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Postural Stability in Men with Anterior Cruciate and Bicruciate Ligament Knee Injury

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SUMMARY

Background. Knee ligaments are not only recognized as mechanical stabilizers, but also as sensorimotor components contributing to the proprioceptive feedback mechanisms and neuromuscular stabilization of knee joint. The study investigated the influence of isolated and bicruciate ligament injury of cruciate ligaments on postural stability in male individuals prior to reconstruction surgery.
Materials and methods. An individual case, control study design was used. Thirty-six patients were categorized into three groups depending on a history of a recent knee joint: ACL group with an anterior cruciate ligament injury, BCL group with an anterior and posterior cruciate ligament injury and control group with no knee injury and no lower limb injury during last 12 months. Postural stability was expressed by body sways (angular degrees, °) in the antero-posterior (AP-Shift), latero-medial (LM-Shift) and in both planes (2D-Shift) assessed with a Delos Postural System in standing one leg position with and without visual control. Non-parametric Kruskal-Wallis and Mann-Whitney U tests were used to assess changes between studied variables.
Results. There was statistical difference between individuals with BCL who had higher body sways with closed eyes in all examined planes while standing on the affected limb compared to control and their own unaffected limbs ($p < 0.05$). Additionally, AP-Shift and 2D-shift were higher in BCL group than in the ACL injured group with eyes closed ($p < 0.05$). The ratio of body sways between closed and open eyes was greater in the BCL group in all planes for both limbs than in the healthy men ($p < 0.05$). In BCL and ACL groups the ratio of body sway distribution during stability tests was two times higher in the injured limb than in the uninjured one ($p < 0.05$). There was statistical difference in AP-Shift between participants with ACL and BCL injury in affected and unaffected limb ($p < 0.05$). The only changed detected in the ACL group was increased body sway for all studied planes when standing on the injured limb with closed eyes as compared to standing with open eyes ($p < 0.05$).
Conclusions. Under lack of visual cues, body sway increases in BCL but not ACL knee injured individuals suggesting a substantial decline in proprioceptive input after the bicruciate ligament rupture.

KEY WORDS

Mechanoreceptors; postural control; proprioception; sensorimotor control; cruciate ligament.

BACKGROUND

The anterior cruciate ligament (ACL) injury impairs postural control. This is manifested by increased body sway, especially during single leg stance on the injured limb without vision (1, 2).
The injured limb is more affected than the uninjured one, although deficits of postural control have been found in both limbs after an ACL injury (3). The effect of the posterior ligament (PCL) injury on the postural control is not known perhaps due to the fact that isolated lesions of this ligament are relatively rare or are not appropriately diagnosed (4). However, patients with a subacute or chronic PCL injury may experience instability during rapid change of movement direction, especially if the injury is combined with patellar lateral subluxation (5).
Postural control is composed of postural orientation and postural stability (6). Postural orientation relies on the ability to monitor the interrelationship between body segments relative to the environment based on visual and vestibular guidance. Postural stability depends on the integration of somatosensory information to control the center of mass in relationship to the base of support (7).
Knee ligaments are not only recognized as mechanical stabilizers, but also as sensorimotor components contributing to the proprioceptive feedback mechanisms and neuromuscular stabilization of the knee joint (8). The ACL and PCL are particularly rich in different types of mechanoreceptors. They participate in the regulation of muscle tone and spinal reflexes (9).
Damage to the knee joint ligament system leads not only to joint mechanical instability but also to a
decreased number of mechanoreceptors involved in the neuromuscular feedback and the motor coordination of periarticular muscles (10).
The importance of the present study is related to the fact that the evaluation of postural stability may serve as a preoperative prognostic factor of the functional status and reinjury and inform preoperative and postoperative therapeutic decision making (11).
The aim of this study was to evaluate static postural stability in patients with an isolated-(ACL) and bicruciate ligament (ACL and PCL) knee injury prior to surgery. It has been assumed that the size of an articular ligament injury will have an impact on stability and that bicruciate ligament knee injuries will cause greater body sway than isolated-ligament injuries.

