The opportunities and limitations of inertial motion capture for horse-rider kinematic analysis

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Summary

This study evaluated the validity of different data processing methods applied to a multi-inertial unit (MIMU) system, for kinematic analysis of a horse-rider on a riding simulator. MIMU systems rectify displacement drift in post processing using foot-contacts. However, some activities, such as equestrian sports, lack foot contacts. The reliability and repeatability of joint angles derived from the standard post-processing method, and an alternative approach of fixing the pelvis in space were assessed. Fixing the pelvis in space improved repeatability of joint kinematics but prevented analysis of pelvis linear displacement. Standard processing enabled pelvis displacement analysis but exhibited lower repeatability and evident drift. Findings highlighted the need for further development of MIMU and related data processing methods to support research of non-pedal activities in non-laboratory environments.

Introduction

Horse-rider biomechanical analysis is challenged by spatial requirements and involvement of large animals. The low-cost and practicality of inertial measurement units makes them alluring tools to expand research in activities challenging to investigate in laboratory conditions [1]. Especially with the integration of advanced data processing methods addressing inertial motion capture challenges, such as the exacerbation of orientation error following sensor fusion, known as drift [1]. Processing techniques have mostly been developed for bipedal activities involving regular ground contact used as a zero-velocity update to correct drift. Some systems, such as MVN Awinda (Movella Inc., U.S.A., 2021), offer the possibility to fix the pelvis in space, in the absence of regular ground contact [3]. This approach though limits pelvic kinematic analysis, essential in horse-rider biomechanics [2], and lacks validation. This study describes an approach to using MVN Awinda for a seated sport and assesses processing methods it offers for rider kinematic analysis completing a jumping simulation on a riding simulator.

Methods

Five female riders (mean ± sd: 63.8 ± 3.3 kg, 171.5 ± 4.5 cm) performed a jumping simulation, on a riding simulator (Racewood Ltd, U.K. 2017), on two separate days. Continuous full body kinematic data were recorded at 60 Hz using MVN Awinda with one sensor fixed to the simulator. Individual static (N-pose) and dynamic (walking) calibrations were performed [3]. MVN sensors were affixed to riders over their riding equipment (including boots and helmet), thus segment measurements and calibration were done accordingly. Data were processed in high definition, in MVN Analyze (Movella Inc., U.S.A., 2024) using single-level (SL) and no-level (0L) scenarios. The former utilises foot contacts to correct drift, and the later fixes the pelvis in space. In Visual 3D (HAS-motion, Canada, 2024), a 4th order lowpass Butterworth filter with a 10 Hz cut-off frequency was applied to displacement data. Elbow, shoulder, hip, and knee joint angles, and pelvis displacement were extracted in all three axes. In MATLAB (R2024.a, Mathworks, U.S.A.), data were time normalised to jump cycles defined by simulator vertical velocity minima framing the jump. Continuous means were estimated over 9 jumps per rider, per day. Root mean square error (RMSE) was calculated between 0L and SL joint angle data. Repeatability of processing methods was assessed using mean RMSE comparing day 1 and 2 data. RMSE were also normalised to range of motion (NRMSE).

Results and Discussion

Comparing 0L and SL across all joint angles, mean RMSE was 5.9 ± 7.7º (NRMSE: 43%), showing the impact of processing differences. Flexion angles showed higher RMSE (13.7 ± 9.2º) than abduction (1.5 ± 0.4º) and rotation (2.5 ± 1.7º), reflecting greater sagittal plane motion. Flexion angles had lower NRMSE (31%) compared to abduction (43%) and rotation (54%).

Joint angles were more repeatable with 0L processing (RMSE: 5.5 ± 2.9º) than SL (7.3 ± 6.4º), but pelvis displacement could only be obtained using SL. Mean SL pelvis displacement repeatability was 0.1 ± 0.1 m, NRMSEs varied from 60% (vertical) to 499% (anteroposterior). Drift and repeatability issues were evident in continuous pelvis position plots (Figure 1).

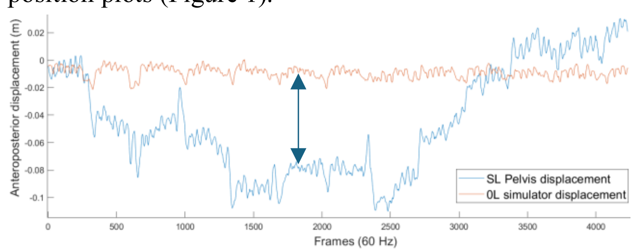

Figure 1: Effect of drift (arrow) on anteroposterior position of a rider’s pelvis processed in SL (blue) compared to that of the simulator, processed in 0L (red).

Conclusions

MVN Awinda captured continuous rider kinematics under challenging circumstances. Further development of processing methods is required, though, to allow comprehensive, reliable kinematic analysis of activities involving no pedal support, in the field.

Reference

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