PROPRIOCEPTION AT THE ANKLE: THE EFFECT OF ANAESTHETIC BLOCKADE OF LIGAMENT RECEPTORS

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Seven subjects with normal joints were tested for active and passive position sense of ankle inversion, peroneal reflex reaction time to sudden ankle inversion, and postural stability during single-leg stance. The tests were performed before and after regional block of the ankle and foot with local anaesthetic. Passive position sense, assessed with the muscles relaxed, was greatly impaired by anaesthesia but active position sense, with the calf muscles activated, was preserved, and the peroneal reaction time to sudden ankle inversion was not altered. The magnitude of postural sway during single-leg stance was also unchanged by anaesthesia of the ankle and foot.

The results suggest that the afferent input from intact lateral ankle ligaments is important in sensing correct placement of the foot at heel-strike, but that this input can be replaced by afferent information from active calf muscles. Afferent input from these muscles seems also to be responsible for dynamic ankle protection against sudden ankle inversion and is adequate to allow stable single-leg stance.

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Freeman, Dean and Hanham (1965) suggested that functional instability of the ankle after ligamentous injuries arose from a proprioceptive deficit due to articular deafferentation. The presence of mechanoreceptors in the ligaments and joint capsule is well documented (Freeman and Wyke 1967; Wyke 1972; Newton 1982) and it seemed reasonable to assume that if the ligaments and capsule were torn, rupture of nerve fibres would also result.

We have studied the effect on proprioceptive function of suppressing afferent information from the ligaments and capsule by anaesthetising the ankle and foot in normal subjects.

SUBJECTS AND METHODS

Seven active men aged from 27 to 38 years with normal ankles were studied by the methods described below, before and after injection of local anaesthetic.

Assessment of active and passive joint positioning. The subject lay supine with the leg supported on a splint and the knee flexed 20° to 30°; he could not see his foot which was padded and strapped to a goniometer footplate. The pivot of the goniometer was aligned approximately with the axis of inversion/eversion movement, which is 25° medial to the longitudinal axis of the foot and at 40° to the horontial plane (Inman 1976). Adjustments were then made until inversion/eversion movements produced as little rotation of the lower leg as possible. The axis found for a given subject was kept throughout the experiments.

For tests of passive movement the subject was asked to relax the leg muscles. The ankle was passively moved by the investigator, at random, to one of five positions of inversion (5°, 10°, 15°, 20°, and 25°) always starting from 0°. The inversion position was reached in one second and was held for five seconds. The ankle was then returned to the neutral position and then gradually inverted at a speed of 2°/second. The subject was asked to say when he thought that his foot had regained the initial position. The error with which he reproduced the initial position was recorded, and a mean error was calculated for the five positions.

For the tests of active movement the subject was asked to invert the ankle from the neutral position at a speed of approximately 15°/second. The foot was then held by the investigator at one of the five positions for five seconds. The subject moved his foot back to neutral and then attempted to replicate the test position actively. A mean error of active positioning was calculated as for the passive tests.

Repeatability of both passive and active positioning had previously been examined in a series of 20 normal young subjects by test-retest measurements. We found repeatability coefficients (2 × SD) of 3.4° for passive tests and 5° for active trials (Bland and Altman 1986).
**Peroneal reaction time.** A trapdoor able to tilt 30° in the frontal plane was used to simulate an ankle-spraining event. Subjects stood with their feet slightly apart with one foot on the trapdoor and the body-weight evenly distributed between the two feet. The axis of rotation of the trapdoor was just medial to the sole of the foot. The delay between release of the trapdoor and the commencement of ankle inversion was found to be a median 12 msec (95% confidence interval 10 to 14).

Surface electrodes 2 cm apart and placed parallel to the peroneous longus muscle fibres over the most protuberant part of its belly were used to record EMG activity. The signal was band-pass filtered and AD converted. The EMG and the electrical signal from the trapdoor switch were sampled at a frequency of 1000 Hz. For both signals the background noise, 100 msec before inversion commenced, was recorded and a standard deviation for this signal was found. Signals exceeding $2 \times SD$ of the background noise were considered to be the times of trapdoor activation and first peroneal EMG response. The time from the moment the trapdoor began to tilt to the first EMG response was recorded as the **peroneal reaction time** and the mean reaction time for three tests was calculated. The repeatability coefficient $(2 \times SD)$ for test-retest measurements in 20 subjects was found to be 5.6 msec.

