OPTIMIZATION OF FULL BODY KINEMATIC MODELS FOR THE ASSESSMENT OF PEDIATRIC GAIT AND POSTURAL STABILITY.

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INTRODUCTION

Estimating the position of the Centre of Mass (COM) of individual body segments and of the whole body has served a fundamental role in developing our current understanding of the neuromuscular strategies involved in the control of postural stability and gait [1,2]. In addition to this body of work, the dynamics of whole body COM displacement have been studied to understand the mechanical work done [3] and its relationship with the metabolic cost of walking [4]. This field of research has significant importance for ambulatory children living with disabilities where it is of primary interest to develop interventions that will optimize functional mobility and participation in the community. Within this context, there is a greater interest to understand the associated demands of activities such as running which are dynamic in nature. The emergence of new technology has provided opportunities to develop simpler measurement tools that are adaptable to a variety of conditions, however attention should be focused on accurately capturing key clinical information for each patient population.

The assessment of COM displacement during gait has primarily been performed using a multi-segment kinematic model or through the double integration of ground reaction forces obtained from a force plate [5]. In children and youth, a rapid change in segmental mass distribution associated with growth has led to the development of age specific anthropometric parameters [6] that may be integrated into a kinematic model. Previous work has found a strong agreement between this approach and the ground reaction force method [5]. However, muscle spasticity, skeletal deformity and muscle atrophy is often found in children with Cerebral Palsy and Muscular Dystrophy. The presence of these attributes is often perceived as an internal rotation of the femur, tilt of the pelvis, and rotation of the thoracic cage or shoulder complex. In light of these complex postural deformities, attention should be devoted to the implementation of kinematic models that are sensitive to detecting changes that may occur with disease progression or therapeutic intervention.

OBJECTIVES

The present project falls within the context of a longitudinal research program at Bloorview Kids Rehab that is focused on further understanding the normal development of gait and postural control in able bodied children and children with disabilities. The objective of this study was to compare two approaches to estimate the position of the COM during a dynamic task such as running. Building off this work, the overall goal is to determine and/or develop techniques and/or models for COM estimation that may be accurately applied to children with disabilities across a number different tasks and activities.

METHODS

Participants

This ongoing work is presently recruiting able-bodied male and female participants aged between 3 and 21 years old. Presently we have collected 5 youth with an average age of 12±2 years (weight 43±12 kg, height 1.6±0.10 m).

Task Conditions

Participants were asked to perform three tasks in the laboratory. The first task involved standing in a quiet upright standing position, followed by level over ground walking and running at a self selected pace.

Instrumentation

Each participant underwent a standardized gait assessment in the Human Movement Laboratory at Bloorview Kids Rehab. This involved the identification of 44 anthromopetrical landmarks located bilaterally on the feet, shank, thigh, pelvis, trunk, arms, forearms and head. Reflective spheres (6 mm diameter) were placed on these landmarks, and their 3-Dimensional co-ordinates captured by a 7 camera Vicon Mx system (sampling frequency 120 Hz). Two Bertec multi-axial force plates embedded in the floor captured ground reaction forces and the centre of pressure.

Outcome parameters

The whole body COM displacement in reference to the laboratory reference system was calculated for walking and running utilizing anthropometric parameters developed for children (COM-seg) [6]. This COM model was compared to one point located on the posterior aspect of the pelvis at the level of the 1st sacral vertebra (COM-pel). To account for existing postural abnormalities, postural alignment parameters such as pelvic tilt and shoulder-pelvic rotation were estimated [7].

RESULTS

The segmental angles calculated for the standing condition revealed minimal postural abnormalities in the participants (pelvic tilt: -1.2º±1º; shoulder-pelvic rotation: -1.7º± 2.7º). For the walking and running conditions, the average spatial-temporal parameters are presented for 4 participants in Table 1.

Table 1: Spatiotemporal parameters for walking and running.

	Velocity (m/s)	Stride Length (m)	Cadence (steps/min)	Percent Stance (%)
Walking	1.4 (0.2)	1.3 (0.2)	128 (10.5)	57.6 (2.0)
Running	3.3 (0.8)	2.2 (0.6)	178 (15.6)	35.6 (5.5)

Visual inspection of the COM-seg, and COM-pel displacement in the vertical direction revealed similar phase and amplitude characteristics (Figures 1 and 2). However, in the medial-lateral direction, the COM-pel was out phase with the COM-seg and had different amplitude characteristics. For walking a partial phase shift was evident (Figure 3), while for running a full, 180 degree phase shift was seen in some subjects (Figure 4). The average range of COM displacements in the vertical and medial-lateral directions across subjects are presented in Table 2.

Table 2: Average range of COM displacement in the medial-lateral direction during walking and running.

