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REVIEW

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Biomechanical Analysis of Walking Stability During Pregnancy and the Fall-Prevention Effects of Negative Heel Shoes

PhD thesis

Doctoral School: University of Pannonia, Doctoral School of Chemical Engineering and Material Sciences

Reviewer: Dr. habil Molnár Ildikó

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The revised version of the doctoral dissertation addresses a highly relevant and multidisciplinary research topic situated at the intersection of biomechanics, clinical sciences, and applied engineering. The investigation of walking stability during pregnancy and the potential role of footwear interventions remains both scientifically significant and socially relevant. Compared to the previously submitted version, the dissertation shows clear and meaningful improvements, particularly in the clarity of theoretical framing, methodological transparency, and articulation of research objectives. The candidate has demonstrably considered several of the earlier critical remarks and has strengthened the internal coherence of the work.

The structure of the dissertation remains logical and follows the standard format expected of a PhD thesis. The organization into introduction, methods, results, discussion, and conclusions is appropriate, and the overall length remains justified by the complexity of the research questions.

Introduction and literature review

The introductory chapter is extensive, well-structured, and significantly more analytically developed than in the earlier version. The discussion of pregnancy-related biomechanical changes now demonstrates a more consistent effort to distinguish between mechanical loading, structural adaptation, and neuromuscular control mechanisms (e.g. separation of loading vs. tissue stiffness effects in foot deformation).

A notable improvement is the more cautious and scientifically precise interpretation of connective tissue changes, avoiding overly simplified assumptions about uniform ligament laxity. The author also makes a stronger attempt to highlight uncertainties and inconsistencies in the literature, which strengthens the academic rigor of the review.

At the same time, the literature review still remains predominantly descriptive in certain sections. Although synthesis has improved, the explicit identification of a clearly defined research gap and its direct translation into a tightly formulated research strategy could be further strengthened.

Aims and hypotheses

The revised thesis now includes a clearer statement of aims and hypotheses in Chapter 1.5, which represents a significant improvement compared to the previous version. The three main research directions remain focused on the mechanical drivers of foot deformation, the nature of gait adaptation as either an active or passive process, and the stability-related effects of footwear. These objectives are logically derived from the existing literature and provide a coherent framework for the investigation.

Although the aims are now more clearly articulated, the hypotheses could still be formulated in a more explicitly testable and operationalized manner. In particular, a clearer specification of the expected direction of effects, the measurable variables involved, and the criteria used for validation would strengthen the scientific rigor of the work. Consequently, the dissertation occasionally reads as a hypothesis-informed exploration rather than a strictly hypothesis-driven investigation.

Methodology

The methodological framework remains one of the strongest aspects of the dissertation and has been further clarified in the revised version. A major strength of the work is the successful integration of finite element modeling, gait analysis, and musculoskeletal simulation. The use of pregnancy-specific anthropometric adjustments is methodologically important and enhances the relevance of the models employed. Furthermore, the application of parametric modeling enables the separation of individual mechanical factors, while the use of Induced Acceleration Analysis allows for a deeper biomechanical interpretation of gait adaptations.

The methodological descriptions are now more transparent than in the previous version, and the overall workflow is easier to follow, particularly regarding the finite element modeling procedures and gait data processing.

Despite these strengths, several limitations remain. The finite element model is still based on a single subject, which restricts the generalizability of the findings. In addition, the absence of EMG validation remains unchanged, meaning that conclusions related to neuromuscular mechanisms continue to rely on indirect evidence. The footwear intervention was also limited to short-term observations, which constrains the interpretation of its real world relevance. Although these limitations are acknowledged by the author, their implications for the strength of the conclusions could be emphasized more explicitly.

Results

The results are clearly structured and follow the stated hypotheses more closely than in the earlier version of the dissertation. The distinction between the effects of loading and tissue stiffness on foot deformation is convincingly demonstrated, and the integration of model based and experimental findings has been substantially improved. The presentation of gait adaptation as a coordinated, multi-level process is also persuasive and contributes to the overall coherence of the work.

The results sections are now more consistent, and the transition between the methodological descriptions and the reported findings is smoother. Nevertheless, there are instances in which the interpretation extends slightly beyond the direct evidential basis, particularly with respect to conclusions concerning neuromuscular control. Moreover, the relationship between intermediate findings and the final conclusions could be articulated more explicitly, especially for readers who may be less familiar with computational modeling approaches.

Discussion and interpretation

The discussion has been substantially improved in the revised dissertation. The author integrates the findings more effectively with the existing literature, distinguishes more clearly between mechanical explanations and broader interpretations, and acknowledges uncertainties in a more consistent manner.

The interpretation of gait adaptation as a conservative strategy aimed at maintaining stability is generally well supported, and the biomechanical reasoning is more nuanced than in the previous version. Nevertheless, two issues remain noteworthy. First, the distinction between active and passive mechanisms of gait adaptation is still derived exclusively from modeling results. Second, the proposed relationship between biomechanical indicators and reduced fall risk remains indirect. Consequently, these interpretations should be presented primarily as informed inferences rather than as direct empirical evidence.

Evaluation of thesis points

Thesis 1

The separation of the mechanical drivers of foot deformation, specifically loading and stiffness effects, through finite element modeling remains a clear scientific contribution. The revised version offers a more nuanced interpretation of the findings, which strengthens the argumentation. However, the limitation associated with the subject-specific nature of the model remains. Overall, this thesis point can be accepted as a new scientific result, provided that the conclusions are expressed with appropriate caution.

Thesis 2

The interpretation of gait adaptation as an expression of active neuromuscular control has been strengthened through improved theoretical grounding. However, the lack of EMG validation remains a significant limitation, and the conclusions continue to rely exclusively on model-based inference. Therefore, this thesis point is acceptable, but it should be explicitly presented as a biomechanical interpretation derived from modeling rather than as direct evidence of neuromuscular control.

Thesis 3

The revised dissertation provides a clearer biomechanical explanation of the relationship between center-of-mass and center-of-pressure behavior in the context of negative-heel footwear. Nevertheless, the investigation remains limited to acute effects, and no direct evidence concerning fall risk is provided. As a result, this thesis point represents a valuable applied contribution, but it should not yet be interpreted as clinical evidence for fall prevention.

Questions for the public defense

How could EMG validation be incorporated in future investigations to strengthen the conclusions regarding neuromuscular control? To what extent might psychological factors, such as fear of falling, contribute to the observed gait adaptations? How could future research establish a direct relationship between biomechanical indicators and actual fall risk?

Final evaluation

The revised dissertation shows clear improvement over the previous version, particularly with respect to conceptual clarity, methodological transparency, and scientific positioning. At the same time, several important limitations remain, most notably those related to the generalizability of the findings, the reliance on indirect model-based inference, and the absence of longitudinal validation.

Despite these limitations, the dissertation demonstrates a high level of methodological competence, strong analytical thinking, and an original scientific contribution to the field. Overall, the work meets the expectations of doctoral level research and represents a valuable addition to the literature.

In light of the above considerations, I recommend that the dissertation be accepted and that the candidate be admitted to the public defense.

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