CONSIDERATIONS FOR THE DESIGN OF THE 'IDEAL' ANKLE ORTHOSIS

(ABSTRACT VERSION)

BY

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ACKNOWLEDGMENTS

The Author wishes to thank the following people for the assistance in preparation of this paper.

Dr R Borrenger and Mr Ron Avery, Cumberland College of Health Science, for their co-operation in providing access to anatomy "wet" laboratory.

Mr George Gedge, for his encouragement of the original idea for this study.

Mr Andrew Cogian, for his help in constructing the surveys.

Those athletes and related professional who took the time to complete the surveys.

Contents

Anatomy and functional anatomy

According to Wright (32) the ankle and subtalar joints function similar to a universal joint. When motion parallel to one plane is limited, for example the ankle axis during rotation of the lower leg, motion must occur at the other joint, in this case rotation about the subtalar axis. Reciprocally, where STJ ROM is restricted or exceeded in supination, the analogy of the universal joint means that this motion must then be resolved at the ankle joint, through the restricted motion of internal rotation of the talus within the ankle mortise; a motion limited by the lateral ligaments. With loss of subtalar motion (for any reason), the ankle has no relief from superimposed rotational forces as the leg rotates (43).

During a lateral ankle sprain the anterior talofibular ligament ruptures first as the limit of STJ ROM is reached, allowing the fibula to slide posteriorly, releasing the leg to externally rotate. As Rotation progresses, the calcaneofibular ligament is stressed and is the next to rupture. As this happens the loading appears to shift to the medial dorsal talus. This observation is consistent with the findings of Bruns and Rosenback (40) who demonstrated pressure increases on the medial talar border at a similar stage of ligament dissection. Along with other researchers (41,42,43) they have related the incidence of posteromedial osteochondral lesions to a history of lateral ankle sprains. Glick et al (24) however have demonstrated radiographically the inability of rigid tape to hold the talus within the ankle mortis for any time longer than 20 minutes and was in fact probably effective for less. Larsen (55) after similar findings had good reason to doubt the validity of ankle taping as a prophylaxis for chronically unstable ankles.

