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Proprioceptive defects after an anterior cruciate ligament rupture – the relation to associated anatomical lesions and subjective knee function

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Abstract A disturbed proprioception has been described in patients with an anterior cruciate ligament (ACL) deficient knee. The relation to demographic data and to different commonly associated anatomical lesions, as well as to subjective knee function, was prospectively studied in 16 consecutive patients after an acute knee ligament injury. All patients had a complete rupture of the ACL, but variable associated anatomical lesions. The threshold to detect a passive motion, as a measure of their proprioceptive ability, was registered repeatedly during the first year after injury. Four of the patients had consistently severe and persistent deficits at 1, 2 and 8 months. These four individuals had more chondral lesions and a lower subjective rating of their knee function than the remaining patients. In the whole group there were significant correlations between the recorded thresholds and associated chondral lesions, meniscal lesions and the subjective rating of knee function. We found no significant relation between age, gender, activity level, grade of mechanical laxity increase or a medial collateral ligament rupture, and the proprioceptive recordings. Thus, morphological lesions other than a rupture of the ACL seem to contribute to the proprioceptive deficits after a knee ligament injury, and the patients' ability to detect a passive motion showed a relation to subjective knee function from the time of injury onwards.

Key words Knee · Injury · Proprioception

Introduction

Afferent information is essential for both voluntary movements and reflex mediated muscle responses [17]. Proprioceptive receptors are located within most soft tissues of the knee and surrounding structures [1, 12, 13, 19, 26, 28, 29, 32, 37]. Nervous fibres have also been found in the epiphyseal region of the femur and the tibia in rats [7].

Proprioceptive deficits have been described, in selected populations, at different times after a knee injury with a rupture of the anterior cruciate ligament (ACL) [4, 5, 8, 9, 10, 14, 15, 21, 24]. Some patients with an ACL injury have a severe disturbance in proprioception at later time intervals after the original injury, in addition to the defective mechanics [4]. A better correlation to functional outcome after an ACL reconstruction has been reported based on the patient's proprioception rather than on traditional scoring systems and laxity testing [5]. We have previously reported proprioceptive defects in consecutive patients after a recent knee ligament injury [11], but to our knowledge, no study has analysed the contribution from different morphological lesions to the individual patient's proprioceptive ability. The purpose of this study was to further investigate the relation between the proprioceptive recordings and demographic data, commonly associated anatomical lesions and subjective knee function at repeated time intervals after a primary knee ligament injury in the same consecutive patients who were previously reported on as a group [11].

Patients and methods

The population consisted of 16 consecutive patients, 11 males and 5 females. The mean age was 26 years (range 15–36 years). No patient had any history of significant injuries of the lower limbs or any general disease that might interfere with peripheral or central neural function. Laxity testing during anaesthesia and intra-articular evaluation of the joint with arthroscopy were performed within 10 days after the original injury, and a total rupture of the ACL, with or without associated lesions of the collateral ligaments, the menisci and the cartilage, was verified in all patients. In all patients the ACL lesion was treated non-operatively with an immediate rehabilitation program [36]. Initial emphasis on treatment of swelling and on regaining range of motion was followed by closed-chain exercises designed to restore the neuromuscular function of the limb.

Since an effect on proprioception from training has been found [3], the patients were asked to estimate their activity level according to the Tegner scale [34]. This scale (0–10) is based on how troublesome certain activities are to perform after an ACL rupture. The highest score before the injury was 9, equal to competitive sports such as soccer in lower division, ice hockey or gymnastics, and the lowest score was 2. The median score was 6, equal to recreational sports. The Lachman test [35] was graded as positive when a clear side-to-side difference (> 5 mm) was noted and pivot shift, as measured with the flexion-rotation-drawer test, was positive when there was an "obvious jerk or impingement" [25]. A medial collateral ligament lesion was diagnosed when there was a clear side-to-side difference (> 5 mm) in valgus laxity at 20° flexion. A chondral lesion was registered if there was a sharp disruption of or a defect in any of the femorotibial cartilage surfaces at arthroscopy. Superficial cartilage fibrillation was not included as a lesion and no patient had any deeper degenerative changes. A meniscus lesion was noted when there was a tear in the substance, either partial or full thickness, as well as if there was a menisco-capsular avulsion. Subjective rating of knee function was made on an ordinal scale from 1–10 (1 = recently injured; 10 = healthy, without any functional limitations).

