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Review

The subtalar joint: Biomechanics and functional representations in the literature

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ABSTRACT

The subtalar joint is important for gait and function of the foot and ankle. With few external landmarks, the joint is difficult to conceptualize and study *in vivo*. There have been several functional representations put forth in the literature which can be combined to give a broader understanding of the overall function and mechanics of the subtalar joint. This understanding is clinically important when considering the impact that disease has on the subtalar joint as well as how treatment of the subtalar joint impacts on the surrounding structures.

Contents

1. Introduction

Bipedal gait, known to have occurred in humans and their ancestors for the last 4.4 million years, is highly dependent on the efficient repetitive transfer of force [1]. This requires the foot to make a conformational change throughout the gait cycle so that it is flexible during early stance phase of gait while force is being transferred to the ground, yet rigid during toe off so that the body can be propelled forward. This dual function requires a complex interplay between the rigid structures that support the foot and the muscles and tendons that traverse them.

Joints of the body are often described based on related simple machines in order to help understand their function such as a ball and socket (hip) or a sloppy hinge (elbow and knee). The difficulty in understanding the function of the subtalar joint and its relation to the ankle and transverse tarsal joint is that it cannot be easily understood biomechanically as a simple machine. Additionally, the talus is an intercalated segment, without muscular attachment and a paucity of external landmarks which also makes clinical examination difficult. The geometry of these bones, their relationship to one another, and their function are complex. At each joint, motion occurs which is dependent on several factors including the anatomy of the joint surface, the orientation of the joint surface and joint axis,

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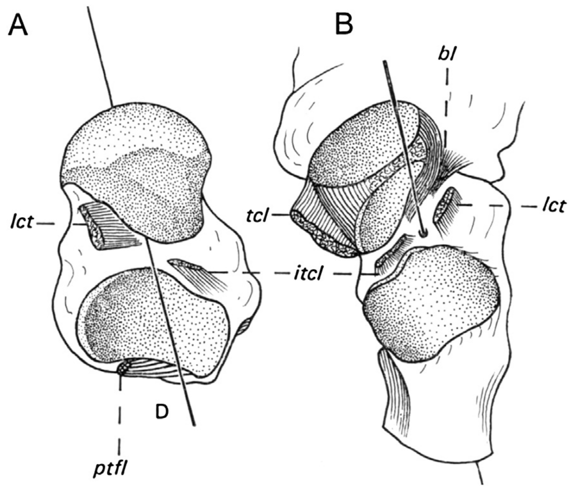

Fig. 1. (A) Inferior aspect of the talus articulates with (B) the corresponding articular facets on the calcaneus, navicular, and calcaneonavicular ligament (shown overlapping the talocalcaneal portion of the deltoid ligament, *tcl*. Note the stubtalar joint axis which runs through the center of the talar head. *bl*, bifurcate ligament; *ptfl*, posterior talofibular ligament; *ifcl*, interosseous talocalcaneal ligament; *lct*, ligamentum cervicis tali.

Used with permission, Lewis [5].

the surrounding ligaments, and the muscles that cross the joints. Technology is helping further the science but much work is still needed to bridge the basic science to clinical practice. This work aims to summarize the evidence of concepts related to the biomechanics of the subtalar joint and how they apply to foot and ankle surgery.

1.1. Anatomy

The subtalar joint is made up of three articulations between the talus and calcaneus, see Fig. 1. The posterior facet of the talus is a concave articular surface that articulates with a convex calcaneal surface. The middle and anterior facets make up the anterior portion of the joint. The floor of the anterior facet is made up of a cartilaginous articular like surface of the calcaneonavicular ligament which articulates with a convex facet of the talar neck and head. The alternating concave and convex surfaces between the posterior and anterior facets, in addition to the strong ligaments that bind the talus, calcaneus, and navicular together, make for a relatively stable joint. This is evidenced by the relatively low clinical rate of dislocation [2–4].

Anatomically, the anterior and middle facets are considered separate from the posterior facet [5]. Functionally and clinically however, they can be considered as one because they share a functional axis of motion. Although they have independent synovial cavities, they do not have independent motion, much like a door that has two hinges [6].

1.2. Axes of rotation

Motion about the ankle and subtalar joint is complex. The ankle is not a simple hinge, although conceptually it is often referred to as one. In addition to motion in the plantarflexion–dorsiflexion axis, slight abduction–adduction or rotation is present. The subtalar joint axis is less easy to conceptualize because there are few external landmarks and the axis of rotation is oblique to the traditional anatomic orthogonal planes. Subtalar joint motion combines dorsiflexion–abduction–eversion in one direction and plantarflexion–adduction–inversion in another. These motions are also commonly referred to as pronation and supination, respectively, and can be reproduced clinically as shown in Fig. 2.

Table 1
Subtalar joint axis.

	Average (°)		
	Inclination	Deviation	Number of specimen
Manter, 1941 [19]	42	16	16
Root, 1966 [58]	41	17	22
Close, 1967 [59]	42	16	3
Isman, 1969 [60]	41	23	46
van Langelaan, 1983 [61]	41	26	10
Lundberg, 1993 [9]	29	29	6
van den Bogert, 1994 [62]	35	18	14
Leardini, 2001 [63]	53	38	6
Payne, 2003 [64]	–	9	47
Arndt, 2004 [8]	34	20	2
Lewis, 2007 [65]	30.6	23.2	6
Biemers, 2008 [66]	9.5	23.6	20
Sheehan, 2010 [7]	Variable	Variable	25

In general, the axis has been described as a finite helical axis, an axis formed between two extreme static poses, although there is building evidence that the physiologic axis cannot be represented this simplistically [7–9]. When projected onto the sagittal plane, the axis lies at an angle of about 41° from the horizontal axis. When projected onto the AP plane of the foot, the axis is deviated about 23° medially and anteriorly from the midline of the foot or about 16° from an axis oriented relative to the first webspace, see Fig. 3. There is considerable anatomic variation and the values reported in studies vary considerably, as shown in Table 1. In the early studies, the axis was determined from static cadaver studies. These have been followed up by passive *in vivo* experiments as well as more recent dynamic MRI studies [7].

A useful clinical landmark is the talar head; the subtalar joint axis normally runs through the center of the talar head which can be visualized on a normal weight bearing AP radiograph [10,11]. The relationship between the subtalar joint axis and the talar head has been shown to be reproducible throughout the range of subtalar joint motion [12]. A few studies have shown the radiographic projection of this nonorthogonal axis to have some clinical utility [13–15].

1.3. Range of motion

The values for the magnitude of subtalar joint range of motion are reported by different methods and vary widely but it is generally reported as an inversion–eversion motion as shown in Table 2. In analyzing the published literature, it can generally be concluded that total normal motion ranges from about 40° to 60°, with inversion motion greater than eversion.

Table 2
Subtalar joint range of motion.

Author	Year	Subtalar joint range of motion
Fick [11]	1911	20° min–45° max
Manter [19]	1941	10–15°
Hicks [10]	1953	24°
Wright [25]	1964	6°
Beetham [67]	1965	50° (30° inversion to 20° eversion)
Close [59]	1967	9.9–28.0°
Kapandji [68]	1970	20°
Lanz-Wachsmuth [69]	1972	60° (30° inversion to 30° eversion)
Ambagtsheer [70]	1974	45°
Inman [16]	1976	10° min–65° max
MacMaster [71]	1976	30° (25° inversion to 5° eversion)
Brantigan [72]	1977	38° (SD 5°)
AMA [73]	1988	50° (30°inversion to 20° eversion)