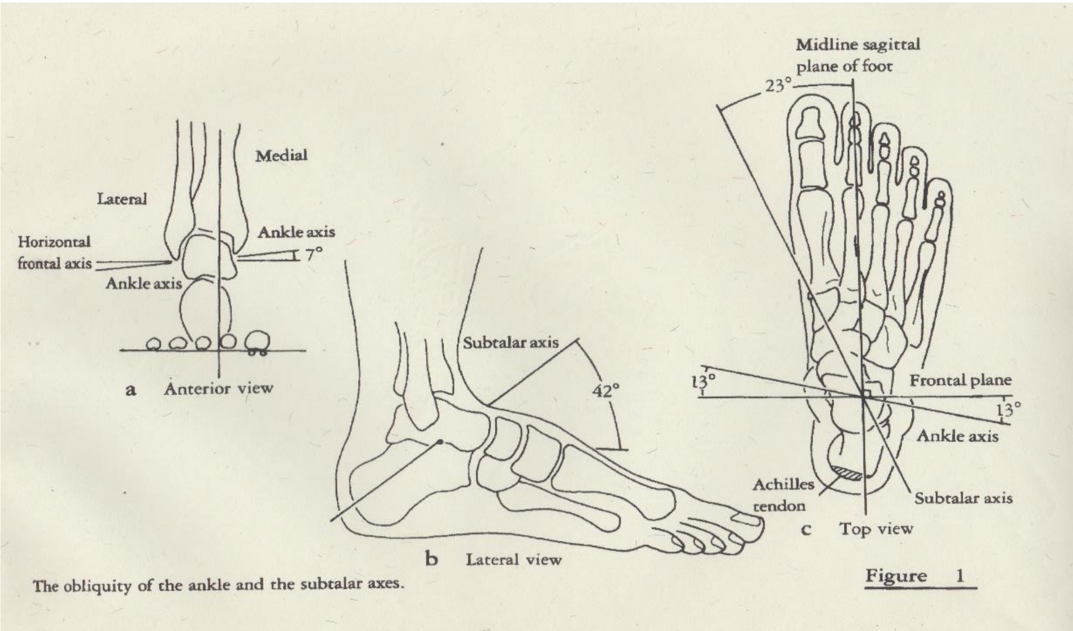

FIGURE 1 THE OBLIQUITY OF THE ANKLE AND THE SUBTALAR AXES (A) ANTERIOR VIEW (B) LATERAL VIEW (C) TOP VIEW

The shape of the articular surfaces is particularly important to the evaluation of components of joint motion. Ligaments guide and check excessive joint motion with fibre direction determining what motions are guided and limited (33). The ligaments which stabilise the ankle consist of the strong medial ligament, and the 3 bands of the lateral ligament. Together with the lateral malleolus they provide lateral stability to the ankle joint and stabilise the talus within the ankle mortise (34) (figure 1b and 2 b).

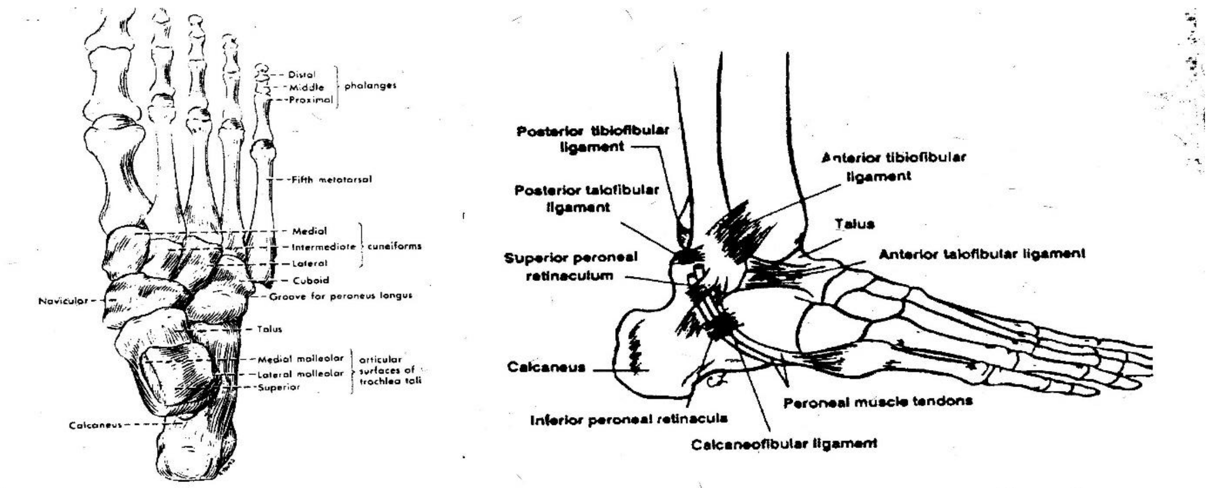

Figure 2 a).

Figure 2.b.

Figure 2

Ankle and subtalar joint motion and stability

Rotary stability in a horizontal plane is provided by tension in the collateral ligaments and by compression of the articular surfaces. It is suggested rotary instability may be an additional factor in patients whose symptoms persist after injury to the lateral ligaments (35). The ankle and subtalar axes are shown in figure 3.

