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Effect of the calcaneofibular ligament on hindfoot rotation in amputation specimens

A kinesiologic study of the range of rotation in the hindfoot after cutting of the calcaneofibular ligament was performed in amputation specimens. Cutting of the calcaneofibular ligament results in a significant increment in the external rotation of the tibial-talocalcaneal joint complex and the talocalcaneal joint, maximum 5.4° and 2.9°, respectively. The total range of rotation in the tibial-talocalcaneal joint complex and the talocalcaneal joint increased 32 and 20 per cent, respectively. The calcaneofibular ligament is an important structure in the rotatory stabilization of the hindfoot.

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Introduction

Chronic lateral instability of the hindfoot is relatively common following injuries to the lateral ankle ligaments (Chrisman & Snook 1969). During the last decade, much attention has been paid to evaluating the type and localization of instability in the ankle joint (Parlasca et al. 1977, Rasmussen 1985), whereas instability in the talocalcaneal joint is rarely mentioned (Laurin et al. 1968, Brantigan et al. 1977).

Injury to the calcaneofibular ligament is common (Leach et al. 1981); during the operation of 22 ankles for chronic instability, they found the calcaneofibular ligament distorted, elongated, or even missing. On the other hand, Broström (1966) reported that in 60 operations for weakness and instability of the ankle, less than one third of the patients had evidence of a previous lesion of the calcaneofibular ligament.

In amputation specimens, we have studied the role of the calcaneofibular ligament in stabilizing the rotation in the hindfoot, especially in the talocalcaneal joint, during plantar and dorsiflexion.

Materials and methods

The experiments were carried out on 10 osteoligamentous specimens obtained after amputations for trauma, malignant tumor, or arterial disease. Only specimens macroscopically normal from 20 cm over the ankle level and distally were used. All were deep frozen to −25° C immediately after the amputation. After thawing, all tissues around the ankle region were removed, preserving the ligaments at the ankle and talocalcaneal joints. During the testing procedure, the specimens were kept moist with saline.

The fibula was pinned to the tibia in a neutral position, and the specimens were suspended from the tibia, which was fixed vertically (Figure 1). A lever was cemented from below in a prepared hole in the os calcis. The lever was aligned with the tibia with the ankle and talocalca-

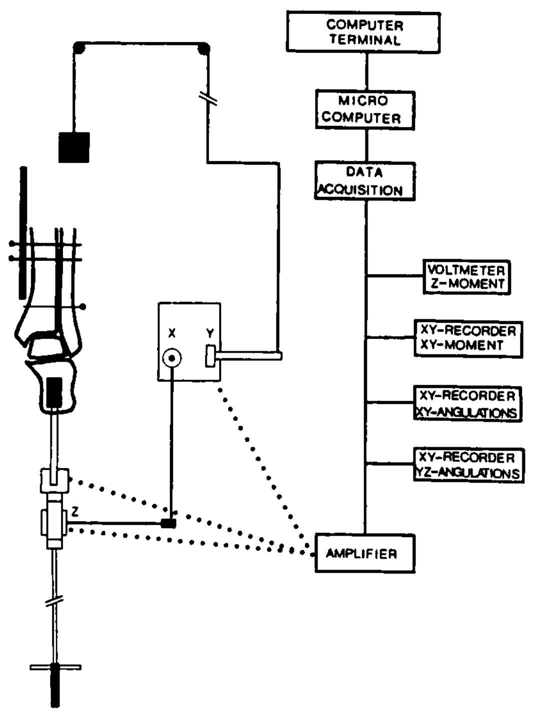

Figure 1. Experimental set-up.

neal joint in a neutral position. A potentiometer (Z) measuring the calcaneal rotation around a vertical axis, in relation to the fixed tibia or tibia-talus, was mounted just distal to the strain gauges. Abduction-adduction (X) and plantar-dorsiflexion (Y) angulations were measured by two potentiometers in a box at right angles to each other and fixed by the X potentiometer to the Z potentiometer so that they were situated at the axis of flexion of the talocalcaneal joint. The axis of angulation for the X and Y potentiometers was placed level with the tarsal sinus for measurement in both the tibial-talocalcaneal joint complex and the talocalcaneal joint. The neutral position (0°) of the hindfoot was defined as the foot at a right angle to the lower leg and the hindfoot seen from behind in a midposition of abduction and adduction. The rotatory neutral position was defined as the position when the long axis of the nonstressed foot passed through the second toe.

