Reviewer's report

Title: Biomechanics of the Natural, Arthritic, and Replaced Human Ankle Joint

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Reviewer: Scott Wearing

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GENERAL COMMENTS
1. This paper provides a comprehensive narrative review of ankle prostheses and ankle joint biomechanics during gait. In general the paper is well written but would benefit by reducing the length of the text (particularly of sections 2.1 & 2.2.1) and further English copy-editing.

SPECIFIC COMMENTS
2. Page 3, Abstract
Consider indicating “… ankle joint complex plays a fundamental role…” as the paper discusses the talocalcaneal and talocrural joints.

3. Page 4, Para 1
Further clarification of terminology and joints/structures involved in the ankle joint complex (AJC) would be beneficial. The text currently indicates that the ankle joint is formed solely by the tibiotalar joint. However, the role of the inferior tibiofibular and fibulotalar joint in the talocrural articulation has not been defined.

4. Page 4, Para 1. “Motion at these two joints is guided by the osteoarticular and ligamentous structures and induced by the forces and moments of the extrinsic muscles.”
Consider rewording as external forces can also induce motion.

5. Page 4, Para 1. “The lever arm lengths are measures of the ability of muscles to produce joint torque in order to generate rotation and/or to resist external forces.”
Lever arm lengths are only one aspect of a muscles ability to produce joint torques – presumably PCSA of the muscle, MTU length etc also have an influence. Please consider re-wording the text.

6. Page 4, Para 1. “… instability or disability …”
The text would benefit from a definition of both instability and disability. While instability is defined later in the text, it would seem reasonable to define it on first use.

Page 5, 1.1 Joint mobility in the normal ankle
It is a little surprising that the previous research on ankle joint motion, including
that of Hicks, Sammarco et al, Siegler et al, Lundberg, 1989, Singh et al, Kitaoka et al. etc have not been addressed in the review.

7. Page 5, Para 2. “In particular, knowledge of the changing geometry of the passive structures throughout the range of passive flexion (mobility) is necessary for a successful mechanical analysis of the response of the joint to external load (stability)”

This sentence is somewhat confusing. As written the text would seem to indicate that mobility reflects passive flexion only. However, mobility can also be influenced by muscular activity. Similarly, stability, as defined, is influenced by both passive and active structures.

Please consider revising the text to help clarify this point.

8. Page 5, Para 2. “…(49° vs 30°)…”

Please indicate that the talocrural joint is associated with 49° of rotation and talocalcaneal is associated with 30° of rotation.

9. Page 6, line 1. “…three anatomical planes were found on average about 15°, 8°, and 8° at the ankle, 7°, 10°, and 7° at the subtalar (Lundgren et al. 2008).”

Consider modifying to “were found to be on average about 15°, 8°, and 8° at the ankle joint, and about 7°, 10°, and 7° at the subtalar joint (Lundgren et al. 2008).”

10. Page 6, Para 1. “…In these joints therefore, rolling as well as sliding occurs, …”

Do the authors mean rotation and translation? If not, please define rolling.

11. Page 6, Para 1. “A more isometric pattern of rotation …”

This sentence is somewhat confusing as written. Presumably, the authors are indicating that (sagittal?) rotation of the talocrural joint takes place with minimal change in length in the calcaneofibular and tibiocalcaneal ligaments? Please consider revising the text.


As above, the term ‘isometric pattern of rotation” is confusing”. Is it the authors contention that strain was minimal in the CaFi and TiCa ligaments with dorsi/plantarflexion? Please consider revising the text.

13. Page 6, Para 3. “Therefore, the ankle complex exhibits one degree of unresisted freedom and the subtalar joint complex behaves as a flexible structure which moves only because of soft tissue deformation when loaded.

The authors provide evidence for the tibiotalar joint acting as a single DOF mechanism in the previous sentences. However, evidence indicating that the subtalar joint moves only due to soft tissue deformation has not been provided and this would benefit from some discussion/justification.

14. Page 6, Para 3. “…by the isometric rotation of the two ligament fibres about
their origins and insertions, without tissue deformation.”

Figure 3 of Leardini et al (2009a) would seem to indicate that TICaL and CAFIL strains may be of the order of 5-10% during dorsi/plantarflexion, while those of other ligaments were generally higher. This level of strain is not insignificant given that many ligaments fail at strains of around 15%. The authors should clarify this point further within the text.

15. Page 9, Para 1. “At each joint position within the flexion arc, the ligament structures which resist the external force change not only orientation, but also the thickness …”

While a change in ligament orientation with flexion is understandable, it is not clear what is meant by a change in ligament thickness (especially in light of earlier statements that there is negligible ligament deformation). Stagni (2004) seem to report changes in length and orientation. The section of text would benefit from further clarification.