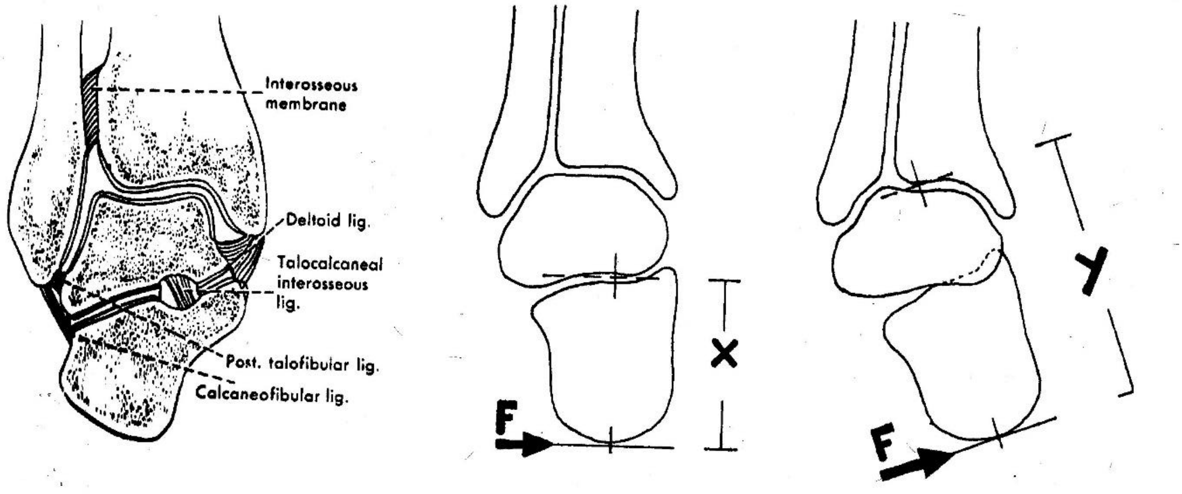

Figure 3.a.: Frontal section through the talocrural and subtalar joints. (38) page 481

Figure 3.b.: Representation of a laterally applied force along moment arm X inverting the calcaneus.

Figure 3.c.: Same force transfered to the ankle joint at the limit of subtalar ROM along moment arm Y.

Figure 3

During contact the talus and lower leg function as one unit, the calcaneus and foot as another. During this phase the foot is fixed to the surface so that any rotation of the leg must be resolved through rotation at the STJ (32).

Lateral ankle sprain mechanics

The AJ rather than the STJ is likely to be damaged during inversion stress since the thick and strong inter osseous talocalcaneal ligament (internal) and the joint capsule which maintain the joint's integrity are both close to the axis and to the applied force (figure 5a). When an inverting force is applied to the calcaneus a rotary torque is created about the STJ axis (figure 5b) along the moment arm X. When the limit of STJ motion is reached, the calcaneus and talus would then become a rigid lever Y (figure 5c). The torque is then transmitted to the ankle joint along this longer moment arm Y. If the loading force is rapid and is not resisted, the high impulse moment tending to separate the joint laterally may be greater than that which was applied about the subtalar axis.

Functional instability

Functional instability (FI) of the ankle refers to repeated sprains or giving way of the ankle (freeman et al 1965) cited by (8, 19, 20, 23) and was a residual disability presenting in 20-40% of inversion sprains (19, 21). Smith and Reischl (46) report residual symptoms in 50% of young basketball players following lateral ligament injury. It has been proposed that injury my lead to a partial deafferentation of peripheral reflex mechanisms (23).

Konradsen and Raven (23) measured the peripheral and central reaction times in unstable and stable subjects using a tilting trapdoor (figure 4a). They were able to show that peripheral reaction time was increased significantly ($p < 0.01$) in FI subjects (84 ms vs. 69 ms) and that central reaction time was uncharged (20 ms). Central reaction time was the time from the first peroneal response to the first hamstring or quadriceps response which indicated suprapinal postural adjustments and a pressure relief through a shift in the centre of pressure (figure 4b) (23). Springings and Pelton (45) demonstrated that the time for the foot to invert through 30 degrees stepping down from a height of 30 cm onto a collapsible platform was in the vicinity of 150 ms. It is postulated therefor that functional mechanisms will be insufficient to prevent lateral ligament injury during most sporting activities.

