker Ltda), was employed with a built-in manual on-off switch, which was held by the subject. For this experiment, system speed was adjusted to 0.5 degree/ second, in which a system for measuring voltage variation was added, connected to an analog/ digital plate that, by means of LabVIEW software (Version 8.0 - National Instruments), recorded these data. This system was employed for capturing voltage variations at the start and end of the CPM system motion, allowing for calculating the on-duty and moving time, enabling to accurately estimate angle dislocation. The frequency was set up at 100 Hz.

The experiment was carried out with patients lying on a bed with the lower limb to be tested supported by a system arm. Approximately at the level of umbilical line, a shield was kept, preventing subjects to view how the lower limb was positioned during the experiment. With the “on-off” switch in hands, the subjects were asked to press the manual control switch as soon as they realized any knee motion, thus shutting the equipment down. The evaluation of the threshold for detecting passive motion of the knee joint was carried out at 15 and 45 degrees for flexion and extension movements. In this evaluation, two different sources of additional sensory information were included: infrapatellar tape and infrapatellar strap. Thus, the evaluation at both pre-determined amplitudes was carried out for three sensory conditions, namely: 1) normal information (NI), i.e., the tests were conducted without including any additional sensory information; 2) infrapatellar tape (IT), where a 2.5-cm wide water-resistant bandage (Cremer®) was applied on subject's skin just below patella and long enough to cover the anterior region of the knee, fixated from medial to lateral knee surface, and; 3) infrapatellar strap (IS), where the evaluation was carried out by including a subpatellar padded strap (Salvapé®) just below subject's patella, and made of 2.5-cm wide elastic band with anterior microfoam pad and sealed by Velcro tape. Three attempts were made for each sensory condition at each direction (flexion and extension), at both pre-determined positions (15 and 45 degrees), for each lower limb, randomly determining the directions and positions, totaling 72 attempts.

For data assessment, a function designed on MATLAB (version 5.3 - Math Works, Inc.) language was used, which displayed the two voltage variation moments corresponding to the start and end of motion as a graph. Then, the temporal difference was calculated between these two events, and then converting the values in seconds into degrees, thus determining angle dislocation. Angle dislocation was the threshold measurement factor for detecting knee joint passive motion, this being the difference of angle position between motion start and the moment in which the subject shut the system down.

For statistically evaluating this experiment, two variance analyses (ANOVAs) were carried out, having as factors both groups (CG and IG), both knees (standardized correlation: RK/IK and LK/NIK), both initial joint positions (15 and 45 degrees), and the three sensory conditions (NI, IT, and IS), with the last three factors being treated as repeated measures. Variables dependent on the two ANOVAs were: angle dislocation for flexion and angle dislocation for extension.

Stance control evaluation: Stance control was examined by using a force platform (AMTI-OR6-7-1000). Subjects were guided to perform an experimental situation of right monopodal support (R) and left monopodal support (L), remaining as still as pos-

sible on the center of the force platform. The contralateral limb should remain lifted throughout the task, with the hip at neutral position, knee flexed at 90° and with arms parallel to the body.<sup>17</sup> For this task, two different kinds of additional sensory information (infrapatellar tape and infrapatellar strap) were included. Thus, the task was made under three sensory conditions, being these described for evaluating the threshold for passive motion detection.

The force platform provided data on the strengths and moments of the vertical and horizontal axis, from which the pressure center (PC) was calculated at anteroposterior and mid-lateral directions. Force platform signs were acquired at a frequency of 100 Hz. Three attempts were made for each sensory condition at each unilateral support, randomly distributed as blocks, for a total of 18 attempts. Each attempt was recorded for 30 seconds.

The data provided by the force platform were assessed by means of a function designed on MATLAB (version 5.3) language, which processed data concerning the strength applied on the platform: Fx (force applied to the platform at anteroposterior direction), Fy (force applied at mid-lateral direction), and Fz (force applied at vertical direction), as well as the moments for these directions. From those data, pressure center (PC) was calculated at anteroposterior and mid-lateral directions and, from the PC, the following variables were calculated: mean oscillation amplitude and mean dislocation speed for anteroposterior (AP) and mid-lateral (ML) directions. For calculating the mean oscillation amplitude (MOA), a first order polynomial was calculated and subtracted from the signs on each attempt. Following, the average was subtracted from all values and then the standard deviation for these values was calculated, obtaining a value corresponding to the variance of values associated to body oscillation. The average speed was calculated by dividing the sum of dislocations on each axis by the time of each attempt.