	Range of Motion (mm) (Medial-lateral)		Range of Motion (mm) (Vertical)	
	COM-seg	COM-pel	COM-seg	COM-pel
Walking	28.9 (8.1)	35.7 (7.5)	31.2 (10.3)	37.0 (12.0)
Running	24.4 (8.5)	35.1 (27.3)	81.9 (29.3)	93.1 (29.7)

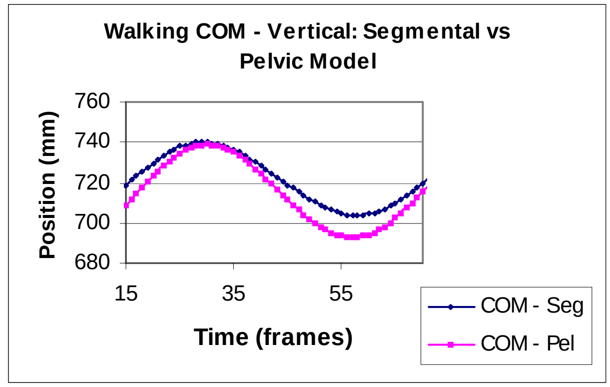

Figure 1: Vertical displacement of the COM during walking for one subject.

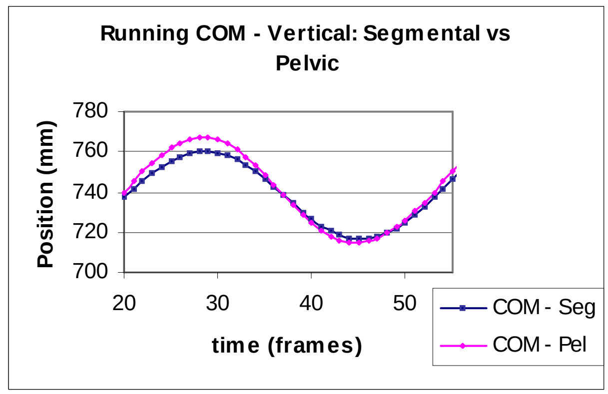

Figure 2: Vertical displacement of the COM for one subject during running.

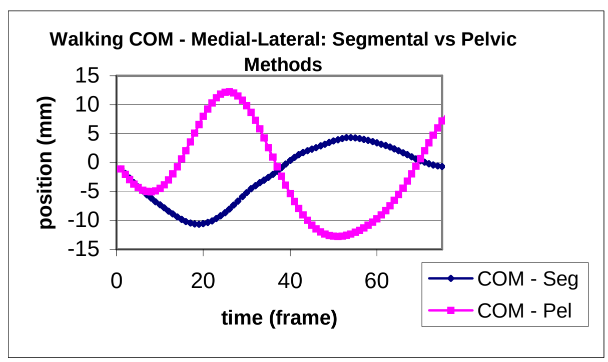

Figure 3: Walking medial-lateral COM displacement for one subject.

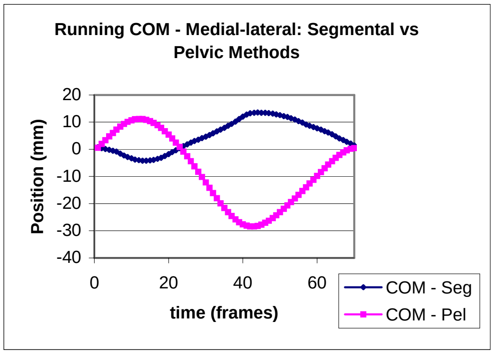

Figure 4: Medial-lateral COM displacement for one subject during running.

DISCUSSION

The objective of this study was to compare two approaches to estimate the position of the COM during a dynamic task such as running. This was performed in an initial cohort of able-bodied youths who had no pre-existing neurologic/musculoskeletal impairments. The postural alignment of the participants revealed no structural deformity, with the variability in pelvic obliquity and shoulder-pelvic rotation comparable to that found in previous work [7]. Previous work has investigated the effect of different models on the COM trajectory during walking [5]. Similarly, the present study revealed comparable phase characteristics between models, but larger amplitudes of excursion of the COM-pel in the vertical direction during walking, with consistent findings during running. In contrast, the COM-pel model had different amplitude and phase characteristics in the medial-lateral direction. This finding is of particular relevance with respect to future work that will be focused on the development of simplified approaches to estimate COM excursions. Of specific interest is to investigate COM dynamics and its relationship with oxygen consumption [4], as well as medial-lateral stability during walking and progression around obstacles [8,9].

CONCLUSION

The initial results of this ongoing work has highlighted how the displacement characteristics of the COM may be affected by characeristics of the kinematic model. Future work will further investigate the feasibility of minimizing marker placement, validating with the ground reaction force method and integrating new sensor technology in populations that include Cerebral Palsy, Muscular Dystrophy and Spina Bifida.

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