**Postural control.** Postural control was expressed as the amplitude of sway of the centre of pressure during single-leg stance on a force plate. The subject stood with his eyes open. The force plate measured both the gravity forces and the forces exerted by the subject’s muscles in his attempts to keep the line of action within the support area (Tropp 1985). The co-ordinates of the intersection between the line of action of the total force and the surface of the plate were recorded with a sampling frequency of 33 Hz over a period of 60 seconds. An average position of the centre of pressure was then calculated. From each sampling, a transient centre of pressure was found and a transverse vector $(a)$ from the average centre of pressure to this transient centre of pressure was constructed. The transverse sway was then calculated by the method described by Jansen (1988). The mean transverse sway value of three tests was used.

**Anaesthesia of the ankle and foot.** The leg was elevated for three minutes and a tourniquet inflated to a minimum pressure of 350 mmHg just above the ankle, distal to the muscle bellies. Carbocain 0.5% (Astra, Södertälje, Sweden), 20 ml, was injected into two distal veins of the foot, half into a vein of the great saphenous system and half into a vein of the small saphenous system. Anaesthesia was considered to be complete in 20 minutes.

### RESULTS

The results of the passive and active ankle position tests with and without ankle anaesthesia are given in Table I. The mean error of passive position assessment increased from a median of 1.8° before to a median of 5.8° after injection of local anaesthetic $(p = 0.02$, Pratts test). The mean error of active position assessment did not change significantly (median 1.7° without; median 1.8° with anaesthesia; $p = 0.75$, Pratts test). The mean peroneal reaction time was a median 80 msec without and a median 83 msec with anaesthesia $(p = 0.25$, Pratts test; Table II). There was no significant change in the reaction time between the first and the third trapdoor tests $(p = 0.65$, Friedman test).

The median postural sway was 5.0 mm before and 5.4 mm after injection $(p = 0.28$, Pratts test; Table III). There was no significant change in sway values between the first and the third sway tests $(p = 0.73$, Friedman test). During anaesthesia all subjects were unable to feel tension in the lateral ligaments when the foot was stressed into maximum inversion.

### DISCUSSION

The ankle and foot complex is quite stable when loaded in a neutral position due to the structural anatomy of the talocrural joint (Stormont et al 1985), but it is unstable when moving from an unloaded to a loaded condition. This circumstance occurs during walking at the time of heel-strike. Normally, eversion is initiated when the body-weight loads the foot at the beginning of the stance phase (Perry 1983). If, however, the ankle is loaded in inversion a varus torque results and the medial malleolus loses its stabilising function and comes to act as a fulcrum for further inversion; tearing of the lateral ligaments may then result (Tropp 1985).

We have studied two situations during the walking cycle when the ankle may be loaded in inversion: when the foot is in abnormal inversion during the last part of the swing phase, just before heel-strike, but is not perceived to be at risk; and when the foot is in a normal degree of inversion at the time of heel-strike but is forced...
into abnormal inversion by an uneven surface and subsequently loaded.

In the first case the risk of excessive ankle inversion is normally avoided by the ankle's proprioceptive mechanism (Tropp 1985). In the second case injury may be avoided if the proprioceptive reflex of the ankle evertors (Tropp 1985) and of the body as a whole (Nashner 1976; Dietz, Quinern and Sillem 1987; Konradsen and Ravn 1990) is sufficiently prompt.

No ideal model exists for measuring the integrity and quality of these proprioceptive responses since it would require the ability to record the response to inversion while walking in a totally unsuspecting subject. Our methods are a compromise. To evaluate the subject's proprioceptive mechanism before heel-strike we chose a test in which the desired degree of inversion had to be reached during one second, the time usually taken for the swing phase in walking. We settled for replication of a chosen degree of inversion by the same foot having tried previously bilateral ankle matching (Berenberg, Shefner and Sabol 1987) and measurement of ankle inversion by a visual analogue model as used by Barrett, Cobb and Bentley (1991) for the knee. Neither of these methods, however, reproduced well for inversion/eversion movement. The subtalar axis is difficult to determine and is not constant for the inversion/eversion movement (Lundberg 1988). Producing equivalent axes for both feet thereby proved unreliable, and when attempting a visual replication, subjects had difficulty in picturing a degree of ankle inversion, in contrast to the better defined angles of knee flexion (Barrett et al 1991).