In the statistical analysis of this experiment, two Multiple Variance Analyses (MANOVA) were carried out, having both groups, both supports and the three sensory conditions (NI, IT, and IS) as factors, the latter two being treated as repeated measures. For these MANOVAs, dependent variables were the following: mean oscillation amplitude at AP and ML directions and the mean dislocation speed at AP and ML. All statistical procedures were conducted with the aid of SPSS software (SPSS for Windows - release 10.0 - SPSS, Inc.), keeping the significance level at 0.05. Whenever required, post-hoc Tukey's tests were carried out in order to identify potential differences between sensory conditions.

## RESULTS

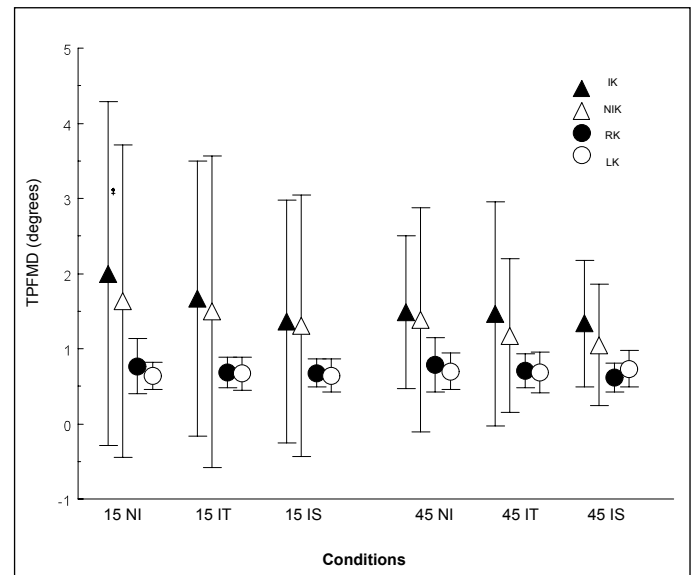
The results suggest that individuals with ACL injuries show damaged proprioception and stance control when compared to individuals with healthy knees. However, the addition of sensory information reduced the threshold for passive motion detection and body oscillation of individuals with unilateral ACL injury.

### Threshold for knee joint passive motion detection

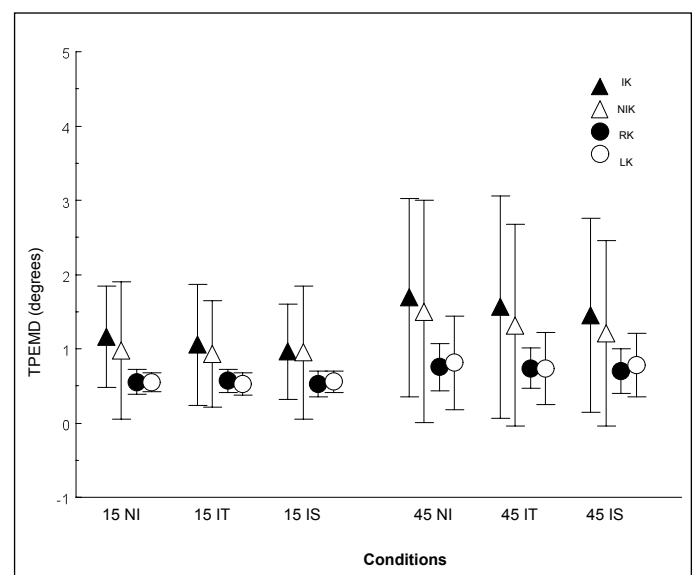
Figures 1 and 2 show mean and standard deviation values for threshold for knee joint passive motion detection for flexion and extension. IG showed a greater threshold for detecting passive flexion and extension motion compared to CG for both predetermined joint positions. However, the results were similar for both groups between RK and LK and between IK and NIK. For

flexion, there was no threshold difference as a result of the initial position of the test. Nevertheless, for extension, the threshold for passive motion detection was greater at 45°. In addition, the results suggest that the threshold for passive flexion and extension motion detection on IG is reduced as a result of additional sensory information. (Figure 1)

For flexion TPMD, ANOVA revealed a significant difference only between the groups  $F(1.54)=9.373$ ,  $p<0.01$  and between conditions,  $F(2.108)=6.041$ ,  $p<0.05$ . Post-hoc tests for sensory conditions revealed differences between normal information and infrapatellar tape conditions,  $F(1.54)=10.01$ ,  $p<0.01$ ; and between normal information and infrapatellar strap conditions,  $F(1.54)=7.29$ ,  $p<0.01$ . (Figure 2)



**Figure 1** – Mean and standard deviation values for threshold for passive flexion motion detection (TPFMD) at initial positions of 15 and 45 degrees, in the conditions of normal sensory information (NI), with infrapatellar tape (IT) and with infrapatellar strap (IS).



