Multi-segment Models Used for Kinetic Analysis in Pregnant Women: A Systematic Review

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Summary

This systematic review evaluated 14 pregnant-specific multi-segment models used across 19 kinetic studies, focusing on their development, applications and limitations. These models employed varying methods for estimating body segment inertial parameters such as regressions or 3D digital shape models. Applications focused on daily activities (e.g. gait and chair-rise), primarily in the third trimester. However, most models lack validation and detailed lumbopelvic modeling. Most musculoskeletal models relied on static optimization, limiting their accuracy for muscle force estimation. Future research should focus on developing validated and personalized models to better understand pregnant-related movement adaptations and musculoskeletal disorders.

Introduction

During pregnancy, significant physiological, morphological, and hormonal changes profoundly affect biomechanics, increasing the risk of falling and musculoskeletal complaints, especially in the third trimester [1]. To understand movement adaptations and musculoskeletal disorders in pregnant women, kinetic analysis using pregnant-specific multi-segment or musculoskeletal models is essential. This review aims to evaluate the development, applications and limitations of such models intended for kinetic analysis in pregnancy.

Methods

This study followed a systematic review methodology, the PRISMA guideline review methodology [2].

Results and Discussion

A total of 14 different pregnant-specific multi-segment models used within 19 kinetic studies met the selection criteria and were included in this review. The selected studies were of high quality, with a scoring ranging between 80% and 100% and a mean score of 90%.

Pregnant-specific Modifications: Nine models used scaling tools to create their segment geometry. Body Segment Inertial Parameters (BSIPs) were mainly estimated by regression equations (5 out of 14) or 3D digital shape models (3 out of 14) [3]. About one-third of these models are musculoskeletal models, including three of them which modified abdominal muscle paths. However, none changed musculotendon parameters.

Applications for Kinetic Analysis: Numerous research (8 out of 19) utilized models to explore lower-limb kinetics during gait or other activities during pregnancy, while many others (8 out of 19) applied models to evaluate lumbopelvic loads. Most studies (17 out of 19) included the 3rd trimester of pregnancy as their research focus. More than one-third of these studies (7 out of 19) focused on pregnant-related gait analysis, and many studies (6 out of 19) explored the sit-to-stand motion. Some studies (4 out of 19) examined standing posture, or in conjunction with some specific tasks while standing. Most studies (14 out of 19) utilized Inverse Dynamics (ID) to compute joint moments. Most studies of musculoskeletal models (3 out of 5) employed Static Optimization (SO) to estimate muscle forces, while other studies applied the Genetic Algorithm (GA) [5].

Limitations: Most pregnant-specific models lack validation. Low back pain and pelvic pain are prevalent in pregnant women, but models with detailed and advanced lumbar spine and/or pelvic modeling are rare. Muscles play a significant role in pain, yet pregnant-specific musculoskeletal models are still limited. Most musculoskeletal models rely on SO for muscle force calculations, which overlook muscle co-contraction. The pregnancy-induced anthropomorphic changes are sometimes pregnant-specific for different subjects. More personalized musculoskeletal models for pregnant women with accurate BSIP estimates are essential in the future research.

Conclusions

Most existing pregnant-specific models lack validation and detailed lumbopelvic modeling, and mainly relied on static optimization for muscle force calculation, which neglects co-contraction. Future research should prioritize the development of more detailed and validated models, alongside advanced workflows for more accurate model personalization and muscle force estimation, to better account for the biomechanical changes during pregnancy.

References

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