COMPARING NORMAL GAIT ANALYSES USING CONVENTIONAL AND LEAST-SQUARES OPTIMIZED TRACKING METHODS

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INTRODUCTION

The conventional gait model (CN) was pioneered in the late 1960s [1] and has seen widespread clinical use since that time. A desire to minimize the number of motion capture markers in this model was motivated by equipment limitations, including the use of only two or three cameras, and manual digitization of each camera's cine film. This led to the use of markers on one segment to define virtual markers that tracked adjacent segments with no correction for measurement error, and the use of a simple vector to represent the foot. The advent of multi-camera, automated motion capture systems provided opportunities to improve upon these techniques. In particular, an optimized (least-squares), six degree-of-freedom approach (OP) can use an over-determined set of physical markers to track individual segments while adjusting for measurement error [2]. The purpose for this human subjects approved study was to compare gait analysis variables across CN and OP models in normal children. We hypothesized that OP would provide data similar to CN in the sagittal plane, and different from CN in both coronal and transverse planes.

METHODS

Both biomechanical models were created in Visual3D (C-Motion, Inc.). CN was implemented using the Helen Hayes option for the lower extremities and pelvis. OP began with CN joint centers and local reference frames, but tracked all body segments using a minimum of four physical markers. A hybrid marker set allowed a single stride to be analyzed using CN and OP models in 25 normal children. Marker trajectories were collected at 120 Hz using a ten-camera Vicon 612 system, with interpolation and low-pass filtering (6 Hz cutoff) performed in Visual3D. Ground reaction forces were collected at 1560 Hz using three AMTI force plates. Twenty key, functionally-grouped gait analysis variables were calculated in Visual3D (e.g., maxima and minima in hip, knee, and ankle angles, moments, and powers). Dependent t-tests detected differences in these variables across models, using a Bonferroni-adjusted alpha of 0.0025 (i.e., 0.05/20).

RESULTS AND DISCUSSION

Six of nine variables were significantly different in the sagittal plane, yet associated graphical data were unlikely to change clinical interpretations (see sample data, Figure 1a). These differences were attributed to the higher fidelity foot model in OP, and to a more anterior position of the knee center when correctly tracked by four thigh markers in OP, rather than a virtual hip center, a thigh wand, and a lateral knee marker in CN. This latter marker moves posterior to the femoral epicondyle when the knee is flexed, causing decreased hip and knee flexion angles calculated in CN. No differences were found in five coronal plane variables. Four of six variables were significantly different in the transverse plane, and these were appreciated graphically (see sample data, Figure 1b). In all planes, important, yet untested, features of curves were identified for additional analysis (e.g., maximum knee valgus, etc.). Results for all three anatomical planes require more rigorous accuracy tests. In the meantime, our study shows that for normal children, sagittal and coronal plane biomechanical interpretations, based upon these tested variables, are unlikely to change due to optimized segment tracking alone. The value in these methods seems instead to involve higher fidelity input for forward dynamics [3], and we intend to explore this as one measure of accuracy. These relationships may change when pathological movements exacerbate model differences in a companion study of patients not yet completed.

REFERENCES

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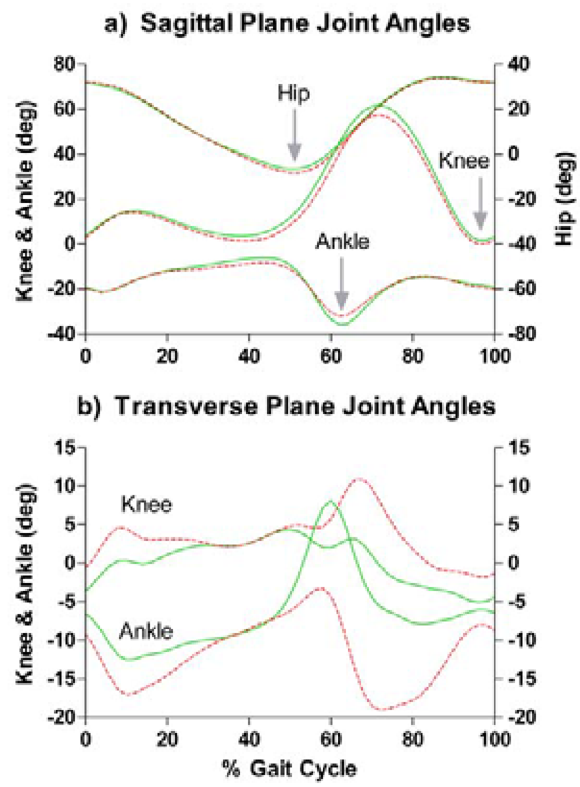

Figure 1: **Sample ensemble average joint angles (n=25). (a)** Significant differences in sagittal hip, knee, and ankle minima (arrows) would be unlikely to change clinical interpretations. **(b)** Transverse plane angles, averaged across the gait cycle, were significantly different between OP and CN models. (OP solid green, CN dashed red.)