**Figure 2** – Mean and standard deviation values for threshold for passive extension motion detection (TPEMD) at initial positions of 15 and 45 degrees, in the conditions of normal sensory information (NI), with infrapatellar tape (IT) and with infrapatellar strap (IS).

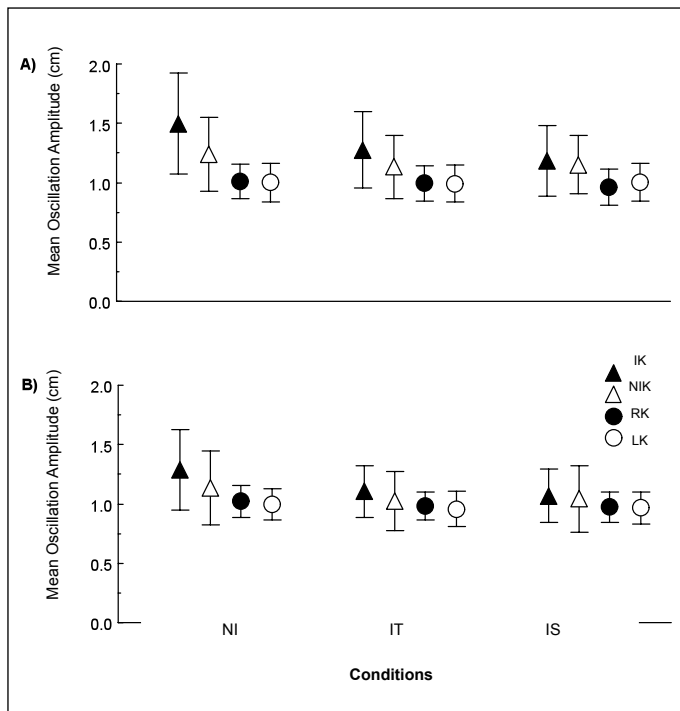
For extension TPMD, ANOVA revealed a significant difference between groups,  $F(1.54)=11.44$ ,  $p<0.01$ , between positions,  $F(1.54)=26.49$ ,  $p<0.01$  and between conditions,  $F(2.108)=3.93$ ,  $p<0.05$ . Post-hoc tests for sensory conditions revealed difference only between normal information and infrapatellar strap,  $F(1.54)=6.82$ ,  $p<0.01$ .

### Stance Control

Overall, the results revealed damage to stance control of individuals with ACL injury when compared to individuals with healthy knees. However, in individuals with ACL injury, an improvement of the stance control is observed when additional sensory information is added, whereas in individuals with healthy knees, this is not found.

### Mean Oscillation Amplitude

Figure 3 shows the mean and standard deviation values for mean SC oscillation amplitude for CG and IG groups at anteroposterior (A) and mid-lateral (B) directions. The mean SC oscillation amplitude at AP and ML directions is greater on IG than on CG. In the CG, the results are similar between RK and LK support. However, on IG, the mean SC oscillation amplitude is greater in IK than in NIK, and NIK shows superior values to those observed for RK and LK support on the CG. Furthermore, the results suggest that the mean SC oscillation amplitude on IG is reduced in all conditions where additional sensory information was included. (Figure 3)