MATERIALS AND METHODS

Participants

Only male respondents were sought among the individuals referred to the outpatient orthopedic clinic and they were retrospectively selected to the inclusion and exclusion criteria (12, 13) (**table I**).
In the case of the third degree of anterior or posterior instability, the subjects were qualified for reconstructive surgery (14). Injuries to the knee joint ligaments were verified by the same orthopedic physician during manual examination and all of the participants were precisely assessed in magnetic resonance imaging. In the ACL group, there were 2 patients with isolated ACL injuries, 8 with the ACL and medial meniscus injuries, and 2 with the ACL and lateral meniscus injuries. In the BCL group, 5 patients had ACL and PCL ligament injuries, 7 had ACL, PCL and medial meniscus injuries. During manual testing, a total translation of the tibia relative to the femur was assessed with the knee at 30° (Lachman test) and 90° of flexion (drawer test).
An individual case control study design was used. The sample size was determined based on the significance level, power, and magnitude of the difference (effect size) (15). However, before starting the study we established a sample size based on the previous study report (8, 16).

Table I. The inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Only male volunteers, not athletes	Previous ligaments injuries in lower limb
Age between 18 and 45 years old	Surgical procedures in lower limb
Isolated ACL rupture qualified for reconstructive surgery	Orthopedic problems
ACL + PCL qualified for reconstructive surgery	Neurological disorders Visual disturbances
Chronic phase of ligament rupture od > 3 months after injury (not more than 12 months)	Balance problems including: inner ear, vestibular disorders, low back pain)
	Pharmacological treatment that may impair balance problems

ACL: anterior cruciate ligament; PCL: posterior cruciate ligament.

Twelve male participants with an anterior cruciate ligament injury (ACL group) and the same number of respondents with an anterior and posterior cruciate ligament injury (BCL group) were included in the study. The control group consisted of 12 non-injured men corresponding with age, height and body weight to the subjects from the other groups. The subjects had no prior ligament injuries, did not undergo surgeries in the past, and did not have other orthopedic or neurological problems of the limbs. They were not athletes. They did not receive pharmacological treatment and were recruited among employees and students of the university and the outpatient clinic and authors' colleagues. The demographic data of the studied individuals has been presented in **table II**.

In the ACL group, there were 12 patients with the isolated ACL injuries, and in the BCL group 12 patients had ACL and PCL ligament injuries. Most of the injuries were caused by accidents during recreational activities (5 in ACL injuries, 4 in BCL), some patients were injured during road accidents (4 in ACL, 6 in BCL) and due to a fall (3 in ACL and 3 in BCL). Functional assessment of the knee joint was performed according to the IKDC 2000 form where the transformed score was interpreted as a measure of function. Higher scores represented higher levels of function and lower levels of symptoms. A score of 100 points is interpreted to mean no limitation with activities of daily living or sports activities and the absence of symptoms (17) (**table II**). The average time duration from injury to examination was over 6 months in both groups.

The subjects did not experience pain during the test with eyes open and closed, which could possibly affect the final result.

The study was approved by the Bioethics Committee of the Medical University of Poznan. All subjects gave informed consent to participate in the study.

Postural control assessment

The evaluation of postural control was performed using a postural balance control system (Delos Postural System, Italy) (18). The system consists of a vertical controller which is synchronized (the data is recorded simultaneously) with the sensorized bar. The vertical controller is a two-dimensional accelerometer (7 × 4.5 × 2.5 cm in size) that records in real-time the antero-posterior and latero-medial body sway expressed in angular degrees (°) from the vertical (sensitivity of 0.1° with respect to center of mass, the measuring range up to ± 2G). The sensorized bar is an adjustable in height support frame equipped with an infrared sensor that allows assessment of the time during which subjects lean on it. Twenty out of twenty-four patients from both groups had an injury of the right lower limb. Therefore, the affected limb of ACL and BCL injured individuals was compared to the healthy right lower limb of the uninjured subjects. In patients with ACL and BCL injury, the injured limb was additionally compared with the non-injured limb, while in the subjects from the control group the right limb was compared with the left one.

