Ankle instability caused by prolonged peroneal reaction time

Lars Konradsen[1] and Jesper Bohsen Ravn[2]

The reaction of 15 functionally unstable ankles to sudden inversion was described by monitoring muscle activity, joint motion, and alternation of the body center of pressure. The results were compared with those of 15 stable controls. Stable and unstable subjects showed a similar reaction pattern to sudden inversion: first, a peripheral reflex action, namely, a contraction of the peronei counteracting the ankle inverting momentum, and, then, a centrally elicited pattern, namely, a flexion of the hip, knee, and ankle relieving the vertical pressure on the ankle and producing ankle eversion. Unstable subjects did not show a defect in their central processing of afferent input. In contrast, a prolonged reaction time (median 84 msec compared with 69 msec in stable subjects) suggested a partial deafferentation of the reflex stabilization of the ankle and substantiated the theory of a proprioceptive deficit being responsible for ankle instability.

Although the pathology and treatment of ankle joint lesions induced by inversion trauma have been thoroughly investigated, the reflex reaction of subjects exposed to sudden ankle inversion has not been studied.

Based on a connection between functional ankle instability and an impaired ability to maintain postural control during single-limb stance (Freeman 1965, Tropp 1985), ankle stability has been suggested to be dependent on an intact reflex mechanism (Freeman 1965). Functional instability, that is, recurrent sprains and/or a feeling that the ankle gives way, may result from damage to mechanoreceptors in the lateral ligaments (Freeman 1965) or muscle/tendons (McCloskey 1978) with subsequent partial deafferentation of the proprioceptive reflex.

We have studied the reaction pattern displayed by stable and unstable subjects to sudden ankle inversion, to assess whether reflex stabilization is disturbed in functional instability, and to determine whether the deficit is situated in the peripheral reflex arch or centrally.

Patients and method

A trapdoor capable of suddenly tilting 30° in the frontal plane simulated an ankle-spraining event. Surface electromyographic (EMG) signals were recorded using surface bipolar electrodes placed 2 cm apart and centered over the muscle bellies of the rectus femoris, the biceps femoris, the peroneus longus, and the peroneus brevis muscles. The diameter of the electrodes was 5 mm. The skin was prepared by shaving off hair, by rasping the area gently with sandpaper, and by cleaning with alcohol before electrode cream was applied. In the first patient, trials were performed with both needle electrodes and surface electrodes. Because we found no differences in the recorded signals, surface electrodes were applied throughout the remaining of the investigation. The EMG signal was high- and low-pass filtered (Biomet). EMG activity was recorded for the four muscle groups every millisecond and

---

Department of Orthopedics[1], County Hospital, Hillerød, and the Biomechanical Laboratory[2], Gentofte Hospital, University of Copenhagen, Denmark

Correspondence: Dr. Lars Konradsen, Møllebakken 36 st tv, DK-3400 Hillerød, Denmark. tel: +45 42 26 76 24

saved on tape by the equipment described by Jansen (1988) for later computer analysis. A raw and an integrated signal could be extracted. The time from the moment trapdoor tilting began to the first muscular response recorded by EMG over the peronei was designated the peripheral reaction time. The time from the first muscular response recorded by EMG over the peronei to the first response over either the biceps or the rectus femoris was designated the time for central processing of the afferent input.

Joint movement of the ankle, knee, and hip was recorded by electrogoniometers and computer processed (Chatteux Corp.). Alternations of the body center of pressure were recorded on a force plate and computer-processed (Jansen 1988). The trapdoor was mounted securely on the force plate and with the corners of the trapdoor matching the corners of the force plate. To differentiate the effect of forces from the body from the impact from the ground and to exclude maldeductions caused by resonances or vibrations from impact, tests were performed with and without immobilization of the knee and hip; and the difference between the two recordings was considered to be the effect of active muscle involvement. Pressure results were considered only in the form of patterns and not in numeric values.

All the recordings could be synchronized with respect to time by simultaneous recording on tape (Jansen 1988).

Functional instability was considered to be present in subjects who complained of frequent sprains and/or sensations of the ankle giving way.

Thirty active soccer and cross-country runners were tested (median age 27 [21–32] years). Fifteen had complaints of severe instability and used tape or ankle orthoses whenever participating in sports; the rest were functionally stable. They all completed three trapdoor tests, and the shortest reaction time for each muscle was considered.

The Mann-Whitney *U*-test was used for group comparisons.

Results

When exposed to sudden ankle inversion, all the subjects reacted with an ankle dorsiflexion of a median of 20° (10°–25°), a knee flexion of 30° (20°–40°), a hip flexion of 25° (20°–35°), and a hip adduction of 5° (0°–15°) (Figure 1). There was no difference between subjects with stable and unstable ankles.