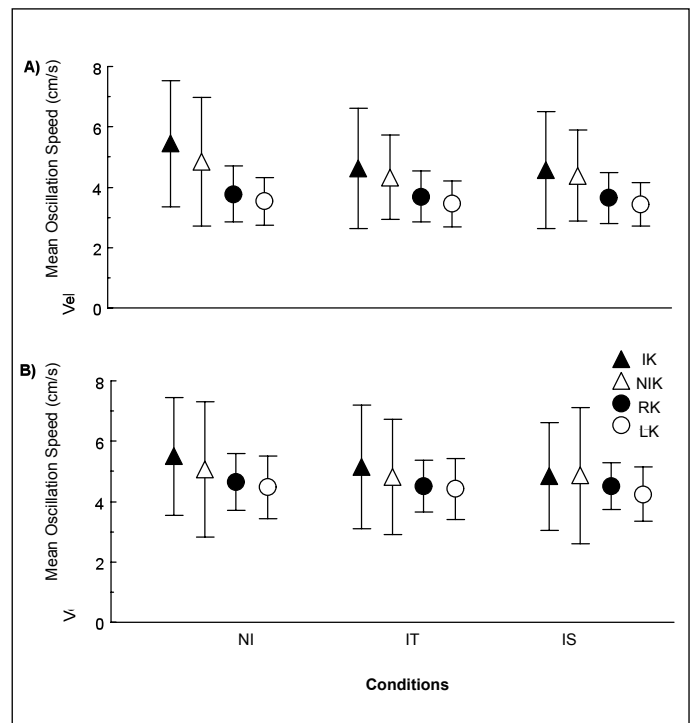
**Figure 3** – Mean and standard deviation values for mean oscillation amplitude at anteroposterior (A) and mid-lateral (ML) directions, on injured knees (IK) and non-injured knees (NIK) of IG and on right knees (RK) and left knees (LK) of CG, in the conditions of normal sensory information (NI), with infrapatellar tape (IT) and with infrapatellar strap (IS).

For mean oscillation amplitude, MANOVA revealed a significant difference between groups, Wilks' Lambda=0.728,  $F(2.53)=9.91$ ,  $p<0.01$ ; between supports, Wilks' Lambda=0.793,  $F(2.53)=6.92$ ,

$p<0.01$ ; between conditions, Wilks' Lambda=0.586,  $F(4.51)=9.00$ ,  $p<0.01$ ; and for interactions: group and support, Wilks' Lambda=0.800,  $F(2.53)=6.63$ ,  $p<0.01$ ; group and condition, Wilks' Lambda=0.686,  $F(4.51)=5.83$ ,  $p<0.01$ ; support and condition, Wilks' Lambda=0.791,  $F(4.51)=3.37$ ,  $p<0.01$ . Post-hoc tests suggested differences among all sensory conditions for AP and ML directions.

### Mean Oscillation Speed

Figure 4 shows the mean and standard deviation values for mean SC dislocation speed at AP and ML directions for CG and IG. The results evidenced that the mean SC oscillation speed at AP and ML directions is greater in IG than in CG. In CG, the results are similar between RK and LK support. However, in IG, the means SC oscillation speed is greater with IK and with NIK, with NIK showing greater values compared to RK and LK support of CG. Furthermore, the results suggest that the mean SC oscillation speed on IG is reduced in all conditions where additional sensory information was included, whereas on CG this reduction is not noticed. (Figure 4)



**Figure 4** – Mean and standard deviation values for mean oscillation speed at anteroposterior (A) and mid-lateral (ML) directions, on injured knees (IK) and non-injured knees (NIK) of IG and on right knees (RK) and left knees (LK) of CG, in the conditions of normal sensory information (NI), with infrapatellar tape (IT) and with infrapatellar strap (IS).

For mean oscillation speed, MANOVA revealed significant difference only between groups, Wilks' Lambda=0.843,  $F(2.53)=4.93$ ,  $p<0.05$ ; between supports, Wilks' Lambda=0.837,  $F(2.53)=5.17$ ,  $p<0.01$ ; between conditions, Wilks' Lambda=0.579,  $F(4.51)=9.27$ ,  $p<0.01$ ; and for interaction: group and condition, Wilks' Lambda=0.742,  $F(4.51)=4.43$ ,  $p<0.01$ . Post-hoc tests suggested that the mean SC oscillation speed for TS condition was smaller than other conditions (NI, IT and IS), both for ML and AP directions.

## DISCUSSION

This study investigated the effects of using additional sensory information on the threshold for passive motion detection and on stance control of individuals with ACL injury and individuals with healthy knees. At first, the results showed that individuals with ACL injury present with damaged threshold for passive motion detection and stance control in normal sensory information conditions when compared to individuals with healthy knees. It is interesting to outline that the damage found on the injured knee is also found on the non-injured knee of individuals of the IG. However, NIK performance is different from other assessed kneed, being superior to IK and inferior to RK and LK of control group.