Our young subjects with stable joints reproduced ankle inversion angles with about the same degree of precision as has been reported for ankle dorsiflexion and plantar flexion (Glencross and Thornton 1981; Gross 1987) and for knee flexion (Skinner, Barrack and Cook 1984; Barrett et al 1991). Anaesthesia of the ankle and foot complex made assessment of passive ankle position virtually impossible, totally blocking the afferent input from the mechanoreceptors in the ligaments and capsule. However, active joint position sense persisted, suggesting that this sense was subserved by receptors in the muscles and tendons above the anaesthetised area. These results agree with several previous studies on other joints (Goodwin, McCloskey and Matthews 1972; Cross and McCloskey 1973; Vallbo 1974; Gandevia and McCloskey 1976).

It is difficult to know whether passive or active position sense is most relevant to the dynamic situation since there is controversy as to whether the peroneal muscles are active or relaxed just before and at the time of heel-strike (Glick, Gordon and Nishimoto 1976; Walmsley 1977; Shiavi et al 1981; Shiavi 1985; Mann, Moran and Dougherty 1986; van Linge 1988). Our results suggest that an accurate sense of ankle position could be present despite ligamentous rupture.

In the second situation, in which sudden ankle inversion occurs after ground contact but before ankle loading, the ankle inverts in a few tenths of a second. The subject reacts in a preprogrammed pattern (Dietz et al 1987), and EMG activity in the peroneal muscles seems to be the first active response (Konradsen and Ravn 1990). In our trapdoor model the 'true' peroneal reaction time can be estimated by subtracting the 12-msec delay from inversion of the platform to inversion of the ankle from the times measured. Our results then give a mean reaction time of 78 msec which accords well with the onset latency for the gastrocnemius in response to unpredictable accelerations when walking on a treadmill (Dietz et al 1987).

Suppression of all afferent information from the joint and ligament mechanoreceptors of the ankle did not influence this reflex which seemed to depend only on information from muscle and tendon organs. Active muscle protection may therefore be intact even although

<p>| Table II. Mean peroneal reaction time (msec) for seven subjects before and after injection of local anaesthetic |</p>
<table>
<thead>
<tr>
<th>Subject</th>
<th>Before anaesthesia</th>
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</thead>
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<td>2</td>
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</tr>
<tr>
<td>Median</td>
<td>80*</td>
<td>83*</td>
</tr>
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</table>

* p = 0.38

<p>| Table III. Mean postural sway (mm) for seven subjects before and after injection of local anaesthetic |</p>
<table>
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<tr>
<td>4</td>
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<tr>
<td>Median</td>
<td>5.0*</td>
<td>5.4*</td>
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* p = 0.59
the lateral ligaments and joint capsule have been disrupted.

Several authors have found an association between impaired postural control and symptoms of functional ankle instability (Freeman et al 1965; Itay et al 1982; Evans, Hardcastle and Frendo 1984; Tropp 1985) and it has been suggested that instability during single-leg stance reflects the proprioceptive deficit from torn ligaments and capsule (Freeman et al 1965). We found, however, that postural stability was maintained equally well with or without anaesthesia of the normal ankle and foot and our results agree with those of De Carlo and Talbot (1986). They found that postural stability was improved after injection of local anaesthetic into the anterior talofibular ligament and the lateral capsule. They interpreted this unexpected finding as due to inadequate blockage of afferent nerve fibres and to the effects of learning from repeated trials.

We venture two explanations for our findings. It may be that afferent impulses from the mechanoreceptors of the ankle and ligaments are less important than those coming from muscle and tendon receptors. It may also be that when the afferents from the joint are disrupted, higher centres quickly learn to replace this information with that from the muscles and tendons. Our results for the third recorded test were no better than those for the first, and we believe therefore that the more likely explanation is the superior importance of muscle and tendon information for single-leg stance.

In conclusion our results suggest that loss of afferent input from torn ligaments may render the ankle susceptible to undetected abnormal inversion positions and therefore to repeated inversion injuries. If the calf muscles are active, however, input from muscle and tendon afferents is adequate for the precise judgement of ankle position. The dynamic reaction to sudden inversion seems to depend only on information from muscle and tendon afferents, and information from these sources seems also to be sufficient for maintaining postural stability during single-leg stance.

Our results explain why co-ordination and strength training of the peroneal muscles can effectively stabilise a mechanically unstable ankle (Freeman et al 1965) despite rupture of the lateral ligaments, and suggest that structures other than the peroneal muscles should be utilised for the surgical restoration of ligamentous stability.

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REFERENCES


