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Function after anterior cruciate ligament injuries

Influence of visual control and proprioception

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Information about limb positions and movements consists of input from visual, vestibular, cutaneous, muscular, tendinous and joint receptors, but the relative contribution from each type and location of receptors is not known. The aim of this study was: a) to measure the contribution from visual control on extremity function, as measured with a one-leg hop test in healthy persons, in patients with an asymptomatic ACL injury, after non-operative treatment and in patients with a stable knee after an ACL reconstruction, b) to investigate if there was any relation between proprioception from the extremity, as measured with the threshold for detecting passive motion of the knee, and the one-leg hop test with a gradual decrease in visual control.

There was a decrease in hop-length when the subjects were deprived of visual control that was significant when the dominant eye or both eyes were blinded, both in the 2 patient groups and the reference population. The magnitude of the length reduction did not differ between the groups or between injured and healthy limbs.

In all 4 threshold tests performed as a measure of peripheral proprioception, a stronger relation to hop-length was recorded for the blinded hop than with full visual control in the patients with nonoperated ACL injuries. The coefficients of correlation between hop-length and the proprioceptive recordings in the injured limb were of the same magnitude as on the healthy side.

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This study was initiated by the outcome of a knee ligament injury in a 42-year-old manager of a riding school. During gelding of a stallion, the horse suddenly sat down on the patient's right leg, causing complete ruptures of the anterior cruciate ligament (ACL) and the medial ligaments together with bilateral lesions in the posterior part of both menisci. The ligament lesions were primarily treated nonoperatively with an immediate neuromuscular rehabilitation program. After the rehabilitation, the patient could ski downhill and do more spectacular big-foot skiing after horses, without sensations of instability. 3 years later, he suffered a second horse-related injury, when a small metal piece penetrated his left eye with resultant blindness. Thereafter, he could no longer control his knee, even when walking on uneven ground, and had a constant sensation of instability and repeated "giving-way". The patient's own opinion was that this was due to his lost ability to estimate distances. After a combined reconstruction of the ACL and the medial collateral ligament, he could resume his skiing and riding activities and has not, 6 years after surgery, had any complaints of instability in the injured knee.

To guide muscular activity properly, afferent information is crucial. The 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 also contain neuronal receptors and afferent fibers (Kennedy et al. 1982, O'Connor 1984, Schultz et al. 1984, Schutte et al. 1987, Zimney 1988). Information on limb positions and movements consists of input from visual, vestibular, cutaneous, muscular, tendinous and joint receptors (Williams 1981, Johansson et al. 1991), but the relative contributions from each type and location of receptors are not known (Petersen 1995).

The importance of visual control for posture has long been used in the Romberg test and has later been documented by others (Lee and Lishman 1975, Ring et al. 1989).

In this study, we: a) measured the contribution from visual control of extremity function, as measured with the one-leg hop test (Daniel et al. 1982, Tegner et al. 1986, Barber et al.1990, Noyes et al. 1991), and compared the results between patients with an asymptomatic ACL injury after nonoperative treatment, patients with a stable knee, after an ACL reconstruction and a control group, b) investigated if there was any relation between proprioception as measured with the threshold for detecting a passive motion and the one-leg hop test with a gradual decrease in visual control, in patients with ACL injuries treated nonoperatively. The hypothesis was that deprivation of vision would increase the relative importance of afferent information from receptors in the extremity.

Patients and methods

The patients consisted of 3 groups. 17 patients (10 men) were selected from a prospective, consecutive series of ACL injuries treated nonoperatively during 1984–1988. The mean age at testing was 28 (21–39) years. Their median activity level (Tegner and Lysholm 1985) was 4 (2–9) and they had no major symptoms from their knees, despite a persistent laxity increase.

20 patients (10 men) with a stable knee after an ACL reconstruction were selected and measurements made 2 years after surgery. The mean age was 26 (19–44) years. Their median activity level was 5 (1–9).

The control group consisted of 40 healthy subjects (19 men), with a mean age of 25 (18–34) years and a median activity level of 4 (2–9).

None of the subjects had any injuries or complaints in the uninjured limb. All refractory defects were compensated and there were no other complaints about the eyes.

The one-leg hop test was performed by hopping and landing on the same leg and the longest distance in 3 consecutive trials was recorded. A gradual reduction in visual control was made by blindfolding the nondominant eye, the dominant eye and both eyes. Although there are many definitions of ocular dominance (Porac and Coren 1976), we defined the dominant eye as the one chosen for sighting with one eye (Classé et al. 1996).

The proprioceptive measurements were performed with the patients in a lateral decubitus position having the lower foot and calf resting in a slightly concave plastic splint, which was connected to an electrical motor with a wire (Figure). The knee was carefully positioned in the rotatory center and a pull in either direction on the wire moved the knee into extension or flexion.

