Development and Analysis of Multi-Dimensional Head-Trunk-Pelvis Movement Models During Seated Reaching Tasks

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Abstract

Six healthy subjects (22-27) were assessed during seated reaching at multiple speeds, with targets randomly placed in four directions at the boundary of the subject's workspace. Pitch, roll, and yaw angles of the pelvis, trunk, and head were compared across reach directions, speeds, and across multiple segments in same direction and speed trials.

Results indicate that the trunk is primarily responsible for maintaining postural balance for with high exertion tasks, while subsequent segments tend to overcompensate for balance.

Introduction

Seated reaching tasks are incredibly common and crucial for ease and quality of everyday life. These tasks are even more important for individuals recovering from stroke or spinal cord injuries, which often limits patients to upper body movement initiated from seated positions, e.g. wheelchairs.

In order to develop support devices and physical therapy for spinal cord injury (SCI) patients, detailed movement and coordination data is needed to obtain insight into healthy movement patterns of the pelvis, trunk, and head during seated reaching tasks. Coordination data is especially useful for identifying segment dependencies and guiding training protocols during physical therapy [1].

[1] Peeters, L.H.C., Kingma, I., Faber, G.S. et al. Trunk, head and pelvis interactions in healthy children when performing seated daily arm tasks. Exp Brain Res 236, 2023–2036 (2018).

Methodology

Tracker data from the pelvis, trunk, head, and hand were collected for three repetitions of each set of conditions (target direction and speed) from each subject. The pitch, roll, and yaw angles between the inertial frame and pelvis (pelvis-seat), trunk-pelvis, and head-trunk were then averaged across repetitions for each subject, and across subjects.