Single stance balance assessment procedure

Trunk angular sway during stance has been shown to be a reliable measure of changes in balance stability. The vertical controller was attached using an elastic strap to the sternum right above the xiphoid process, allowing for the recording of body sways in frontal and sagittal planes.

Before each attempt, the accelerometer was calibrated with respect to the vertical position of the erect body while standing on both feet. The procedure was explained

Table II. Clinical and demographic parameters score for patients described by mean, standard deviation and distribution (n = 36).

	CON (n = 12)	ACL (n = 12)	BCL (n = 12)
Age (years)	29.8 ± 9.0	29.4 ± 8.6	32.2 ± 9.0
Height (cm)	180.5 ± 6.8	180.0 ± 5.8	180.6 ± 4.8
Body weight (kg)	83.8 ± 8.9	83.7 ± 10.9	82.0 ± 11.6
BMI (kg/m²)	25.7 ± 7.8	25.9 ± 7.8	25.1 ± 8.5
Injury duration (months)	-	6.6 ± 3.44	6.2 ± 2.7
IKDC 2000 score (%)			
90-100 points	-	11%	0%
76-89 points	-	0%	0%
50-75 points	-	33%	17%
< 50 points	-	56%	83%

Data is expressed as mean ± SD with minimum and maximum values in brackets; CON: control group; ACL: individuals with ACL rupture; BCL: individuals with ACL and PCL rupture; International Knee Documentation Committee; Subjective Knee Evaluation Form (2000 IKDC).

to the participants, and they were familiarized with the commands for subsequent measurements. The static balance test was carried out for lower limbs separately while standing barefoot on one leg with upper limbs hanging aside. The untested lower limb was held slightly flexed in the hip, knee and ankle joint just above the ground. During the test, the subjects looked forward. No feedback on postural sway was given during the tests. The sensorized bar was located 30 cm in front of the subjects to protect them from falling and to enable rapid regaining of vertical posture in case of balance loss. In accordance with the previous recommendations, four 30-second trials of stability assessment were performed for each lower limb, two with opened (EO) and two with closed (EC) eyes. The trials proceeded automatically with an alternated sequence of the left and the right limb stance, performed first with EO and then with EC (**figure 1 a, b**). This was a sort of randomization procedure because most of the patients had injury to the right while some to the left knee. Each trial was followed by a 15-second break. Prior to testing the participants were subjected to a familiarization test performed on each limb. The accelerometer sensor output was digitized at a rate of 100 Hz and recorded with a personal computer equipped with dedicated software (DPPS 5.0). The raw data were initially averaged with a 4-tap sliding window, to narrow the 3 dB bandwidth to approximately 11 Hz. The average amplitude (expressed in angular degrees) of body sway (BS) was derived from the average body instability in the frontal (latero-medial direction, LM), sagittal (antero-posterior direction, AP) planes as well as both planes combined (2D). The exact equation algorithms used for the calculation of the studied variables have been precisely described in the previous report of Riva *et al*. (18). The best trial out of 2 for each leg, *i.e.*, the trial with the least BS was analysed. The ratio of body sways between EC and EO testing conditions was calculated to depict the increase in the body sway between both conditions. The second-

Figure 1. (**A**) The measurement of postural sway with eyes opened. (**B**) The measurement of postural sway with eyes closed.

ary variable was the total time of not leaning against the barrier (expressed in seconds) and thus maintaining the postural balance.