Two bars served as guidemarks 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 neutralize any cutaneous sensation, all subjects were wearing short pants and a thick woollen sock so that the knee had no contact with the underlying surface. Visual control of the leg was prevented by the positioning and auditory impulses were blocked by earphones, with a sound imitating the motor.

The threshold for detecting a passive motion was measured in a lateral decubitus position.

The threshold for detecting a passive motion was registered towards flexion (TF) and towards extension (TE) from two starting positions: 20° and 40°. The subjects were asked to concentrate and say when they felt definite 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°/sec. The motor went on after a random delay, varying between 5 and 15 seconds, when the subjects were asked to be ready. When they responded, the motor was stopped and the movement was registered in degrees. The median value of three consecutive trials was used for the statistical analysis (Fridén et al. 1996). The reproducibility of this test has previously been evaluated during repeated measurements 1 month apart in 19 healthy subjects (Fridén et al. 1996) (Table 1). These subjects also constitute the control group for the proprioceptive recordings in this study.

Statistics

Two-tailed Student's t-tests were used for comparisons in and between groups and Pearson's coefficients of correlation were calculated. The statistical analyses were performed using Minitab 10 and SAS 6.10 program packages.

Table 1. The mean difference with 95% confidence intervals (CI) between repeated measurements (°) of the threshold to detect a passive motion in 19 healthy young subjects

Type of test [a]		Mean difference	CI
Towards extension from	20°	0.13	0–0.38
	40°	0.25	0–0.63
Towards flexion from	20°	0.13	0–0.25
	40°	0.00	0–0.13

[a] Threshold to detect a passive motion towards extension (TE) and towards flexion (TF) from a 20° and a 40° starting position

Results

There was a gradual decrease in hop length both in the patients and reference group, when they were deprived of visual control, with significant differences when the dominant or both eyes were blinded. The magnitude of the hop-length reduction did not differ between the groups or between injured and healthy limbs (Table 2).

The threshold for detecting a passive motion in the patients with nonoperative treatment was comparable to that in age-matched healthy subjects, from both the 20- and from the 40-degree starting positions, and there were no differences between the injured and healthy limbs (Table 3).

The relationship was assessed between the threshold tests and the one-leg hop-length at the various grades of visual deprivation. The highest coefficients of correlation were registered for the blinded hop (Table 4).

The coefficients of correlation between hop-length and the proprioceptive recordings in the uninjured limb were of the same magnitude as on the injured side. In all 4 threshold tests, a stronger relationship was consistently recorded at a higher degree of visual deprivation than at full visual control (Table 4).

Discussion

Alterations in the relative importance of afferent information from different receptors has been described after a congenital bilateral vestibular loss (Enbom et al. 1991). These patients were able to compensate for the loss by vision and peripheral proprioceptive information, but if proprioception was disturbed experimentally, there were defects in these patients' postural

Table 2. The one-leg hop length and *SD* (cm) and the length reduction, *SD* (cm) and p-value recorded at the various degrees of visual deprivation in the 2 patient groups and control group

	Hop-length		Decrease in hop-length with eye/s blinded								
	Full vision		Nondominant			Dominant			Both		
Nonop, n 17											
Injured	171	*31*	0	*12*	0.9	–3	*9*	0.01	–10	*9*	0.000
Healthy	182	*32*	–4	*10*	0.1	–5	*8*	0.02	–16	*14*	0.000
Operated, n 20											
Injured	154	*30*	–3	*8*	0.1	–4	*7*	0.01	–14	*12*	0.000
Healthy	158	*29*	–3	*7*	0.07	–3	*7*	0.06	–9	*9*	0.000
Reference, n 40 [a]	168	*34*	–2	*5*	0.007	–3	*6*	0.001	–11	*9*	0.000

[a] Average of right and left in the reference group. Significance levels for differences compared with hop-length with full vision

Table 3. Comparison of the threshold for detecting passive motion and *SD* (°) on the injured and healthy side in the patient group with nonoperative treatment (n 17) and a control group of age-matched, healthy subjects at the same activity level (n 19)

Type of test		Injured limb		Healthy limb		Control group [a]		Difference [b]
Towards extension from	20°	1.1	*0.9*	1.1	*0.9*	0.8	*0.5*	Ns/Ns
Towards flexion from	20°	0.9	*0.7*	1.4	*1.6*	1.0	*0.6*	Ns/Ns
Towards extension from	40°	0.8	*0.5*	1.2	*0.9*	1.1	*0.9*	Ns/Ns
Towards flexion from	40°	0.8	*0.7*	0.6	*0.2*	0.7	*0.4*	Ns/Ns

[a] Average of right and left in the control group.
[b] Difference referes to separate comparisons of patients' injured / healthy limbs with the control group.

