Evaluating the loads on the female pelvic floor during full-body activities using computational models

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Summary

This work investigated the loads on the female pelvic floor during various full-body movements using computational models to calculate abdominal pressure and organ dynamic loads. While high-impact exercises resulted in higher loads, other movements showed lower loads, potentially indicating, which movements may be performed without risking pelvic floor overload and subsequent dysfunctions.

Introduction

The pelvic floor, composed of muscles, fascia and ligaments supports the pelvic organs at the lower trunk. Its functionality depends on the loads the pelvic floor tissues experience [1]. These loads result from the gravitational and inertial forces of the organs and abdominal pressure [2]. Failure to withstand these stresses can lead to disorders like stress incontinence, pelvic organ prolapses or fecal incontinence [1]. Nearly 24% of women in the US suffer from these symptoms [3], which can severely affect the quality of life [4]. The aim of this study was to investigate the stresses placed on the female pelvic floor during various full-body movements and to identify the movements that could potentially overload the pelvic floor. Since these loads are hard to measure in full-body movements, new computational models were developed to estimate them.

Methods

A marker-based motion capture system (Vicon Nexus 2.15) was used to record female subjects performing physiotherapy exercises, activities of daily living and high-impact exercises. Pelvic floor loads during these exercises were calculated using a combination of two computational models.

The AnyBodyModelling system (AMMR4-beta, Aalborg, Denmark) was used to calculate the abdominal pressure forces, while additional forces generated by the organs were determined using a new model developed in RecurDyn (FunctionBay, Seongnam, South Korea). Relevant organs and their attachment structures (e.g. ligaments and mesenteries) were identified. Using an MRI dataset, the origin and insertion points of the ligaments were localized, and the mechanical parameters of the organs (center of mass, mass, inertia tensor) were determined. The organs were modeled as rigid bodies, while the attachment structures were represented as springs with non-linear stiffness based on literature. Simplified rigid bodies simulated the boundaries of the abdominal cavity, including the pelvic floor. Kinematic data from the exercises were applied to the trunk structures to simulate organ dynamics. Contact modeling predicted pelvic floor loads from collisions between the organs and the pelvic floor. The model was validated with kinematic data of pelvic floor structures. The final load on the pelvic floor was estimated by summing the two derived force components.

Results and Discussion

The counter-movement jump (high impact exercise) was chosen as an example to illustrate the results. Figure 1 shows the total load on the pelvic floor, the force composition from organ and abdominal pressure loads, and the pelvis vertical position. During the stance phase, the load from organs and abdominal pressure remains nearly constant increasing during the downward and upward movements. While these load components approach zero during the flight phase, maximum pelvic floor loads occur during landing, when the pelvic floor decelerates the organs, and abdominal pressure rises to stabilize the trunk. However, there is currently no medical threshold for when the pelvic floor is considered overloaded.

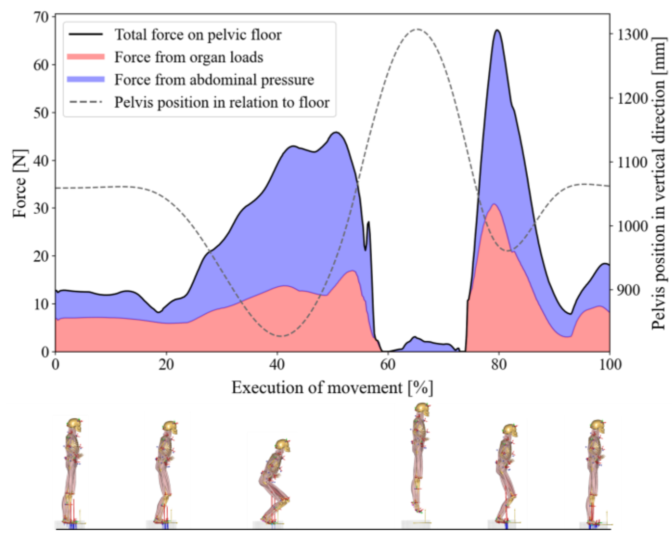

Figure 1: Pelvic floor loads during a counter-movement jump

Conclusions

The calculated loads may help identify movements that avoid pelvic floor overload and the development of dysfunctions.

Acknowledgments

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