Statistical analysis

The statistical analysis was performed using Statistica 8 Software. The demographic details and main characteristics of respondents were summarized using descriptive statistics. Data distribution was tested using the Shapiro–Wilk test, while homogeneity of variance was verified with Levene's test. As the distribution of variables was different than normal and no homogeneity of variance was observed, non-parametric Kruskal-Wallis test was used for the statistical analysis. The Mann-Whitney U test was applied for the post-hoc analysis of independent variables. The alpha level of significance was set at $p < 0.05$.

RESULTS

Regarding the differences in the total time without leaning against the frame, there were significant differences in the examination with eyes closed and opened in the injured limb, in the ACL and BCL groups and in the non-injured limb in the BCL group. No significant interactions were noted between the limbs in all the groups (**table III**). Hence, the time of maintaining the postural control was similar for all the studied groups.

The comparison of stability between injured and uninjured subjects

Compared to the control group, the BCL group showed significantly higher median values of BS in tests conducted with EC in all the examined planes (LM BS by 283%, AP BS by 310% and 2D by 278%) only when standing on the injured limb. In addition, median values of AP BS and 2D BS were greater by 194% and 174%, respectively, than in the ACL group during tests with EC (**table IV**). In the ACL group, stability did not differ from that in healthy individuals.

The comparison of stability between subject's own limbs

In the control group and ACL group, no differences in BS were found in any tested plane when comparing own lower limbs, either in trials with EO or EC (**table IV**). In contrast, in the BCL group, significantly higher median values of BS were found in all the examined planes (LM BS by 126%, AP BS by 182% and 2D by 142%) while standing on the injured limb compared to the healthy limb, but only during tests with EC (**table IV**).

The comparison of stability in tests with eyes open and eyes closed

Apart from the left limb in the control group, LM and 2D BS were higher in all the groups in trials with EC than in those with EO. AP BS was greater during EC than EO only in the injured limb of the ACL group and in the injured and non-injured limb in the BCL group (**table IV**).

In the ACL group, no changes in ratio of sways were observed compared to the control group. In the BCL group, except for AP BS for the non-injured limb, the ratio of body sway between EC and EO was higher in both limbs than in the control group. This ratio was also greater than in the ACL group for LM BS in the non-injured limb and for AP BS in the injured limb.

Furthermore, only in the BCL group, the ratio of sways was greater for AP BS in the injured limb than in the own non-injured limb (**table V**).

DISCUSSION

As hypothesized, greater ligament injury to the knee joint resulted in increased antero-posterior, latero-medial and two-dimensional body sways during single leg stance on the

Table III. The mean of time without contact with the supporting frame during the stability test.

	CON (n = 12)				**ACL** (n = 12)				**BCL** (n = 12)			
Limb	**Left**	P value EO *vs* EC	**Right**	P value EO *vs* EC	**Non-injured**	P value EO *vs* EC	**Injured**	P value EO *vs* EC	**Non-injured**	P value EO *vs* EC	**Injured**	P value EO *vs* EC
EO (s)	18.7 ± 4.3		18.6 ± 4.8		20.0 ± 1.5		19.9 ± 0.4		19.5 ± 1.8		19.6 ± 1.5	
		0.273		0.109		0.028		0.018		0.028		0.028
EC (s)	17.9 ± 5.5		16.9 ± 6.9		17.7 ± 4.0		16.9 ± 4.5		18.0 ± 3.2		15.4 ± 6.5	

Values are shown as means ± SD; EO: eyes opened; EC: eyes closed; s: seconds; CON: Control group; ACL: subjects with ACL rupture; BCL: subjects with ACL and PCL rupture; Post Hoc. Paired tests comparisons.

Table IV. Comparison of body sway distribution during tests with the eyes opened and closed.

