The Concurrent Equivalence and Reliability of In-Lab Markerless Motion Capture in Estimating Joint Kinematics during Load Carriage

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Summary

Load carriage can alter trunk and lower limb biomechanics, increasing the risk of musculoskeletal injuries. Marker-based (MB) and markerless (ML) motion capture provides a deeper understanding of these biomechanical changes, aiding in reducing injury and enhancing the safety of service members (SM) and first responders. Limited research has assessed the agreement between these modalities during load carriage. The purpose of the study was to evaluate a MB and ML motion capture system in estimating trunk, pelvis, hip, knee, and ankle sagittal plane kinematics during load carriage. The findings suggest that MB and ML systems measure knee flexion similarly, but greater variability is observed during trunk, pelvis, hip, and ankle kinematics during load carriage.

Introduction

Many SM and first responders are required to carry heavy loads while remaining highly aware as an integral aspect of their job. Carrying weighted loads requires postural adjustments leading to restricted mobility, decreased situational awareness, and increased injury rates, particularly within the trunk and lower body [1]. Load carriage negatively impacts gait as the load causes an increase in trunk flexion, pelvic tilt, hip rotation and abduction, and knee flexion [1, 2]. A greater understanding of these biomechanical changes will ensure mission completion while minimizing injury.

Motion capture evaluates biomechanical changes of load carriage. MB systems assess movement through the use of reflective markers placed on bony landmarks to detect joint centers in space. ML motion capture eliminates the use of markers and utilizes deep learning models to estimate 3D positioning. Currently, there is limited data reported on the use of a ML system in estimating kinematics during load carriage. The purpose of this study was to evaluate *Theia3D* (ML) compared to a MB system in measuring trunk, pelvis, hip, knee, and ankle sagittal plane kinematics during load carriage.

Methods

Participants (n=12) completed ten walking cycles while carrying an 18 kg pack. Sixty strides were analyzed using a Concordance Correlation Coefficient (CCC) and modified Bland Altman (MBA). The CCC and MBA evaluated the agreement and reliability between the modalities in estimating maximum trunk flexion, pelvic tilt, hip flexion, knee flexion, and ankle dorsiflexion from right heel strike (RHS) to RHS during load carriage.

Results and Discussion

The ML and MB systems indicated low agreement and reliability in estimating trunk, pelvis, hip, and ankle sagittal plane kinematics, but greater equivalence and reliability in estimating knee flexion. The results displayed sporadic kinematic measurements, larger limits of agreement (LoA), and low reliability for trunk flexion (CCC=0.10), pelvic tilt (CCC=0.04), hip flexion (CCC=0.20), and ankle dorsiflexion (CCC=0.20), indicating greater uncertainty between the modalities. The variability observed could be attributed to different modeling methods of the motion capture systems. Conversely, a moderate correlation (CCC=0.60), smaller LoA, and consistent kinematic measurements were observed during knee flexion, indicating greater agreement (Figure 1). These results suggest that joint kinematics with larger ranges of motion, such as knee flexion, are highly comparable between the motion capture systems during load carriage.

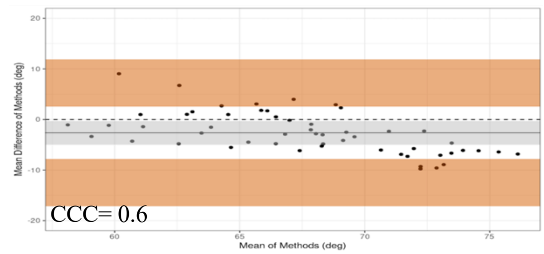

Figure 1: Sample MBA plot and CCC value for knee flexion.

Conclusions

The findings suggest that MB and ML modalities measure knee flexion similarly, but display differences in evaluating trunk, pelvis, hip, and ankle sagittal plane kinematics during load carriage. While both systems pose limitations, the MB and ML modalities may be better suited for specific scenarios. The MB systems should be used in controlled environments, while ML systems can measure kinematics more precisely when joints are occluded. During load carriage, the pack could obstruct joint centers, making the ML technology an effective alternative for measuring kinematics to overcome occlusions.

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References

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