

Alternate Approaches to Calculating Foot Progression Angles

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Introduction: Foot progression angle (FPA) is a typical kinematic measurement utilized in the motion analysis of subjects. This particular motion is calculated as the transverse plane projection the foot relative to the laboratory. The calculation for FPA assumes the subject will walk in a relatively straight line parallel to a laboratory axis. If the subject's gait deviates from this straight line, the measurement becomes inaccurate. Because clinicians use this measurement as a part of the interpretation of the subject's gait, FPAs need to be precise. The purpose of this study was to determine a new method of calculating FPAs for subjects whose gait pattern typically deviates from the assumed straight line.

Statement of Clinical Significance: FPAs are typically calculated assuming the subject will walk in a straight line. Therefore, new methods of calculating this measurement need to be determined in order to improve the accuracy for all gait patterns regardless of the path in which subjects walk.

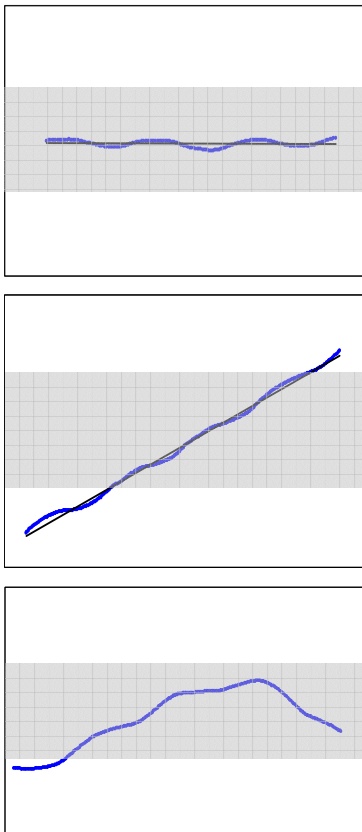


Figure 1: Sacral motion for walking trials. The grey band represents the laboratory walkway.

Methodology: Reflective markers were placed on the skin over the sacrum, right calcaneus, and the midpoint of the right forefoot of one able-bodied adult subject. The motion of these markers was captured at 60 Hz. using a movement measurement system (Motion Analysis Corporation, Santa Rosa, CA, USA). The subject complete three trials: 1) walking in a straight line parallel the laboratory axis of progression (straight), 2) walking in a straight line at an angle to the laboratory axis of progression (angle), and 3) walking in a weaving motion through the lab (weave). The path of the sacral marker for these three trials is shown in Figure 1. FPAs for each trial were calculated during right stance phase using four different approaches: 1) transverse plane projection of the foot relative to the laboratory (room), 2) transverse plane projection of the foot relative to a best fit line calculated by linear regression on the traverse plane motion of the sacral marker over the entire trial (regression), 3) transverse plane projection of the foot relative to a best fit line calculated at each sample point by linear regression on the traverse plane motion of the sacral marker over the 10 sample before and after the point of interest (moving regression), and 4) transverse plane projection of the foot relative to the direction of the instantaneous velocity of the sacral marker (velocity).

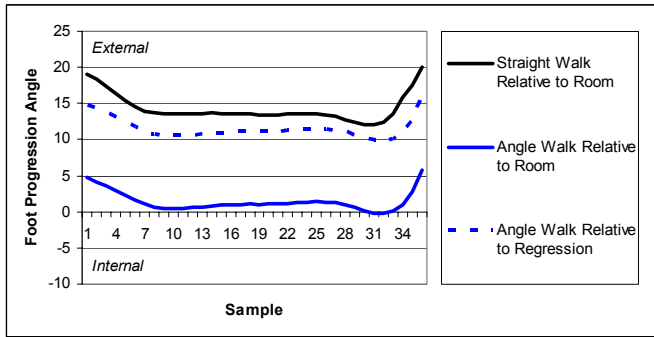


Figure 2: Foot progression angles for angle walk.

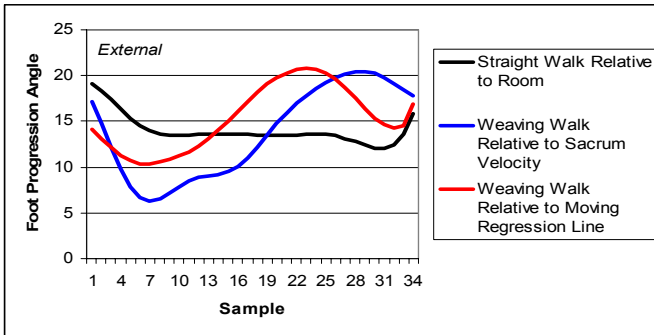


Figure 3: Foot progression angles for weave walk.

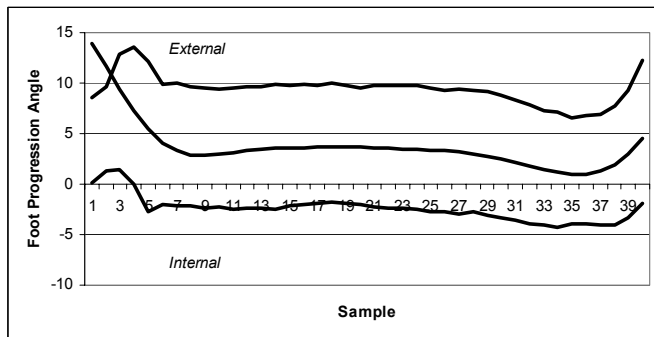


Figure 4: Foot progression angles for three steps during the weave walk relative to the room.

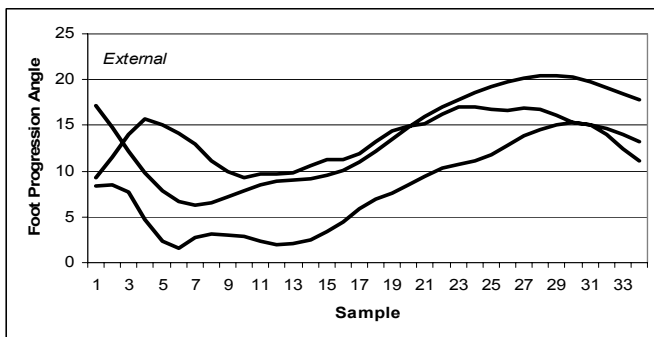


Figure 5: Foot progression angles for three steps during the weave walk relative to sacrum velocity.

Results: The FPAs for a straight walk calculated relative to the room, an angle walk calculated relative to the room, and the same angle walk relative to a regression line are shown in Figure 2. As expected, when the subject walked at an angle from right to left and the FPAs were calculated relative to the room, the FPAs were internal relative to those observed during the straight walk. However, when the FPAs for the angle walk were calculated relative to the regression line they were very similar to those observed during the straight walk. Figure 3 shows the FPAs for the weaving walk calculated relative to the sacrum velocity and the moving regression line. The FPAs for three consecutive steps during the weaving walk are shown in Figure 4. The FPAs for the same three steps calculated relative to the sacrum velocity are shown in Figure 5.

Discussion: The results show that when a subject walks in a straight line at an angle to the laboratory coordinate system, the FPAs can be corrected by calculating the angles relative to a regression line describing the actual direction of progression. When a subject walks in a weaving pattern in the laboratory it is more difficult to determine a line of progression. Using the methods described here more consistent FPAs can be obtained when the subject does not walk in a straight line; however, the patterns obtained using these methods are subjectively different from those obtained during a straight walk. These approaches may also be used for calculating pelvis and trunk rotations relative to the laboratory.