After calibrating for angulation and torque, abduction-adduction and rotation in the tibial-talocalcaneal joint complex and talocalcaneal joint were successively measured by operating the lever manually. The joint complex was moved from full plantar flexion to full dorsiflexion during abduction and adduction. The plantar-dorsiflexion movement was then repeated with simultaneous application of internal and external rotation torque.

The torque was kept constant at 1.5 Nm, because this torque has been found not to overstrain ligaments in ankle specimens (Rasmussen 1985). The magnitude of the torque was secured by zig-zagging the pen on the torque recorder over a square corresponding to the selected torque of 1.5 Nm so that the load varied about 1.5 Nm. Because the standard arm from the strain gauges to the joint was 15 cm, the resulting force submitted to the joint was 1.5/0.15=10 N.

Signals from the strain gauges and potentiometers were amplified with off-set adjustment to three X–Y recorders and a voltmeter (Figure 1). One X–Y recorder displayed the torque during abduction-adduction and plantar-dorsiflexion movements. The axial rotation torque was recorded on the voltmeter calibrated to 1 V/Nm numerically. Movement curves for abduction-adduction and axial rotation were recorded on the remaining two X–Y recorders. The results for torque and rotation were processed by a data acquisition system and a microcomputer and stored. Angulation and movement corresponding to the selected torque of 1.5 Nm were calculated, and the final mobility patterns were plotted (Disspla; Nielsen et al. 1985).

All the specimens passed the following sequence:

1. The motion in the tibial-talocalcaneal joint complex was registered.

2. The ankle joint was fixed in neutral position with four crossing Steinmann pins. Mobility in the talocalcaneal joint was measured.

3. The calcaneofibular ligament was cut and the mobility in talocalcaneal joint was recorded.

4. The ankle joint fixation was abolished and the tibial-talocalcaneal joint complex mobility with sectioned calcaneofibular ligament was recorded.

A paired Student's t-test was used for comparison of the results before and after section of the calcaneofibular ligament (Swinscow 1981).

Results

Tibial-talocalcaneal joint complex. Cutting the calcaneofibular ligament caused the external rotation to increase ($P<0.01$) regardless of the degrees of plantar-dorsiflexion (Figure 2). The increment ranged from a maximum of 5.4° at 15° of dorsiflexion to a minimum of 2.2° at 25° of plantar flexion.

The increment in internal rotation after cutting of the calcaneofibular ligament (1.2°–2.3°) was also significant ($P<0.02$) in the total range of plantar-dorsiflexion, although much less than the increment in external rotation.

The total increments in internal-external rotation after cutting of the calcaneofibular ligament at various levels of plantar-dorsiflexion and their percentage of the total range of rotation of the intact ligament at the same levels of plantar-dorsiflexion gives more precise information about the instability in the joint. The total rotatory

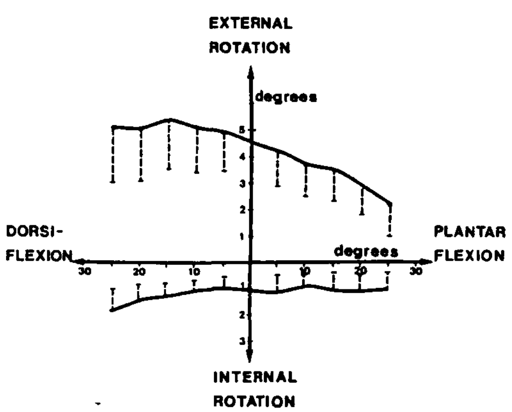

Figure 2. Increments in external and internal rotation in the tibial-talocalcaneal joint complex after cutting of the calcaneofibular ligament related to the degree of plantar-dorsiflexion. Inaccuracy is given as two standard errors of difference. The ordinate shows the actual mean motion at the intact ligament. At contact between the confidence limits and the ordinate, $P>0.05$.

Table 1. Percentage increment in rotation in the tibial-talocalcaneal joint complex (A), and talocalcaneal joint (B) after cutting of the calcaneofibular ligament

	A		B	
	Ankle position (degrees)	Increment	Ankle position (degrees)	Increment
Dorsi flexion	25	32		
	20	29		
	15	27		
	10	22	4	16
	5	19	2	20
	0	18	0	16
Plantar flexion	−5	17	−2	13
	10	14	4	16
	15	15	6	21
	21	13		
	25	11		

increments after cutting of the ligament constituted 32–11 per cent of the total range of rotation, decreasing with increased plantar flexion (Table 1).