The proprioceptive measurements were performed with the patients in a lateral decubitus position with the lower foot placed in a plastic splint, which was connected to an electrical motor by a wire (Fig. 1). The knee joint was carefully positioned in the rotatory centre, and a pull in either direction on the wire moved the knee into extension or flexion.

Two bars served as guide marks for placement of the thigh and trunk in a standard position, with the hip joint in semiflexion. Care was taken to eliminate any external cues to limb movements except those from the knee joint and surrounding structures. To minimise any cutaneous sensation, the patients wore short pants and a thick woollen sock and the knees had no contact with the underlying surface. Visual control of the leg was prevented by subject positioning and by auditory impulses from earphones with a sound imitating the motor.

The threshold for detection of a passive motion was performed with both flexion (TF) and extension (TE) from 20° and 40° starting positions. The subjects were asked to concentrate and respond verbally to a clear sensation of movement or change in position of the knee or the lower limb. The examiner then turned on the tape recorder and started the motor, which was calibrated to an angular velocity of 0.5°/s. The onset of the motor had a random delay, varying between 5 and 15 s after the subjects were asked to be ready. When they responded, the motor was stopped and the movement was recorded in degrees. The median value of three consecutive trials was used for statistical analysis. The tests were made on both the injured and the uninjured legs by reversing the apparatus arrangement, and each patient was tested at 1, 2, and 8 months after injury.

The reproducibility of the threshold tests has been evaluated with repeated measurements in healthy individuals (Table 1). The results from the present patient group have been described in a previous study [10] and are shown in Fig. 2a–d [11]. In a further analysis, using multiple, stepwise regression analysis, age, gender, activity level, associated meniscal, cartilage and collateral ligament lesions, Lachman and pivot shift tests, as well as subjective rating of the knee function (from 1–10), were used as independent variables.

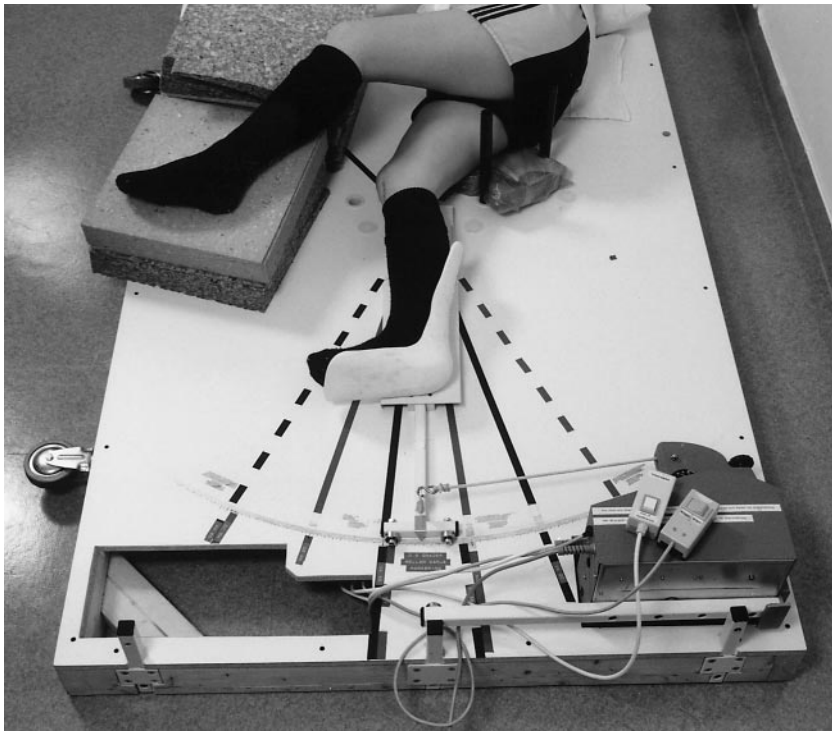

Fig. 1 The thresholds to detect a passive motion in flexion and extension, registered in a lateral decubitus position

