# Mechanistic analysis of pelvic floor functionality using musculoskeletal simulation

**Ina Adler**[1], Nikolas Förstl[1], Hana Čechová [2], Vít Nováček[2], Franz Süß[1], Sebastian Dendorfer[1,3]
[1]Laboratory for Biomechanics, OTH Regensburg, Regensburg, Germany
[2] New Technologies – Research Centre, University of West Bohemia in Pilsen, Pilsen, Czech Republic
[3] Regensburg Center for Biomedical Engineering, OTH and University Regensburg, Germany
Email: ina.adler@oth-regensburg.de

## Summary

There is consensus that knowledge about the fundamentals of the pelvic floor remains incomplete, particularly regarding the sensitivity of individual pelvic floor muscles to posture variations. This study aimed to investigate the effects of variations in pelvic tilt and the point of force application induced by changes in posture on pelvic floor activity using musculoskeletal simulation. A parameter study analysed various loading cases, highlighting the coherent response of individual pelvic floor muscles to loads. Muscle activities and forces were compared across different force application points and pelvic tilt angles. A key finding was identifying peak muscle activity conditions that could help better understand the causes of pelvic floor disorders.

## Introduction

Despite its central role, particularly in the area of female health, there is consensus that knowledge about the fundamentals of the pelvic floor is incomplete [1–3]. Nevertheless, several studies have found associations between pelvic floor muscle activity and posture, especially when comparing women with and without pelvic floor disorders [4–6]. However, further research is required to determine the specific sensitivity of individual pelvic floor muscles to variations in more targeted postural parameters.
Therefore, the aim of this study was to investigate the effects of changes in pelvic tilt and point of force application induced by changes in posture on pelvic floor activity. For that purpose, a newly developed musculoskeletal model of the pelvic floor based on anatomical and biomechanical data was used for parameterized analysis. This work is dedicated to basic research and aims to better understand the functioning of the pelvic floor through mechanistic analysis.

## Methods

To perform biomechanical analyses of the female pelvic floor, a musculoskeletal model of the pelvic diaphragm was generated. All muscles were implemented as Hill-Type using literature data. A sensitivity study was conducted to assess the reliability of the model and to identify any potential uncertainties. It incorporated all input parameters of the Hill-Type-Muscle model and the kinematics of pelvic floor muscles. A subsequent parameter study was then used to investigate altered loading cases of the pelvic floor. The modified variables for this parameterized analysis were the pelvic tilt and the point of application of the load acting on the pelvic floor. The subsequent analysis focused on the resulting activation of the muscles and muscle forces.

## Results and Discussion

The results demonstrate a coherent reaction of individual pelvic floor muscles to different loading situations. A comparison of muscle activities and forces at varying points of force application on the pelvic floor muscles, as well as at different pelvic tilt angles, demonstrated varied responses of the respective pelvic floor muscles. Figure 1 provides a visual representation of pelvic floor muscles' reactions to different load stages. This methodological approach enabled the analysis of the reactions of pelvic floor muscles in their totality, while facilitating the investigation of the responses of individual muscle parts. A significant finding of this study was the identification of conditions of peak muscle activity that potentially correlate with the occurrence of pelvic floor dysfunctions.

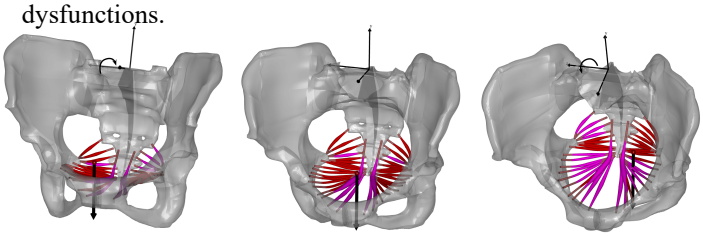

**Figure 1**: Visualization of pelvic floor muscle reactions to loads with different points of force application and tilt angles in representational form. The muscles strands are colored respective to different stages of activity. Higher activities are highlighted by a more intense color. The arrow represents the load acting on the pelvic floor.

## Conclusions

This musculoskeletal model of the pelvic floor offers a systematic, mechanistic representation of its functionality, enabling a deeper understanding of pelvic floor biomechanics as well as a more effective analysis of pelvic floor disorders. It allows for advanced conclusions on more targeted postural parameters influencing muscle activity and provides valuable insights for developing preventive and therapeutic approaches in urogynecology and rehabilitation.

## Acknowledgments

This work was supported by the project no. BYCZ01-014 of the Program INTERREG Bavaria – Czechia 2021–2027.

## References

[1] Elad D. and Abramowitch S. (2015). *J. Biomech.*, **48**:1509-1510.
[2] Bø K. and Nygaard IE. (2020) *Sports Med*., **50**:471-484.
[3] Moser H. et al. (2018). *Int Urogynecol J*., **29**:179-196.
[4] Zhoolideh P. et al. (2021). *Muscle Lig. Tendon. J.*, **11**:77.
[5] Jórasz K. et al. (2022). *Int J Envir Res Pub Health* **20**:369.
[6] Capson AC. et al. (2011). *J Elect. Kinesiol*. **21**:166-177.