Talocalcaneal joint. The increment in external rotation after cutting the calcaneofibular ligament was significant ($P<0.02$) in the total range of plantar-dorsiflexion and ranged from a maximum of 2.9° to a minimum of 1.4° (Figure 3). The range of plantar-dorsiflexion of this joint was only 28 per cent of the total range of plantar-dorsiflexion in the hindfoot.

The increment in internal rotation after cutting of the ligament was about 1° regardless of the degree of plantar flexion. Only the increments in the interval from neutral position to 6° of plantar flexion were found significant ($P<0.05$).

The total increment in rotation after cutting the

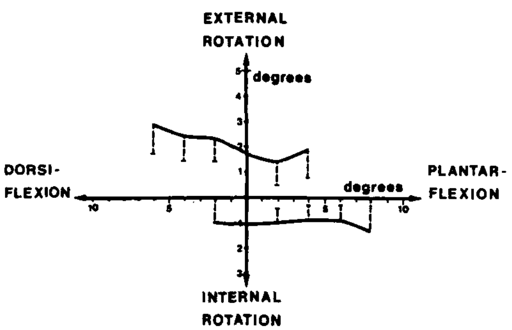

Figure 3. Increments in external and internal rotation in the talocalcaneal joint after cutting of the calcaneofibular ligament related to the degree of plantar-dorsiflexion. Inaccuracy is stated as two standard errors of difference. The ordinate shows the actual mean motion at the intact ligament. At contact between the confidence limits and the ordinate $P>0.05$.

ligament was found rather constant 13–21 per cent of the total range of rotation at the intact ligament at corresponding levels of plantar-dorsiflexion (Table 1).

Discussion

Talocalcaneal joint motion is classically described as solely supination and pronation around the axis of Henke (Close et al. 1967). Green and associates (1979) defined supination and pronation consisting of a triplane motion composed of adduction, internal rotation and plantar flexion, and abduction, external rotation and dorsiflexion, respectively.

Rasmussen (1985) stated, that cutting of the calcaneofibular ligament did not influence abduction or adduction in the ankle joints. In a previous study we found cutting of the ligament to increase adduction in the talocalcaneal joint to a maximum of 5° (Kjœrsgaard-Andersen et al. 1986). This increment was found to constitute two thirds of the total increment in adduction of the hindfoot joint complex.

Rotatory instability in the talocalcaneal joint in the horizontal plane after cutting of the calcaneofibular ligament has been studied experimental by Cass et al. (1984). Surprisingly, they found a decrease in external rotation after cutting the ligament, which may be explained by their experimental set-up. The pinning of the fibula to the tibia in our experimental set-up is important by blocking the free motion of the fibula during the hindfoot motion. By using a constant torque of 1.5 Nm, we found the maximum increment in external and internal rotation in the talocalcaneal joint to constitute 3° and 1°, respectively. Although small, both increments constituted 15–20 per cent of rotation in the joint with intact ligament.

As the calcaneofibular ligament straddles both the ankle and the talocalcaneal joints at their lateral sides, it is of interest to evaluate the stabilizing effect of the ligament on the total hindfoot complex. Cass et al. (1984) found cutting of the ligament did not change the external rotation of the hindfoot. However, we found the maximum increments in external and internal rotation after cutting the calcaneofibular ligament to constitute 5° and 2°, respectively. Our results confirm the findings of Stormont et al. (1985), who stated the calcaneofibular ligament to be the primary restraint of external rotation in the hindfoot joint complex.

It has been proposed that a persistent hindfoot instability after reconstruction of the lateral ankle ligaments could be explained by the instability in the talocalcaneal joint (Zwipp & Tscherne 1984). This has been recognized as a cause of failure after lateral ankle stabilization with the Watson-Jones procedure (Brantigan et al. 1977). Chrisman & Snook (1969) stated the Watson-Jones repair not designed to correct a lesion of the calcaneofibular ligament as the line of pull of the tenodesis is almost at a right angle to the average direction of the normal calcaneofibular ligament.

Although the experimental hindfoot motion is not directly comparable to the clinical situation, we conclude that the calcaneofibular ligament is an important structure in stabilizing the movements of the hindfoot.