Table 1 The difference with non-parametric 95% confidence intervals between repeated measurements in a normal population. From [10]

Type of test		Difference (degrees)	Confidence interval (degrees)
TE	20	0.13	0–0.38
	40	0.25	0–0.63
TF	20	0.13	0–0.25
	40	0.00	0–0.13

Statistics

A multiple stepwise regression analysis was performed using Minitab 10 and SAS 6.10 program packages. Since some individuals had extreme recordings, non-parametric statistics were used with the Wilcoxon rank sum test or Fisher's exact test in the comparisons between groups.

Results

As shown in Fig. 2a–d, the threshold to detect a passive motion was increased after injury and showed the same pattern from 20° and 40° in movements towards both flexion and extension. There was no normal distribution in the population and some patients had consistently high recordings. Four patients, 2 males and 2 females, repeatedly had recordings outside the boxes (Fig. 2a–d) in the four different threshold tests. These 4 individuals together presented 42 of the total 47 extreme values registered, whereas the

Fig. 2a–d The thresholds to detect a passive motion (in degrees) from a starting position of 20° toward extension (**a**) and toward flexion (**b**); from a starting position of 40° toward extension (**c**) and toward flexion (**d**), for the reference group and at different intervals after injury (months) for the patients. Median values are shown as a separate *line* through the box or as the *bottom line*. The box includes the first to third quartiles. *Asterisks* denote outlying measurements. From [11]

