Can 2D motion capture validly detect gait events during overground human walking?

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Summary

Force plate and 3D motion capture methods can accurately detect gait events during human walking, but these methods are restricted to laboratory settings. Here we show that a portable 2D motion capture approach can validly detect gait events based on acceptable agreement with these gold-standard methods. Our approach could be useful for informing exoskeleton support profiles to assist everyday walking.

Introduction

Accurately detecting human gait events is crucial for understanding muscle-tendon unit function during different phases of locomotion and for optimizing the support profiles of exoskeletons that assist human walking. However, current gold-standard gait event detection methods are restricted to laboratory settings. If we want to effectively assist human walking outside of the laboratory with lower-limb exoskeletons, then we must study walking in everyday settings [1], which requires accurate in-field gait detection. Therefore, we aimed to assess the gait detection agreement between portable 2D motion capture and current gold-standard methods during overground walking.

Methods

Kinematic quantities, including the timings of heel strike (HS) and toe off (TO), and ground contact time (GCT), were assessed in sixteen healthy, young participants (mean±SD: 25.7±2.8 yr, 1.73±0.08 m, 66.9±9.9 kg) while they walked overground at their preferred speed and cadence. A minimum of ten walking trials were performed per participant while they walked with their habitual footwear over a 10-m tartan track in one direction. This tartan track had an embedded and isolated force plate (Kistler, Winterthur, Switzerland) in its center, which recorded vertical ground reaction force (vGRF) at 1200 Hz. Concurrently, right ankle joint kinematics were also recorded using 3D marker-based motion capture at 120 Hz with 8 cameras (Vicon, Oxford, UK) and a lower-limb marker set (Plug-in Gait), as well as using 2D video capture at 300 Hz with one camera (Exilim Pro EX-F1; CASIO Europe GmbH) secured to a tripod at shin height in the sagittal plane. Data was synchronized by a LED light that was triggered during 3D motion capture recording.

HS and TO were determined from vGRF data using a 7 N threshold and GCT was defined as the duration between HS and TO. 3D kinematic data was quantified using Vicon Nexus (v2.12), and Tracker (v6.2.0, Physlets) was used to obtain 2D ankle angle by tracking landmarks on the lateral femoral condyle, lateral malleolus, and fifth metatarsal head. HS and TO were determined from sagittal-plane ankle-angle data using a peak vertical acceleration approach [2]. Agreement between methods was estimated using Bland-Altman analysis.

Results and Discussion

GCTs varied between methods, being lowest with 2D motion capture (571±57 ms) and highest with force plate detection (700±61 ms). Relative to 3D motion capture, 2D motion capture underestimated GCT by 9±1 ms (Fig. 1), which was largely driven by early (-52±22 ms) TO detection. Compared to force plate measurements, the 2D method detected HS 7±19 ms too early and TO 130±27 ms too early. Based on an average force-plate GCT of 700 ms, this represents a 1% and 19% error, respectively, which we deem as acceptable for HS detection but unacceptable for TO detection.

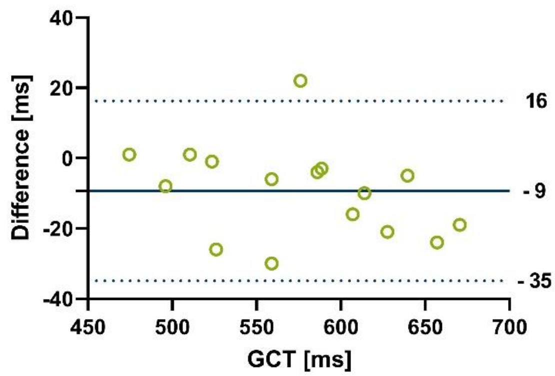

Figure 1: Bland-Altman plot comparing 3D and 2D motion capture GCT. The solid line represents the mean 2D bias, while the dashed lines indicate the 95% limits of agreement (±1.96 SD). Data points show individual differences.

Conclusions

Although the same marker set was used to determine HS and TO, 3D motion capture showed better agreement with force-plate-based detection than 2D motion capture. However, 2D motion capture showed acceptable agreement with 3D motion capture regarding GCT and HS. Unfortunately, the peak vertical acceleration approach detected TO too early from 2D motion capture, which might be mitigated by using a jerk approach [3] that needs to be tested before a portable method can be used to inform exoskeleton assistance during walking.

References

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