A potential explanation for this performance difference of the NIK compared to CG knees is that individuals with ACL injury, due to the damage evidenced on the injured limb cause an overload on the healthy contralateral knee. That overload may lead to hyper stimulation and resultant fatigue of the healthy contralateral limb, reducing its performance when compared to a control group constituted of individuals with healthy knees. It seems that this overload occurs in spite of the reduced daily life activities and of the disuse resulting from ACL injury<sup>18</sup>, producing a stronger demand of the healthy contralateral limb. Another potential explanation is that the individuals presenting with ACL injury would be likely to recurrence or to a new injury on the contralateral limb as a result of a reduced sensory feedback. Thus, such sensory feedback reduction could lead to an inferior performance of the healthy contralateral limb when compared to individuals with healthy knees. In addition, the reduced performance found on the healthy contralateral lower limb may represent an attempt of the control system to keep a relationship as harmonic as possible between lower limbs. In summary, as a result of performance damage found on the healthy contralateral limb, it should definitely not be used as a control limb in experiments investigating changes resulting from ACL injuries.

However, we found that the addition of sensory information fostered an improvement both in the threshold for knee joint passive motion detection and in the performance when standing up with unipodal support in individuals with ACL injury. In the evaluation of the threshold for passive motion detection, we found that the inclusion of additional sensory information such as infrapatellar tape and strap provides an easier detection of this kind of motion in individuals with ACL injuries. This result is consistent with other previous studies<sup>13-15</sup>, in which an improved proprioceptive ability was found with the use of functional orthoses in individuals with different knee injuries. However, in the present study, the resources employed showed a smaller knee coverage area compared to the studies mentioned above. Specifically, the infrapatellar strap was applied below the patella and only on the anterior knee surface, while the infrapatellar strap had the same positioning and width, but covered the anterior and the posterior knee surface. Despite of this reduced sensory stimulus area, we could find a decreased threshold for passive motion detection both for flexion and for extension, but for extension, only the infrapatellar strap was effective to enhance passive motion detection. Anyway, the results of this study suggest that the addition of sensory information may provide an improved sensory discrimination on knee joint in individuals with ACL injury.

Oppositely, no difference was found on individuals with healthy knees with the addition of sensory information for the threshold

for passive motion detection. A potential explanation may be the fact that these subjects do not present with proprioceptive deficit, which is corroborated by comparing the values reported in this study to those of previous studies.<sup>7,8</sup> It seems that, in this group, additional sensory information does not provide any change, because, for being intact, the system itself can get this kind of information by means of the existent intact structures. In this sense, perhaps only individuals with some proprioceptive deficit are benefitted by the use of these resources, thus obtaining an improved proprioceptive ability. For example, in individuals with ACL injury and submitted to reconstruction<sup>7,8</sup> and with femoropatellar syndromes<sup>13-16</sup>, this additional sensory information is critical for improving system function.

Similarly to the case of threshold for passive motion detection, individuals with ACL injury are benefitted with the addition of sensory information, improving stance control system performance when keeping an upright position. Decreased body oscillation with the use of additional sensory information had already been reported in smooth touch situations in individuals without muscle or sensory conditions<sup>10,11</sup> and even in situations of sensory conflict.<sup>19</sup> However, it is interesting to highlight that this study evidenced that, in case of individuals with ACL injury, additional sources of sensory information have also provided conditions for these individuals to present with less significant body oscillation when compared to their performance without using any additional sensory information. These two additional sources of sensory information, probably by stimulating the superficial receptors of the skin and by raising the pressure on local receptors<sup>20</sup>, provide the means for an improved stance control system performance and, consequently, a reduced body oscillation. Thus, these results suggest that these additional sources of sensory information can potentially be used in rehabilitation environments or even for readjustment to sports practice.

Interestingly, additional sensory information, infrapatellar tape and strap, did not cause effect on stance control of individuals with healthy knees. This result further stresses the importance of the availability of additional information in individuals presenting with some decrease of sensory information acquisition. In these cases, any sensory information increment may be useful and used by the system. Moreover, this additional information may be used in the various situations in which sensory information is required, in the present study, both on the threshold for passive motion detection and on more complex tasks, involving a more intricate relationship between sensory information and motor activity, as well as in the maintenance of upright stance.

## CONCLUSION

Individuals with unilateral ACL injuries show an impairment of knee joint passive motion detection and of stance control. However, the use of additional sensory information, such as infrapatellar tape or strap, provides an improvement of the knee joint passive motion detection and of the stance control system performance in individuals with ACL injury. These results are quite encouraging, because they suggest that the inclusion of additional sources of sensory information can be a determinant factor for individuals presenting with some compromise on the acquisition of sensory stimuli.

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