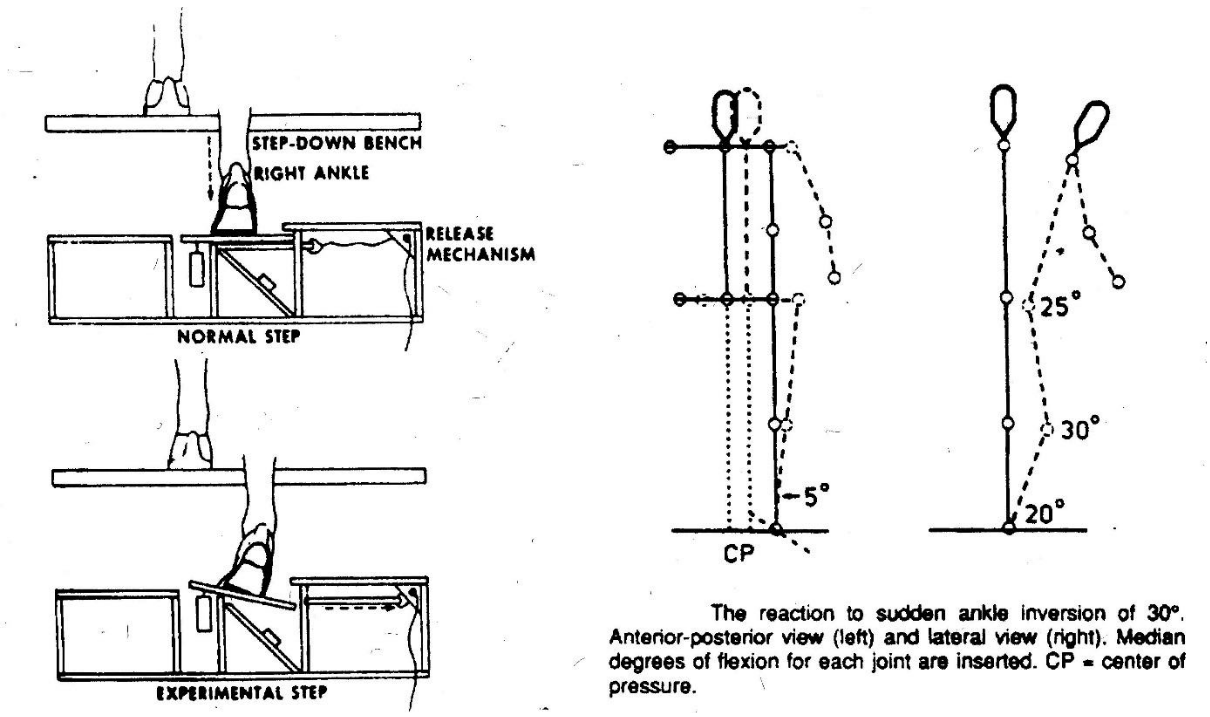

Figure 4 (a)Ankle inverting platform (45) page 73 (b) Postural adjustment to sudden ankle inversion (23) page 389.

From this discussion it can be seen that during even mild inversion stress, motion could well progress past the midpoint of motion before any spinal level reflex can be anticipated (Peroneus Longus 65 ms, Peroneus Brevis ms), and still a further 20 ms is required before postural adjustments which further absorb shock and relieve pressure, can take place (23) (see figures 4a, 4b). Since it is anticipated that most sporting landings would be more rapid than the step down studied, inversion stress could easily disable reflex as a preventive mechanism (52).

Taping and Bracing as ankle injury prophylaxes

The principle of ankle taping with its support structure established by anchors, stirrups and heel locks of rigid tape is widely used and recommended. The reports of the behaviour of this structure under exercise conditions were reviewed by the Author to identify the causes of loosening during exercise (62). The findings of this review are summarised.

The lateral stirrup and anchor sites were most affected, with tearing of the stirrups and/or displacement of the stirrup and anchor down the leg. Loosening occurred below each malleolus with the tape later functioning as a canvas boot. Tensile stress concentrations within the stirrups, high impulse loading and shear stress at the skin – anchor and anchor – stirrup junctions were believed to be responsible for the loss of support strength as the foot attempted to accommodate a normal range of motion. Perspiration contributed to loosening, affecting adhesion and inducing creep.

Statements of researchers such as Delarcerda (18) that ***"… the purpose of ankle taping is to reduce joint range of movement…."*** (p 78) have reinforced the traditional belief that to protect the ankle from injury it is necessary to restrict the ankle from inverting by limiting the ankle range of motion (ROM) in this direction.

Garrick and Requa (2) have proposed a theoretical aim of ankle taping ***"…to support externally a ligamentous structure without limiting normal range of motion of function. This support of ligaments need be present only when the physiologic or normal ranges of motion have been exceeded."*** (p 202). They also contend, ***"….the achievement of this goal, however, is virtually impossible."*** (p202).

Further, ***"… one must establish that restriction of normal motion is an adequate indicator of the protective influence of the method of support and has no other deleterious effects."*** (p202).

Gross, Lapp and Davis (17) evaluated the comparative effectiveness of Swede-o-Universal Ankle support (SO) (currently being used at the Australian Institute of Sport), Aircast Sport-Stirrup (AS) and ankle tape in restricting eversion-inversion ROM before and after exercise (10 minute figure eight running and 20 unilateral toe raises). The found that all support systems significantly reduced eversion and inversion both before and after exercise.

