PROPRIOCEPTION IN THE CRUCIATE DEFICIENT KNEE

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Proprioception was measured in the knees of 20 subjects with instability of the anterior cruciate ligament and compared with 17 age-matched control subjects. There was diminished position sense and threshold for movement detection in the injured patients compared with the control group. The proprioceptive deficit recorded from the injured knee showed a significant correlation with the hamstring/quadriceps power ratio recorded from the injured leg.

Instability after injury to the anterior cruciate ligament is characterised by a variable functional deficit in the knee. A proprioceptive deficit following ligamentous injury to the ankle has been described and found to contribute to the instability experienced following such injuries (Freeman, Dean and Hanham 1965; Glencross and Thornton 1981).

Bastian (1888) coined the phrase ‘kinaesthesia’ to describe recognition of position during active or passive movements and resistance to movement. Sherrington introduced the wider term proprioception to include input from vestibular receptors as well as receptors in muscles, joints and bones. Early investigations of proprioception suggested that joint receptors were the determinants of position sense (Browne, Lee and Ring 1954). Later experiments found that muscle receptors could detect movement (Goodwin, McCloskey and Matthews 1972). It is likely that the appreciation of joint position sense is a composite of afferent signals from joint, muscle and skin receptors (Gandevia and McCloskey 1976; Gandevia, McCloskey and Potter 1980; Gandevia et al 1983).

The ability to determine knee position and to detect joint motion is particularly important when the knee has become unstable after ligament injury. This study investigates proprioception of the knee following rupture of the cruciate ligament using standard methods of testing.

Materials and Methods

The study group consisted of 20 subjects with torn anterior cruciate ligaments, proven arthroscopically. The mean age of these patients was 30 years (22 to 40). The time from the original injury ranged from 2 to 14 years (mean 5.25). Seventeen normal healthy male volunteers were chosen as controls, none of whom had a history of previous injury or any surgery to either knee. Their mean age was 28 years (20 to 32).

Testing of proprioceptive sensibility. Proprioception is tested in two ways. The first method consists of determining the threshold for perception of movement when the angle of the joint is altered slowly, less than half a degree per second. The second method examines the ability of a subject to reproduce an angle at which the joint had been placed, before being moved.

The method used in this study was a modification of that described by Barrack et al (1983). Two frames were constructed using 12.5 mm copper pipe (Fig. 1). The radius of curvature of the frame was 65 cm. The two side pieces of the frame were separated by a distance of 20 cm
and between the sides a cradle of radius 10 cm was fixed. The diameter of the limb with an inflated Schuco air-splint (American Caduceus Inc, Williston Park, New York) was exactly 20 cm, therefore the limb fitted snugly into the cradle into which it was strapped. One end of a wire was attached to the frame over a pulley and the other to a calibrated scale to give a direct reading of the joint angle. This allowed angular displacement to be measured from 5° to 75°. Zero degree was taken as the point at which the knee was at a right angle and the tibia vertical. The frames were suspended between vertical uprights on which were mounted geared motors which allowed them to be moved at a rate of 0.3°/sec.

The subjects lay in a reclining position on a couch. A pneumatic cuff was placed on each thigh, air-splints were applied to the legs and maintained at a pressure of 20 mmHg with the ankle in a neutral position. Horch, Clark and Burgess (1975) have demonstrated that skin sensibility fades after two minutes of sustained pressure. The legs were allowed to hang free within the cradle of each frame so that the centre of rotation (taken to be a point at the mid-patellar level and two-thirds posteriorly on the limb) corresponded to the central axis of the frame. A piece of moulded foam rubber was placed over the cuffs and strapped in position to hold the thighs still.

The limbs were then balanced with counter-weights so that, without any effort by the subject, they rested at 35° on the scale. A curtain was then drawn across the subject's chest to remove visual cues; the test procedures were then explained to them.

Threshold responses were always measured first. Random sequences of right versus left leg and up or down were performed. Five estimations for each limb were recorded and the average for each taken as the mean threshold response.

Position sense was tested by moving the limb up or down, from the starting angle of 35°, at a constant rate of 10°/sec. When the test position was reached the subject was informed and asked to concentrate on this position. The limb was left in the test position for four to six seconds before returning it to the starting position, where it was left for a period of 15 seconds. The subject was then asked to return the limb to the test position. The difference between the test position and the subject's estimate of it was measured. Again five estimations were made on each limb and the average taken as the mean position sense.

Estimations of muscle function were obtained for 11 of the subjects by measuring maximal isometric contraction using the Orthotron II dynamometer (Lumex Inc, Ronkonkomo, New York) with the knee at 60° flexion. Statistics were analysed by the two-tailed Student's t-test and linear regression by the method of least squares.