	CON (n = 12)			**ACL** (n =12)					**BCL** (n =12)						
Limb	**Left**	**Right**	P value Left *vs* Right	**Non-injured**	P value ACL *vs* CON	**Injured**	P value ACL *vs* CON	P value Injured *vs* Non-injured ACL	**Non-injured**	P value APCL *vs* CON	P value APCL *vs* ACL	**Injured**	P value APCL *vs* CON	P value APCL *vs* ACL	P value Injured *vs* Non-injured APCL
LM BS															
EO (°)	0.6 (0.5-1.4)	0.5 (0.4-0.9)	0.663	0.7 (0.6-0.8)	0.072	0.7 (0.5-0.7)	0.165	0.183	0.6 (0.5-0.7)	0.038	0.072	0.9 (0.4-1.3)	0.003	0.221	0.218
EC (°)	1.2 (1.0-2.8)	1.2 (1.0-2.0)		1.4 (1.1-2.4)		2.1 (1.3-3.5)			2.7 (1.4-3.2)			3.4 (2.2-6.0)			
AP BS															
EO (°)	0.7 (0.6-1.3)	0.6 (0.5-0.9)	0.931	0.8 (0.6-1.0)	0.368	0.8 (0.6-0.8)	0.075	0.203	0.7 (0.6-0.9)	0.071	0.368	0.8 (0.5-0.8)	0.001	0.010	0.015
EC (°)	1.1 (0.8-1.7)	1.0 (0.8-1.7)		1.2 (0.9-1.7)		1.6 (1.0-1.9)			1.7 (0.9-2.2)			3.1 (1.5-3.8)			
2D BS															
EO (°)	1.0 (0.8-2.1)	0.9 (0.7-1.3)	0.750	1.3 (1.0-1.6)	0.127	1.1 (0.9-1.2)	0.080	0.203	1.0 (0.9-1.2)	0.029	0.127	1.3 (1.0-1.6)	0.001	0.047	0.038
EC (°)	1.7 (1.5-3.6)	1.8 (1.4-3.1)		2.3 (1.6-3.8)		2.9 (2.2-4.3)			3.5 (1.9-4.0)			5.0 (3.3-10.7)			

Values are shown as median (lower quartile - upper quartile); LM BS: latero- medial body sways; AP BP: antero- posterior body sways; 2D BS: two dimensional body sways (angular degrees, °); EO: eyes opened; EC: eyes closed; CON: Control group; ACL: subjects with ACL rupture; BCL: subjects with ACL and PCL rupture; Post Hoc. Paired tests comparisons.

Table V. The ratio of body sway distribution during tests with the eyes opened and closed.

	CON (n = 12)			ACL (n =12)					BCL (n =12)						
Limb	**Left**	**Right**	P value Left *vs* Right	**Non-injured**	P value ACL *vs* CON	**Injured**	P value ACL *vs* CON	P value Injured *vs* Non-injured	**Non-injured**	P value APCL *vs* CON	P value APCL *vs* ACL	**Injured**	P value APCL *vs* CON	P value APCL *vs* ACL	P value Injured *vs* Non-injured
LM BS															
EC/EO	1.9 (1.6-2.7)	1.9 (1.6-2.7)	0.525	1.7 (1.3-3.3)	0.954	3.3 (1.4-6.1)	0.326	0.174	4.0 (2.0-5.9)	0.019	0.047	4.5 (2.4-6.1)	0.045	0.463	0.663
AP BS															
EC/EO	1.5 (1.0-2.1)	1.5 (1.0-2.1)	0.686	1.6 (1.0-2.9)	0.488	2.2 (1.3-2.7)	0.166	0.260	2.0 (1.6-2.7)	0.064	0.414	4.0 (2.0-6.0)	0.002	0.030	0.026
2D BS															
EC/EO	1.7 (1.2-2.3)	1.7 (1.2-2.3)	0.751	1.7 (1.2-2.9)	0.751	2.8 (1.6-4.3)	0.119	0.166	3.1 (1.8-4.0)	0.039	0.103	4.2 (2.4-6.4)	0.007	0.183	0.124