Robinson, Frederick and Cooper (27) used progressive stabilisation with rigid inserts insides high top basketball shoes and performance times on an obstacle course to examine the effects of systematic changes in ankle support on range of motion and performance. Their results showed that systematic changes in ankle and subtalar ROM did measurably and significantly affect performance. Several points raised in their discussion were of interest.

Firstly, ***"Directional changes require a large horizontal component of force. Positioning the leg while manoeuvring is accomplished by the normal ROM at the ankle and subtalar joints. If ankle motion is restricted, then the ability to position the leg to apply a large horizontal force component is reduced, decreasing manoeuvrability."*** P627).

Secondly, in agreement with Garrick and Requa (2), that support need only be present at the extremes of range, Robinson et al (27) state, ***"Obtaining this goal with current technology and traditions is improbable, therefore, prophylactic ankle support becomes a question of balance, with protection and performance at opposite ends of scale."*** (p 627).

Lastly, they suggest**,** ***"Further work is needed to examine the concept of an optimum ROM and restriction for adequate performance and protection."*** (p 628).

The comments of Garrick and Requa in 1973 that support at the limit of range of motion is ***"virtually impossible"*** (p202) can be understood in the context of materials and methods then available. To suggest a compromise between natural function, performance and injury prevention, serves only to emphasise the degree of stagnation present within current ankle support design, research and use.

Implications and contraindications

The restriction of natural range and function, difficulty of application and comfort considerations are some of the major reasons why sportspersons frequently compete without external prophylaxes. Since ankle prophylaxes reduce inversion ROM it can be anticipated that ROM reduction will reduce the capacity for the motion and range dependent responses to inversion stress.

The limit of motion is reached more quickly when inversion ROM is rigidly restricted and possible more frequently. Protective actions of peroneal reflex and postural adjustments are proportionately less likely to have evolved effect. The contraindications of this are that normal and abnormal inversion stresses, instead of being dissipated by muscle and postural adjustments which spread the stress over time are transferred to the leg with an impulse dependent upon the rigidly of the support material.

The effects of these repeated low loadings and occasional high impulse loadings upon the development of over-use syndromes and the ligamentous integrity of the lower limb respectively, has not been investigated. With the development of quantitative assessment techniques, it should be possible to demonstrate the effects of limitation of natural range imposed by current techniques. It will not only require that it be shown that range restrictions are detrimental to performance, function and ligamentous integrity (if this is in fact so), but that an alternative must also be available. These concerns are consistent with Ferguson (1), and relate to the importance of the “ankle safety valve”.

Design Considerations

Improvements indicated at the skin- anchor junction are directed at enhancing shear holding, stress and perspiration dissipation, whilst more effective attachment of the stirrup to the anchor is implied. By making the stirrups from an elastic material capable of storing and transmitting injurious forces over time to the anchor sites, the impulse related to stirrup and displacement in taping is reduced. Injurious forces imposed on the calcaneus will be substantially dissipated during rotation about the subtalar joint with dissipation of this force to the lower limb through extrinsic (attachment to the skin) and intrinsic (muscle forces, postural adjustments) pathways.

It would be desired to make the smallest size available to young children so that they can be protected from an early injury which could present with future complications (functional instability, osteochondral lesions, etc.). To ensure ease of application and diversity of use the substantially re-useable brace is implied. This is a consideration for use in rehabilitation since access to treatment modalities in desired. An ankle orthosis should be able to provide minimal restriction of motion at the neutral position, with support increasing to maximum at the elastic limit of joint motion.

Adjustment is desired for selecting the required amount of inversion, plantar flexed inversion and for correction of talar alignment at heel strike. The features are essential if the orthosis is to be used to non-rigidly correct rearfoot varus and valgus conditions. During rehabilitation active range of function must be controlled so that appositional healing of ligaments is encouraged. This is achieved by superiorly directed non-rigid support of the talus within the ankle mortis for extended periods. The maintenance of ankle joint articular surface contact must be achieved however without causing compensatory motion of the talus in the ankle mortis as a result of restriction of subtalar range of motion.

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