Validation of Whole Body COM Calculation in Children Using the Gait Initiation Task

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Introduction

The whole body center of mass (COM) is a useful biomechanical index of motion, since it represents the net result of all limb movements and force production during a specific task. Its use is becoming more widespread to assess both balance and overall gait performance, as the tools of modern 3D motion analysis have improved [1]. During quiet standing, the projection of the whole body COM in the ground plane coincides with the center of pressure (COP), making the comparison of these two quantities an excellent empirical method for validating COM models. In our laboratory, we have taken the COM and COP calculations from gait initation tasks to evaluate the integrity of new analytical models. Gait initiation data suits this purpose well because it contains both quiet standing (when COP equals COM in ground plane) and dynamic trajectory data as the subject begins walking.

Statement of Clinical Significance

This investigation shows that the accuracy of the calculated whole body COM for subjects (under 14 years of age) was improved after applying a correction factor to a commonly used full body model (Johan.mod). It also demonstrates that gait initiation is an appropriate gait task to routinely record as a method to ensure accurate COM calculation.

Methodology

Data from 6 normal subjects participating in a larger study were selected for this investigation. The data collection began with the subjects having their height, weight, and distance from several bony landmarks measured. Thirty-five retro-reflective skin markers were placed on areas of the subject's head, chest, arms, and legs bilaterally. A 6-camera Vicon 512 kinematic measurement system was used to record and digitize three-dimensional displacements of the markers as the patient performed a gait initiation task. The ground reaction forces were recorded using 4 Kistler Model 9281C piezoelectric force platforms embedded in the floor. The gait initiation task involved the patient standing with each foot on a separate force platform (2 and 3) in the 1-2-1 force platform array. When a visual cue was given, the patient initiated gait. A 13-segment whole body kinematic model was processed. The whole body COM was then calculated using the Johan model by Eames et al [2] and the Vicon WorkStation default model. The Johan model uses Jensen's age scaling data [3] to account for changes in segment COM and mass percentage from growth. These models were used to calculate the COM of each body segment, and sum these segments to find the whole body COM. In the original Johan model for subjects under 14 years of age, the mass percentages of the individual body segments did not sum to 100%, as they did for subjects over 14. Mathematically, the percentage must sum to 100% for this to be a true calculation of the composite COM (or centroid) of the whole body. A scaling factor was calculated in the model, based on the subject's age, that scaled the mass percentages of the individual body segments to sum to 100%. COP and gait event data were exported from Vicon WorkStation and COM data was exported from Vicon BodyBuilder for further processing in Igor Pro engineering analysis software. In Igor Pro, the composite COP from both feet was calculated.

Graphs were then produced to display the COM projection trajectories versus the COP trajectories. Visual inspection and distance from the COM trajectory origin to the quiet standing composite COP were used to compare how well the COM position in the quiet standing component of the gait initiation task matched the composite COP position.

Results

A correction to the calculation of whole body COM for children under 14 years of age, with anthropometrics scaled to age, was applied to the Johan model. The total percentage ranged from 97.7% at age 0 to 96.9% at age 12. Once this correction was applied, the whole body COM was found to have a lower mean error at gait initiation than the other 2 models. The results for the six subjects are summarized in Table 1, where subjects 4, 5, and 6 were below age 14 years. Figure 1 shows a typical comparison.

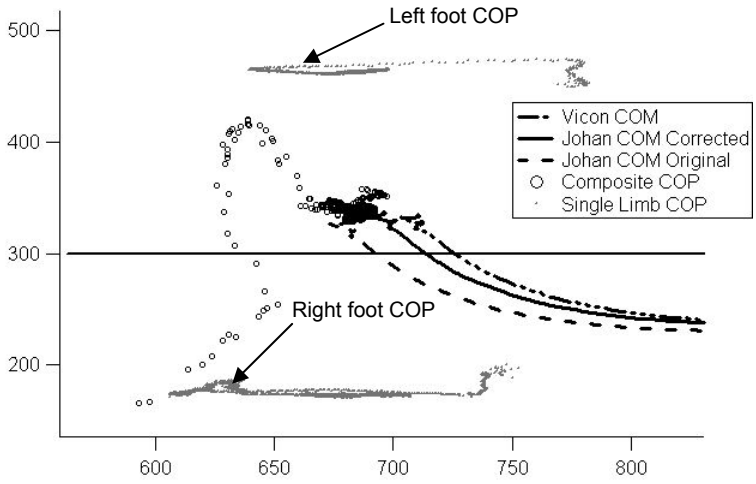

Figure 1: COM and COP Trajectories

Subject	Vicon COM	Johan COM	Johan COM Corrected
1	3.2	0.7	0.7
2	4.1	1.1	1.1
3	2.8	2.1	2.1
4	2.1	1.7	0.2
5	3.0	1.8	1.2
6	2.8	1.5	0.7
Mean	3.0	1.5	1.0
StD	0.67	0.51	0.65

Table 1: COM / COP Error (cm)

Discussion

When calculating the whole body COM location for children under 14 years of age with the uncorrected Johan model, the greater the magnitude of the COM, the greater the error. This creates a problem when calculating whole body COM across large areas. It can be seen in Figure 1 that a small shift in the starting point shifts the entire trajectory significantly, introducing error throughout the trajectory. These results support the inclusion of the task of gait initiation in any COM walking trial as a simple method to ensure system/model accuracy.

References

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