Values are shown as median (lower quartile - upper quartile); LM BS: latero-medial body sways; AP BP: antero- posterior body sways; 2D BS: two dimensional body sways (angular degrees, °); EO: eyes opened; EC: eyes closed; CON: Control group; ACL: subjects with ACL rupture; BCL: subjects with ACL and PCL rupture; Post Hoc. Paired tests comparisons.

injured limb but only for trials performed with closed eyes. The stability was decreased not only compared to the healthy individuals, but to the patients with ACL ligament rupture, who showed changes in body sway only in measurement in the injured limb in all planes with eyes closed (19). The only change detected in the ACL group was an increased body sway for all studied planes when standing on the injured limb with closed eyes as compared to standing with open eyes ($p < 0.05$). Okuda *et al.* (1) conclude that the amount of postural sway in the ACL-injured knee increased significantly on the injured leg standing with eyes closed, and that vision appears to be dominant in compensating for the decreased contribution the ACL. Moreover, the postural sway did not increase significantly with eyes open.

Contrary to the results of the present study, in the recent systemic review of literature it has been shown that patients with a one-sided ACL injury often exhibit greater postural sway than healthy subjects, especially during single limb stance on the injured limb (to a lesser extent on the healthy limb) in tests with closed eyes (20). However, in most of the included studies various derivatives of the center of pressure were used to visualize the amount of body sway. In this study, we assessed the body sway as the trunk angular sway from the vertical. It is important to emphasize the fact that in this study the patients were after the injury but before the reconstruction surgery.

This is the factor that distinguishes these results from others. Most systemic reviews of the literature analyze postural stability after reconstruction. This may indicate that the graft implanted during the surgery is only a mechanical stabilizer. The process of re-innervation is long and sometimes does not appear at all. To our knowledge the postural stability measured with a Delos Postural System in one leg standing position with and without eye control before the reconstruction surgery has not been assessed in the literature.

When the base of support is narrow, little ankle torque can be applied to control body stability, and the hip strategy is expected to be employed (21). Thus, it may be speculated that in the present study the ACL injured subjects used the hip strategy to compensate for the increased sway of the center of pressure. The tested individuals with a combined ACL and PCL rupture had increased deficits of postural stability only in the absence of vision and only when standing on the injured limb, even though they did not have any neurological abnormalities, including vestibular disorders. Moreover, they demonstrated a significantly higher increase of body sways between the tests with open and closed eyes than normal and isolated ACL ruptured subjects. As the reduced transmission of proprioceptive signals from mechanoreceptors can be compensated only by vision (22), we suppose that the main reason for postural instability after the BCL rupture was the disturbance in proprioceptive feedback due to the damage to cruciate ligaments and the resultant inability to compensate body perturbations through the hip strategy and trunk proprioceptive control (23, 24).

The ACL contains Ruffini, Pacinian and Golgi's corpuscles providing information about the position of the joint and the movement of the limb (25). The PCL also contains numerous sensory endings, such as Ruffini, Pacinian, Krause's and other morphologically unclassified receptors that play a specific role in the proprioceptive control of the knee joint. The menisci have a small number of receptors and their damage seems to have little effect on postural stability (26). It seems that after the rupture of both cruciate ligaments the transmission from cruciate ligaments is so substantially deprived that it dramatically disrupts sensorimotor postural adjustments.

In addition to sensorimotor aspects, neuromuscular disabilities could also be the cause of impairment of postural control. The ability to maintain small body sways probably depends on the ability to instantly generate brief, rapid muscle contractions (27). There are, however, conflicting eports of the impact of muscle strength on postural stability. Some studies have shown the relationship between muscle strength and postural stability (28, 29), while others not (30). Moreover, if strength deficits contributed to the deficits in the postural control seen after the BCL rupture, body sway would also increase during the trials performed with open eyes, which was not the case.