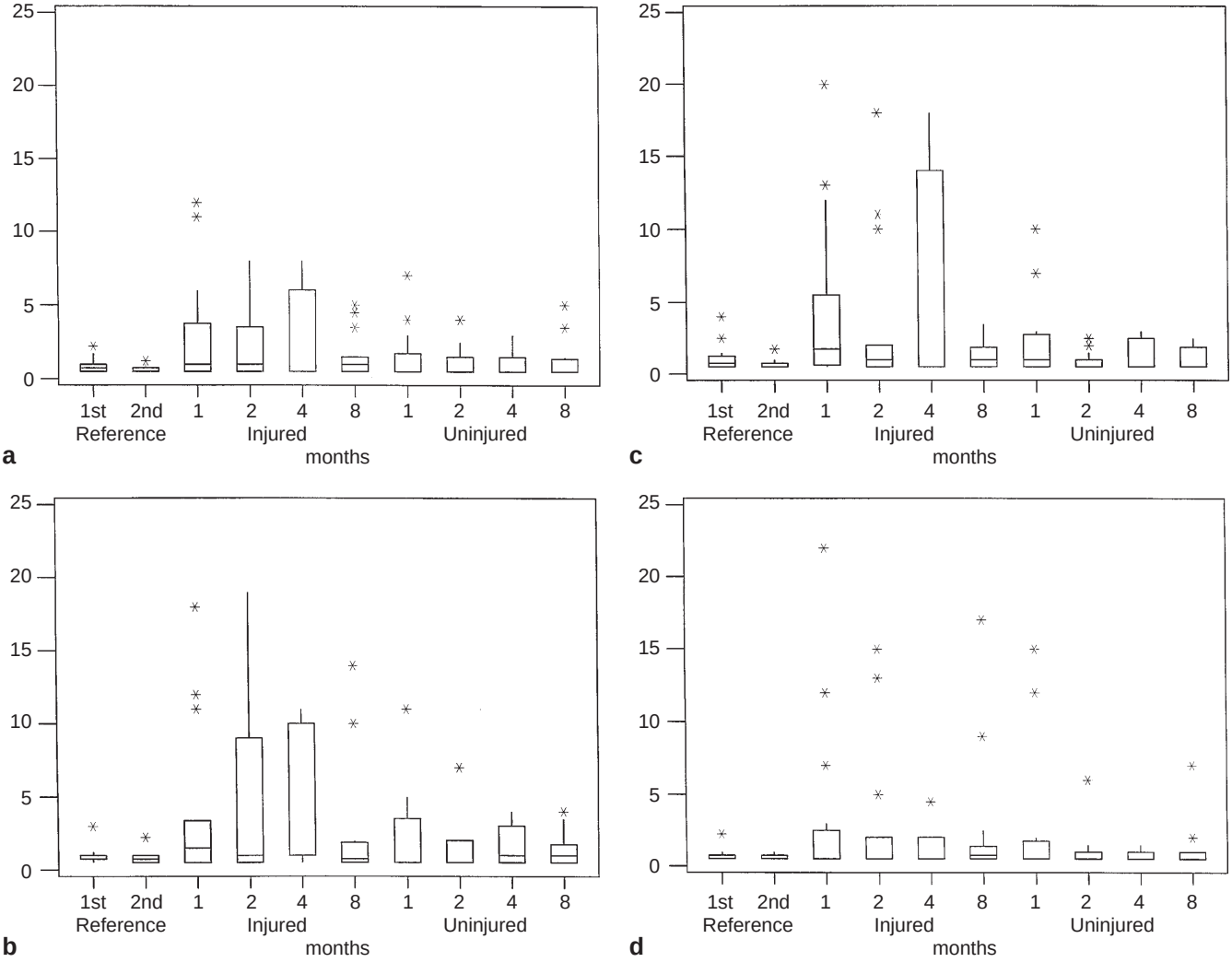

Table 2 Four individuals with consistent severe proprioceptive defects registered repeatedly in the different threshold tests compared with the remaining 12 patients

	Subjects with extreme propriocetive defects (n = 4)	Remaining group (n = 12)	Significance level
Gender (male/female)	2/2	9/3	NS
Age (mean and range)	29.5 (26–34)	24.6 (15–36)	NS
Activity before injury	4.5 (2–9)	6 (2–9)	NS
Lachman (pos/neg)	4/0	7/5	NS
Pivotshift (pos/neg)	4/0	8/4	NS
Lesion of			
Med coll lig (yes/no)	0/4	8/4	NS
Meniscus medial (yes/no)	0/4	2/10	NS
lateral	2/2	9/3	NS
both	0/4	2/10	NS
Cartilage (yes/no)	3/1	1/11	0.03
Subjective rating (1–10)	5.5 (3–7)	8 (6–10)	0.02

Table 3 A multiple regression analysis between the proprioceptive recordings and age, gender, activity level, associated meniscal, chondral and collateral ligament lesions, Lachman and pivot shift tests as well as subjective rating of the knee function as independent variables

Type of test	Time of test (months)	Variable with highest correlation	R^2	Significance level
TE 20°	1	Chondral lesion	0.44	0.007
	2	Chondral lesion	0.53	0.003
	8	Subjective rating	0.38	0.01
TE 40°	1	Chondral lesion	0.67	0.0002
	2	Subjective rating	0.41	0.01
	8	Chondral lesion	0.52	0.002
TF 20°	1	Chondral lesion	0.57	0.001
	2	Subjective rating	0.40	0.01
	8	Meniscal lesion	0.39	0.01
TF 40°	1	Subjective rating	0.43	0.008
	2	Chondral lesion	0.57	0.002
	8	Meniscal lesion	0.54	0.002

remaining 5 extreme values were scattered among the other 12 patients. When comparing these 4 individuals with the remaining 12 patients, significant differences were found in the number of associated chondral lesions, 3/4 versus 1/12 (P = 0.03) and in subjective rating 5.5 (range 3–7) versus 8 (range 6–10) (P = 0.02). There was no difference in any of the other variables (Table 2).