When reconstructing a torn calcaneofibular ligament, care has to be taken to replace it in the anatomic position. The presence of a possible solitary lesion of the calcaneofibular ligament should be kept in mind for patients complaining of recurring distorsions of the hindfoot, where no clinical or stress-radiographic sign can be found for lateral instability (Dias 1979, Francillon 1962, Laurin et al. 1968, Rasmussen 1985, Wirth & Artmann 1977, Zwipp & Tscherne 1982).

References

Brantigan, J. W., Pedegana, L. R. & Lippert, F. G. (1977) Instability of the subtalar joint. Diagnosis by stress tomography in three cases. *J. Bone Joint Surg.* **59-A**, 321–324.

Broström, L. (1966) Sprained ankles. VI. Surgical treatment of "chronic" ligament ruptures. *Acta Chir. Scand.* **132**, 551–565.

Cass, J. R., Morrey, B. F. & Chao, E. Y. S. (1984) Three-dimensional kinematics of ankle instability following serial sectioning of lateral collateral ligaments. *Foot Ankle* **5**, 142–149.

Chrisman, O. D. & Snook, G. A. (1969) Reconstruction of lateral ligament tears of the ankle. An experimental study and clinical evaluation of seven patients treated by a new modification of the Elmslie procedure. *J. Bone Joint Surg.* **51-A**, 904–912.

Close, J. R., Inman, V. T., Poor, P. M. & Todd, F. N. (1967) The function of the subtalar joint. *Clin. Orthop.* **50**, 159–179.

Dias, L. S. (1979) The lateral ankle sprain: An experimental study. *J. Trauma* **19**, 266–269.

Francillon, M. R. (1962) Distorsio pedis with an isolated lesion of the ligamentum calcaneo-fibulare. *Acta Orthop. Scand.* **32**, 469–475.

Green, D. R., Whitney, A. K. & Walters, P. (1979) Subtalar joint motion. A simplified view. *J. Am. Podiatry Assoc.* **69**, 83–91.

Kjœrsgaard-Andersen, P., Wethelund, J-O. & Nielsen, S. (1987) Lateral talocalcaneal instability following section of the calcaneo-fibular ligament: A kinesiologic study. *Foot Ankle* (In press).

Laurin, C. A., Ouellet, R. & St.-Jacques, R. (1968) Talar and subtalar tilt: An experimental investigation. *Canadian J. Surg.* **11**, 270–279.

Leach, R. E., Namiki, O., Paul, G. R. & Stockel, J. (1981) Secondary reconstruction of the lateral ligaments of the ankle. *Clin. Orthop.* **160**, 201–211.

Nielsen, S., Hvid, I. & Andersen, K. (1985) Experimental measurement of rotatory and translatory instability of the knee joint. *Eng. Med.* **14**, 123–126.

Parlasca, R., Shoji, H. & D'Ambrosia, R. D. (1979) Effects of ligamentous injury on ankle and subtalar joints: A kinematic study. *Clin. Orthop.* **140**, 266–272.

Rasmussen, O. (1985) Stability of the ankle joint. Analysis of the function and traumatology of the ankle ligaments. *Acta Orthop. Scand.* **56**, Suppl. 211, 1–75.

Stormont, D. M., Morrey, B. F., An, K. & Cass. J. R. (1985) Stability of the loaded ankle. Relation between articular restraint and primary and secondary static restraints. *Am. J. Sports Med.* **13**, 295–300.

Swinscow, T. D. V. (1981) The *t*-tests. In *Statistics at square one.* 7nd. ed. pp. 38–42. British Medical Journal, Dawson & Goodall Ltd., The Mendip Press, Bath.

Wirth, C. J. & Artmann, M. (1977) Chronische fibulare Sprunggelenksinstabilität – Untersuchungen zur Röntgendiagnostik und Bandplastik. *Arch. Orthop. Unfallchir.* **88**, 313–320.

Zwipp, H. & Tscherne, H. (1982) Die radiologische Diagnostik der Rotationsinstabilität im hinteren unteren Sprunggelenk. *Unfallheilkd. Traum.* **85**, 494–498.

Zwipp, H. & Tscherne, H. (1984) Zur Behandlung der chronischen Rotationsinstabilität im hinteren unteren Sprunggelenk. *Unfallheilkd. Traum.* **87**, 196–200.

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