The latero-medial sways of the body while standing on one limb are linked with the lateral pelvic displacement strategy of maintaining the balance, because the anatomical structure of the knee joint makes it impossible to sway in the frontal plane (31). In patients with BCL the body sway increased in both planes, which could be linked to the greater knee instability. However, previous studies did not find any correlation between tibia translocation and postural sway (1, 2). For example, after a ligament damage, the size of frontal instability in the knee joint did not have an influence on postural stability (32). The lack of changes in body sways in the injured limb in patients with bicruciate ligament injuries during the tests with open eyes indicates that mechanical instability of the joint due to a bicruciate ligament injury was unlikely to be the cause of decreased stability.

In all disorders associated with musculoskeletal knee conditions pain is a consistent feature. However, it is difficult to isolate the effects of nociceptive stimulation on knee joint perception from others associated with inflammation or muscle function. Bennell *et al.* (33) evaluated the effect of experimentally induced knee pain on knee joint position sense in healthy individuals. The results were surprising: knee joint position sense was not alerted by acute knee pain in any of the positions tested (30). Using an experimental pain model in healthy volunteers allows controlled investigation of the effects of pain on proprioception. The authors emphasize that resolution of pain is unlikely to lead to improvements in joint position sense. A similar study was developed to evaluate the effects of knee pain on the standing balance. Postural stability was not significantly alerted by experimentally induced acute knee pain, nor was there any relationship between severity of the reported pain and balance scores (34).

Clinical implications

To our knowledge, this is the first study that has analyzed the relationship between an isolated- and bicruciate ligament knee injury and postural stability in a male group before reconstruction surgery. After the bicruciate ACL and PCL but not isolated ACL injury the postural stability was substantially decreased in frontal and sagittal planes, suggesting poor control of trunk alignment in both planes in this group. An increase of knee load in the frontal plane due to a poorly controlled trunk has been shown as a potential risk factor for ACL injury in a healthy population of female athletes (21). Moreover, poor postural stability is a strong predictor of a second ACL injury after ACL reconstruction (11). Therefore, therapists should recognize that before ligament reconstruction surgery, neurosensory core training (kinesthetic and proprioceptive) (21) and perturbation balance training on the injured and non-injured limb seem to be important therapeutic strategies which need to be included in rehabilitation protocols of men with bicruciate ligament injuries of the knee joint (3).

Limitations

This study presents some limitations. First of all, we did the measurements of static balance after but not before the anterior cruciate ligament and bicruciate (ACL and PCL) injury, which is not feasible. Therefore, we were not able to identify if there were any differences in the control of postural stability before the injury. Furthermore, the level of physical activity was not assessed using a standardized questionnaire. It was only determined in an interview with a patient whether subjects were professional athletes or practiced any sports before and at the time of enrolment to the study. These were the basic criteria for exclusion from the study, due to the possible loss of mechanoreceptors in the ligaments as a result of intense physical exercise history. What is valuable in the conducted research, is that it was possible to select a group of patients with bicruciate ligament knee injury coherent with the study material. This allowed us to describe the functional state of patients and their neurological deficits at the level of proprioceptive sensation. This type of research, when patients are before the surgery, presents biological changes in the functional meaning. It also should be remembered that reconstruction treatment at first brings mechanical stabilization of the knee while the re-innervation process will take much longer. Hence it is worth conducting examinations before surgery to verify the progress of surgical and physiotherapeutic treatment. Future studies should attempt to investigate the influence of isolated and bicruciate ligament injury on postural stability in female individuals prior to reconstruction surgery and also after it.

CONCLUSIONS

The results of the present study confirm the assumption that the greater the size of knee ligament damage, the greater deficits in the postural control. The greatest body sway was found after the bicruciate knee ligament injury. Larger body sways were observed only in the absence of visual control, suggesting that, due to the loss of functionality of articular mechanoreceptors, the proprioception impairment is a major reason for imbalance disorders and presumably contributes to the poor control of trunk stability. The study meets the ethical standards of the journal (35).

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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