16. Page 9, Para 1. “For these phenomena, considerable and complex motion occurs at the many foot joints; in the literature, these mechanisms have been analysed and presented as ‘shock absorption’, ‘navicular drop’, ‘windlass mechanism’, ‘foot clearance’, ‘elica podalica’ (helical airscrew between the rear- and fore-foot) etc.”

Please consider providing relevant references for interested readers.

17. Page 12, Para 1. “Three-dimensional kinematics has been assessed also by means of electromagnetic tracking techniques, although limited to the hind-foot only (Woodburn et al. 2002; Rouhani et al. 2012).”

The study by Rouhani et al. appears to have used inertial sensors rather than electromagnetic tracking techniques. Please revise the text appropriately.

18. Page 13, 2.2.1 “In the arthritic ankle”

The relevance of the first two paragraphs of this section are not apparent (especially in light of the section title). They appear to report rearfoot motion secondary to arthritis involving the forefoot and/or non-specified arthritis. The authors should consider deleting these paragraphs, modifying the section title, or revising the text appropriately.


Please spell out the acronym “TAR” on first use.


Please provide an appropriate reference for the high prevalence of complications with ankle arthrodesis.

21. Page 15, Para 1. Although neither arthroplasty nor arthrodesis restored normal walking speed or lower limb movements, the former group after arthroplasty had greater motion at the ankle, a symmetrical timing of gait and restored ground reaction force patterns, whereas ankle arthrodesis resulted only
in a faster gait with a longer step length compared to arthroplasty.

This text seems to be repeated in the final paragraph of Page 15, although with different supporting references. Please consider revising the text to avoid duplication.

The observation that walking speed and step length are significantly greater with arthrodesis, despite reduced ankle range of motion, seems somewhat disparate and warrants some discussion.

22. Page 15, Para 3. “Increased motion at the hip and knee joints, in ankle power and flexion moment were also measured (Brodsky et al. 2011).”

Please provide greater detail regarding the study. Increased with respect to what?

23. Page 15, Para 3. “Nearly physiological motion and loading in the replaced ankle were observed also during stair climbing (Cenni et al. 2013).”

The research design used by Cenni et al. did not include a control group and consequently conclusions regarding a “near normal physiological motion” were based on previously published values rather than via direct statistical comparison. In addition Cenni et al. noted several differences between operated and non-operated limbs, which seem important but have not been reported. These additional points should be made clearly to the reader.

24. Page 16, Para 1. “For most ligaments, reaction forces remain within corresponding physiological ranges.”

This sentence would imply that either some ligaments are overloaded secondary to TAR or that the mathematical model may not have accurately reflected internal stresses in all ligaments. The authors should comment on this point within the text.

25. Page 16, Para 3. “TAR designers has been…”

Please use plural form ie “TAR designers have been…”

26. Page 17, Para 1. “…unconforming, semi-constrained designs (Figure 10) are sought because these allow for the necessary mobility…”

The text is somewhat confusing. Totally congruent surfaces can allow full mobility but only in a given plane of motion. Presumably, the authors use the term ‘mobility’ to indicate that incongruous surfaces allow non-planar movement (ie greater DOF)? Some clarification of this point is required.

27. Page 18, Para 1. “…and has proven to be unsatisfactory in practice also for knee replacements.

Please provide an appropriate reference.

28. Page 19, Para 2. “A ligament-compatible TAR design can achieve better clinical results (Giannini et al. 2010), a low wear rate (Affatato et al. 2007) and a good recovery of function (Ingrosso et al. 2009).”
It is difficult to understand the statement that the TAR design can achieve “better” clinical results, when the study by Giannini et al appears to have evaluated only one design and did not evaluate a comparator design. Rather Giannini et al reported improvements in clinical outcomes with time following surgery.

Similarly, Affatato et al. 2007 evaluated wear rates in only one design hence direct comparison to wear rates of other designs is problematic.

The text should be modified accordingly and to indicate that direct comparisons and long term outcome studies are required for more definitive conclusions.

29. Figures
Please ensure there are in-text references to all 12 Figures. Figures 4, 5, 6, 9, 12 do not appear to have been cited within the text.

Is permission required or been obtained for Figure 6?

30. References
Please ensure references comply to the Journal format

**Level of interest:** An article whose findings are important to those with closely related research interests

**Quality of written English:** Needs some language corrections before being published

**Statistical review:** No, the manuscript does not need to be seen by a statistician.

**Declaration of competing interests:**

I declare that I have no competing interests