**RESULTS**

Proprioceptive data of threshold and position sense were obtained from right and left knees in both groups (Table I). In the control group there was no significant difference between right and left knees, although there was a tendency for dominant limbs to produce smaller position errors. Right and left were therefore grouped together to

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Table I. Mean threshold and position error (SD)

<table>
<thead>
<tr>
<th></th>
<th>Threshold</th>
<th>Position</th>
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<tbody>
<tr>
<td>Control right</td>
<td>1.04 (0.45)</td>
<td>2.47 (0.93)</td>
</tr>
<tr>
<td>Control left</td>
<td>1.16 (0.42)</td>
<td>2.81 (1.14)</td>
</tr>
<tr>
<td>Study group intact</td>
<td>1.88 (1.20)</td>
<td>4.94 (2.41)</td>
</tr>
<tr>
<td>Study group injured</td>
<td>2.62 (1.76)</td>
<td>5.30 (2.40)</td>
</tr>
</tbody>
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Bar chart of control and study group threshold for movement detection, position error and hamstring quadriceps ratio.

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Table II. Ratio of peak hamstring strength/ peak quadriceps strength (× 100)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control right</td>
<td>43.61</td>
<td>2.84</td>
</tr>
<tr>
<td>Control left</td>
<td>47.33</td>
<td>4.18</td>
</tr>
<tr>
<td>Study group intact</td>
<td>48.15</td>
<td>2.77</td>
</tr>
<tr>
<td>Study group injured</td>
<td>54.85</td>
<td>4.58</td>
</tr>
</tbody>
</table>
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give a common mean of 1.1° (SD 0.41) for the threshold value and 2.64° (SD 0.93) for the position error.

Maximal isometric strengths were determined for a knee angle of 60° flexion and expressed as a ratio of peak hamstring strength/peak quadriceps strength. The results of these estimations are shown in Figure 2 and Table II.

It can be seen that there is more hamstring dominance in the injured leg group than in any of the other groups. The difference, however, was not statistically significant (p = 0.2).

There has been little attention paid to the influence of ligament disruption on knee proprioception (Kennedy, Alexander and Hayes 1982). The results of our study of subjects with anterior cruciate deficient knees suggest a greater disturbance of sensory function than could be explained by the simple loss of the anterior cruciate ligament alone. Animal studies suggest that sensory receptors within the knee, which are located in the posterior capsule (Ferrell 1980) and the peripatellar nerve plexus (Wilson and Lee 1986), are responsible for signalling this proprioceptive information from the normal knee.

Proprioception versus hamstring/quadriceps ratio. The source of proprioceptive information is somewhat controversial but probably relies on joint, skin and muscle receptors. We therefore looked at the relationship between the proprioceptive data and the muscle strength ratios in the various groups. No correlation was found between position sense and muscle strength ratios in the control group (r = -0.25, p = 0.41). In the study group the good leg did not show any statistically significant correlation between muscle data and either threshold or position sense data. However, in the injured leg there was a significant correlation between hamstring/quadriceps ratio and both threshold (r = -0.74, p < 0.01) and position (r = -0.77, p < 0.01, Figs 3 and 4).

DISCUSSION

Symptoms of instability are usually well compensated for during daily activities, but become evident in sporting activities which are associated with twisting manoeuvres. This suggests that the muscles around the knee are able to compensate at relatively slow speeds, but when the speed of the activity increases this compensation becomes inadequate. Proper muscular rehabilitation can improve performance for an individual with a torn anterior cruciate ligament (Tegner et al 1984).
averaged 10% of the control leg value, while the hamstring loss was only 4%. These changes were present one year after injury and did not alter thereafter. Our study suggests that quadriceps atrophy may be an adaptive mechanism whereby proprioceptive signalling is maximised. Since the hamstrings are synergistic to the normal anterior cruciate ligament this type of muscle development would also improve stability of the anterior cruciate deficient knee (Paulos et al 1981; Feagin and Lambert 1985). Instability of any joint is caused by slipping of the joint surfaces relative to one another in an uncontrolled fashion which causes the moments of muscle action to change relative to the centre of rotation. If the rate of joint translation is greater than the ability of the muscle moments to compensate, the joint will give way. An alteration of the balance of the muscles about the knee may prevent the anterolateral translation by increasing posterior shear on the knee.

In summary, subjects with torn anterior cruciate ligaments had diminished proprioception when threshold for movement detection and position sense were measured and compared to normal healthy controls. The proprioceptive data in the study group correlated with the muscle balance of the thigh muscles. Those subjects with greater hamstring dominance showed better proprioceptive performance. In the control group, there was a lesser correlation between proprioception and muscle balance which did not achieve significance level. The quadriceps atrophy, seen in the anterior cruciate deficient knee, may be reflexly induced in order to optimise proprioception from the knee.

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REFERENCES

Gandevia SC, McCloskey DI. Joint sense, muscle sense, and their combination as position sense, measured at the distal interphalan-

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