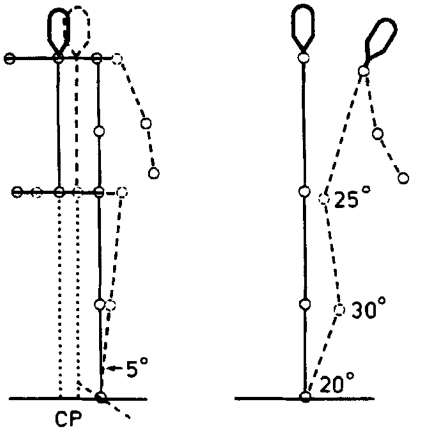

Figure 1. The reaction to sudden ankle inversion of 30°. Anterior-posterior view (left) and lateral view (right). Median degrees of flexion for each joint are inserted. CP = center of pressure.

Table 1. Peripheral reaction time and the time for central processing after sudden ankle inversion. Figures are in msec, median (range)

Functional stability	Peroneal reaction time		Central reaction time
	longus	brevis	
Stable	65 (55–78)	69 (60–80)	20 (14–23)
Unstable	82 (70–90)*	84 (70–94)*	20 (15–24)

* $P < 0.01$.

As a result of the flexion/adduction pattern, the body center of pressure moved 83 (54–103) mm in an anterolateral direction. The vertical force on the tilting foot showed an M-formed curve indicating an intermediate relief of pressure. There was no difference between the groups. To exclude that the movement of the center of pressure was due to a change in the surface angle per se and not the result of the muscular response, inversion was performed with the hip and the knee fixed in the anatomically neutral position. In this situation the center of pressure moved 13 (10–31) mm and the vertical force on the tilting foot showed no intermediate pressure relief. The joint flexion and pressure translation resulted in a median of 5° of ankle eversion.

The central reaction time was 20 msec in both groups, but the peripheral reaction time was prolonged in the unstable group (Table 1).

Discussion

Functionally stable and unstable ankles showed similar reactions to sudden ankle inversion. The build up of tension in the lateral ligaments and the lateral capsule was counteracted by (1) a contraction of the peroneal muscles and (2) a flexion of the hip and the knee and a dorsiflexion of the ankle. This relieved the vertical pressure on the inverting ankle and produced a greater ankle eversion than could be achieved with fixed joints.

Assuming that the reactions are similar to those of the triceps surae muscles under perturbations in the saggital plane (Nashner 1985, Horak and Nashner 1986, Dietz et al. 1987), the peroneal reaction is induced by a stretch reflex through a spinal pathway. The reaction of the upper leg muscles is the result of supraspinal mechanisms capable of choosing different reactions or mediating and optimizing the response to a known perturbation.

Our results suggest that functional instability is not associated with a disturbance of the central processing of afferent information from the ankle-joint area. Nor do functionally unstable subjects choose unfavorable reaction strategies. This is in contrast to the findings of Gauffin et al. (1988), where force-plate measurements on unstable subjects suggested disturbances in central motor programming.

The increase in the peroneal reaction time points to a deficit in the peripheral reflex stabilization of the ankle. The results thus substantiate the theory of a proprioceptive deafferentation being responsible for functional instability (Freeman 1965, McCloskey 1978, Tropp 1985).

Because the results corroborate the proprioceptive theory, the importance of proprioceptive training through ankle-disk training (Tropp 1985) in the rehabilitation of functional instability must be emphasized.

Acknowledgements

The study was supported by the Danish Research Council for Sports Medicine (88-2-07).

References

Dietz V, Quintern J, Sillem M. Stumbling reactions in man: significance of proprioceptive and pre-programmed mechanisms. J Physiol 1987; 386: 149–63.

Freeman M A R. Instability of the foot after injuries to the lateral ligaments of the ankle. J Bone Joint Surg (Br) 1965; 47: 669–77.

Gauffin H, Tropp H, Odenrick P. Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. Int J Sports Med 1988; 9: 141–4.

Horak F B, Nashner L M. Central programming of postural movements: adaption to altered support-surface configurations. J Neurophysiol 1986; 55(6): 1369–81.

Jansen E C. Analysis of gait and postural stability. Thesis, Lægeforeningens Forlag, Copenhagen, Denmark 1988.

McCloskey D I. Kinesthetic sensibility. Phys Rev 1978; 58: 763–820.

Nashner L M. Strategies for organization of human posture. In: Vestibular and visual control on posture and locomotor equilibrium (Eds. Igarashi M and Black F O), Karger, Basel 1985; 1: 1–8.

Tropp H. Functional instability of the ankle joint. Thesis, University of Linköping Medical Dissertations, Linköping, Sweden 1985.