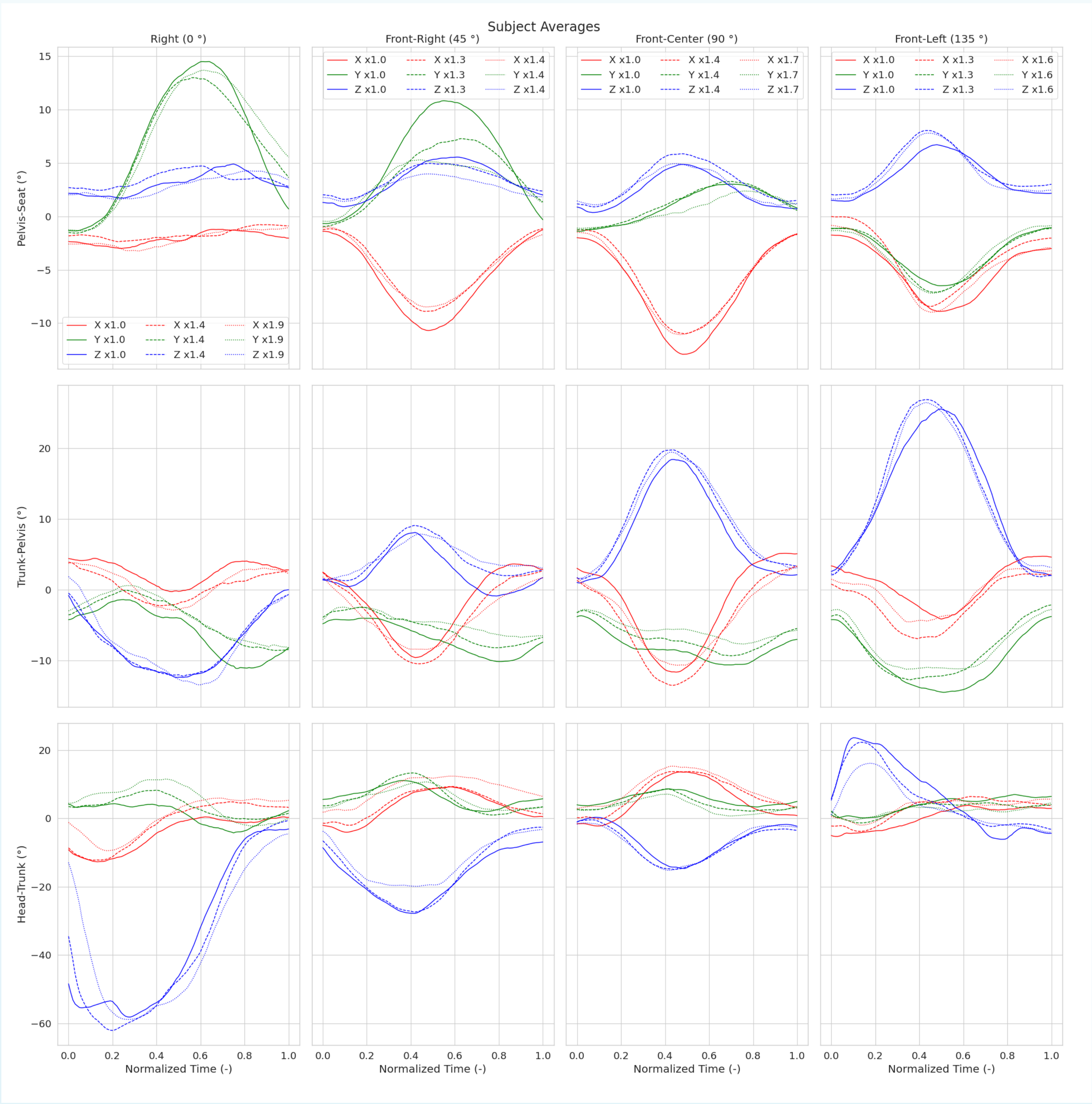

Figure: Average Pitch-Roll-Yaw Across Subjects

Movement patterns were compared across speeds for each segment in each direction, with ANOVA tests used to identify significant deviations of the segment's pitch, roll, and yaw at extreme reach. These deviations were then isolated and compared across segments to identify coordination patterns using cross-correlation tests. Additionally, the correlation of pitch, roll, and yaw from multiple segment movement patterns in each set of conditions were tested for significance.

Results

The movement of the trunk with respect to the pelvis deviated significantly ($p < 0.01$) from the baseline pattern with increased speed in all conditions, but more so in front reaching trials. Most noticeably in roll for front-center trials, trunk deviations across speeds typically opposed pelvis deviations, while head deviations across speeds typically opposed those seen in the trunk.

Head-trunk rotations were consistent across speeds during front-center trials, but showed significant deviations in right, front-right, and front-left conditions. Across all speeds, however, head rotations in yaw preceded those of the trunk and pelvis, with significant cross-correlation values.

Conclusion

Opposing deviation patterns across segments at increased speeds suggest that healthy adults are unable to maintain typical postural balance during high speed seated reaching tasks and are forced to compensate for imbalances in subsequent segment rotations. Since this pattern is most significant for roll in front-reaching trials, the results indicate that flexion introduces more significant postural imbalances than lateral flexion or axial rotation.

Since head-trunk rotations were relatively consistent in front-reaching, this suggests that the trunk is primarily responsible for postural balance during flexion tasks. However, results indicate that the head tends to lead during axial rotation, and therefore contributes more to postural balance.

Recommendations

Movement data at natural speeds is useful for identifying healthy movement patterns. However, data from trials with increased movement speed also offers insight into coordination mechanisms during unbalanced and high exertion tasks. These deviations from typical movement patterns can provide significant information on healthy postural balance mechanisms, and guide physical therapy for similar tasks in SCI patients.

The results indicate that the trunk is primarily responsible for postural balance during flexion tasks, which tend to have more imbalances during high speed movement. Thus, training postural balance for flexion in SCI patients could benefit significantly from training the pelvis and trunk.

Conversely, axial rotation is typically initiated by the head during seated reaching tasks. SCI patients with impaired trunk or pelvis movement may therefore increasingly rely on the head for axial rotation tasks, and may benefit from neck-head restraints when training rotational movements.

Acknowledgements

I would like to acknowledge the Amazon SURE program for making this research possible, and everyone in the ROAR Lab for their support over the course of this project. The encouragement and assistance of my mentors, as well as the support from my peers made my time incredibly fulfilling despite the obstacles I had to overcome.