Table 4. The coefficients of correlation (95% confidence intervals) between the one-leg hop-length(cm) and the threshold to detect a passive motion (°) in the patients with non-operative treatment (n 17) at the various degrees of visual deprivation

Type of test [a]	Full vision	Nondominant eye blinded	Dominant eye blinded	Both eyes blinded
Injured side				
Towards extension from 20°	-0.42 (-0.75 to 0.07)	-0.45 (-0.76 to 0.04)	-0.47 (-0.78 to 0.01)	-0.49 (-0.79 to -0.01)
Towards flexion from 20°	-0.46 (-0.77 to 0.02)	-0.50 (-0.79 to -0.02)	-0.51 (-0.80 to -0.04)	-0.57 (-0.82 to -0.12)
Towards extension from 40°	-0.58 (-0.83 to -0.14)	-0.60 (-0.84 to -0.17)	-0.62 (-0.85 to -0.21)	-0.59 (-0.83 to -0.16)
Towards flexion from 40°	-0.32 (-0.69 to 0.19)	-0.41 (-0.75 to 0.08)	-0.38 (-0.73 to 0.13)	-0.45 (-0.76 to 0.05)
Healthy side				
Towards extension from 20°	-0.37 (-0.72 to 0.13)	-0.44 (-0.76 to 0.05)	-0.55 (-0.82 to -0.10)	-0.52 (-0.80 to -0.05)
Towards flexion from 20°	-0.46 (-0.77 to 0.02)	-0.51 (-0.79 to -0.04)	-0.61 (-0.85 to -0.19	-0.59 (-0.83 to -0.15)
Towards extension from 40°	-0.41 (-0.74 to 0.09	-0.45 (-0.76 to 0.04)	-0.52 (-0.80 to -0.05)	-0.53 (-0.81 to -0.07)
Towards flexion from 40°	-0.43 (-0.75 to 0.07)	-0.49 (-0.78 to -0.01)	-0.51 (-0.80 to -0.05)	-0.55 (-0.81 to -0.09)

[a] Thresholds towards both flexion and extension from the two starting positions at 20° and 40°

control compared to healthy subjects.

A congenital complete loss of peripheral sensory information has been reported to make the patient totally dependent on vision, leading to an immediate fall to the floor in case of sudden darkness (Nance and Kirby 1985). We found the same principle pattern but, to a lesser extent. This suggests that a decrease in afferent information may interfere with extremity function also after a knee ligament injury.

A one-leg hop test is a measure of the overall neuromuscular competence of the lower extremity. It has proved to have a significant relationship to the patients' subjective knee function and a reduced hop-length has been found in most patients after an ACL injury (Barber et al. 1990, Noyes et al. 1991). Several factors, including age, gender, activity level, muscle strength, proprioception, pain and swelling may affect this test and some of these factors probably show a covariation. Due to these various prerequisites, one cannot expect a single factor to show a perfect correlation and causality must be interpreted with caution. A muscle dysfunction with reduced strength correlates with the decreased hop-length (Barber et al. 1990) and may also be related to proprioceptive defects (Elmquist 1988, Sjölander 1989). We found a relation between functional performance and proprioception and since the uninjured side also showed the same correlation between the threshold for detecting a passive movement and the hop-length as the injured, a covariation, with a possible persistent strength reduction or other factors on the injured side, does not seem plausible.

Both patient groups in our study had regained good function whether treated nonoperatively or with an ACL reconstruction. They showed the same reduction in hop-length as the reference population, which indicates a proper limb control, even in more demanding situations. When they were deprived of visual control, however, the remaining afferent information was not enough for full motor performance in any of the groups. No proprioceptive deficits were found in the patients with nonoperative treatment, and therefore the effect of defects in proprioception needs further studies. It must be emphasized that the patients in both groups were selected and the criterion for those in the nonoperated group was that they had no major symptoms of instability—i.e., they were able to compensate for the mechanical defects. All previous reports on threshold as a measure of proprioception have registered defects in ACL-injured patients (Barrack et al. 1989, Corrigan et al. 1992, Lephart et al. 1992, Co et al. 1993, Fridén et al. 1996, 1997) and thus, the present patients belong to a subpopulation also in this respect.

It has been shown that some patients develop persisting and more serious defects in their proprioceptive capacity after a knee ligament injury than others (Barrack et al. 1989, Fridén et al. 1997). It is possible that the case reported in the introduction may give a more detailed description of a patient in such a subpopulation and that his one-eye blindness reduced the overall afferent information to a level where his neuromuscular competence was unable to compensate for the loss of mechanics in his knee.

The findings provide us with a basis for further studies on patients having a decreased proprioceptive ability, in order to learn more about the poorly defined terms "ACL-dominant knee," "copers/non-copers" and possible "compensatory mechanisms", which are arbitrarily used descriptions of individual patients' ability to restore function, after an ACL injury.

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