From the multiple stepwise regression analysis, the independent variables with the highest correlation to the proprioceptive recordings at each proprioceptive test for each time interval are listed in Table 3. There were three variables which accounted for the highest correlations, chondral lesions, meniscal lesions and subjective ratings of the knee function, with coefficients of determination from 0.38 to 0.67.

Discussion

The extent of a knee ligament injury, which often involves more than one anatomic joint structure, is not limited to a mechanical problem since most torn intra- and periarticular tissues contain neuronal receptors and afferent fibres [1, 12, 19, 26, 28, 29, 32, 37]. The proprioception deficit reported in patients at different time periods after a knee injury has mainly been ascribed to an ACL lesion [4, 5, 8–11, 15, 21, 24]. “Insecurity of the actual position of the knee and rate of change in position” has, however, also been described as a phenomenon occurring after meniscal surgery [33], and proprioceptive defects have recently been reported in a study on patients with meniscal lesions [16].

In the present prospective and longitudinal study, all the consecutive patients had suffered a total ACL rupture but had variations in associated lesions. There was a decreased ability to detect a passive motion at 1 and 2 months after injury compared with the reference group. Thereafter, a gradual improvement with time was observed in most patients [11]. A significant correlation between the patients proprioceptive ability and both a chondral lesion and a meniscal lesion was found. There was no correlation with medial collateral ligament lesions and valgus instability. Thus, the proprioceptive defects after a knee injury do not seem to be exclusively related to ligament disruptions. The findings of intra-osseous nerve fibres [7] at sites where bone bruises have been found on MRI [22, 27] in patients with a knee ligament injury may be the morphological explanation for a relation of meniscal and chondral lesions to the registered proprioceptive ability. One might speculate on the similarity of such bruises to a concussion occurring in the knee. The reliability of these findings was supported by the consistency of these correlations in the different threshold tests and at repeated time intervals.

Barrett [5] reported a correlation between subjective knee function and a decreased proprioception at about

3 years after an ACL reconstruction performed on selected patients who had suffered from repeated giving-way episodes after a primary non-operative treatment. However, there was a poor correlation between the mechanical outcome of the ligament reconstruction and the subjective function, and it was concluded that there was a clinically relevant relation between proprioception and the subjective rating by these patients of their functional outcome. However, due to the patient selection procedure and the intervening surgery, no conclusions regarding the aetiology of the proprioceptive defects could be drawn from that study. The subjective knee function might be due to the combined effect of repeated injuries and the outcome of the ligament reconstruction.

The present findings of a correlation between the proprioceptive recordings and the subjective function in the immediate post-injury period indicate that the partial loss of proprioception is of clinical relevance from the time of original injury onwards. As in the study by Barrett [5], no correlation between mechanical laxity and the proprioceptive deficit was found in the present patient group with a primary non-operative treatment of the ligament lesions.

Enhanced proprioception in high performance individuals [3, 20] and a decline in proprioceptive ability with ageing [2, 3, 18, 23, 31] have been reported. In the present study, no correlation between proprioception and the patients' age or activity level was found, which could be explained by the homogeneity of this young population.

Since sensory information has an effect on both the ipsi- and contralateral limb muscles [17, 30], persisting sensory defects after a unilateral injury may be a factor related to both repeated injuries of the ipsilateral knee [19] and to the higher incidence of injuries to the contralateral knee after an ACL injury (unpublished observations). The four individuals with extreme recordings as long as 8 months after the injury showed a tendency towards lower thresholds with time post-injury. However, they never recovered to the level of the reference group. These individuals may have a congenitally inferior proprioceptive ability and they may also represent a subgroup with a bad prognosis, but more studies and a longer follow-up of the present patient group are needed for further analysis.

In conclusion, there were significant correlations at repeated time intervals between the patients' proprioceptive ability and both associated chondral lesions and meniscal lesions, as well as with their subjective rating of knee function. Thus, morphological lesions other than a rupture of the ACL seemed to contribute to the proprioceptive deficits after a knee ligament injury, and the patients' ability to detect a passive motion showed a relation to subjective knee function from the time of injury onwards.

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