Multi-segment Foot Model – Thomas Young

Intro: Measurement of foot kinematics is becoming increasingly common as motion analysis measuring systems become more accurate (Stebbins, 2006). The purpose of this project was to learn how to implement a multi-segment model in the Vicon software for two conditions: walking and running. In addition, data collection included creating a model as well as processing the data collected. A secondary purpose was to examine the changes in the x, y, and z direction for range of motion about the hind – forefoot joint.

Method: The equipment used for this project was the following: One force platform (1200, AMTI), 3D motion analysis system (240 Hz, VICON), Visual3D (C-Motion, Inc.), and reflective markers in the following locations: knee, shank, ankle and hind-foot and fore-foot. The participant was a graduate student from the university who performed no warmup. Reflective markers were placed on the following locations: femoral condyle, tibial tuberosity, head of the fibular, lateral malleolus, medial malleolus, posterior distal aspect of the heel, posterior medial aspect of the heel, lateral calcaneus, sustentaculum tali, base of the first metatarsal, base of the fifth metatarsal, head of the first metatarsal, head of the fifth metatarsal, between the second and third metatarsal heads, and he base of the hallux. A static trial was initially collected to create a model. Once this was achieved, the anatomical markers were removed. For the first condition, the participant was first instructed to walk across the motion capture area at a self-selected speed with his right dominate foot to hit the force platform. A practice trial was conducted first for the subject to become familiar with the machine and in order for the subject to become comfortable staring at the opposite wall instead of the force plate. Once this was achieved, the participant performed five trials. A thirty second rest period was granted between trials. For the second condition, the participant was asked to run across the motion capture area at a self-selected speed with his right dominate foot to hit the force platform. Again, a practice trial was performed to allow the subject to become familiar with the task. Once this was achieved, the participant performed three five trials with thirty second breaks between each trial. Once these tests were completed, they were repeated on the nondominated leg. The lab was cleaned after data collection and data processing was completed with Visual3D in the biomechanics computer lab. RON was defined as the initial contact of the foot on the force plate while ROFF was defined as the moment the foot left contact with the force plate. The data was filtered with a low pass Butterworth filter with cutoffs at 6 Hz and 50 Hz respectively. The following metrics were collected for the hind-for foot: Peak X, Minimum Y, Peak Z. These metrics were then used to determine range of motion of the hind-for foot about the range of motion for the first half of the stance phase in the x (dorsiflexion/plantarflexion), y (inversion/eversion), and z direction (adduction/abduction). These metrics are illustrated in tables 1 and 2 for walking and running respectively and created in excel. Two report pages with mean curves were created to represent the stance phase of the movement starting with RON and ending with ROFF. Figure 1 shows the walking condition while figure 2 illustrates the running condition.

Results:

Figure 1: Ankle, Hind-For Foot, Shank Hindfoot, and Shank Forfoot Angle in x, y, and z direction

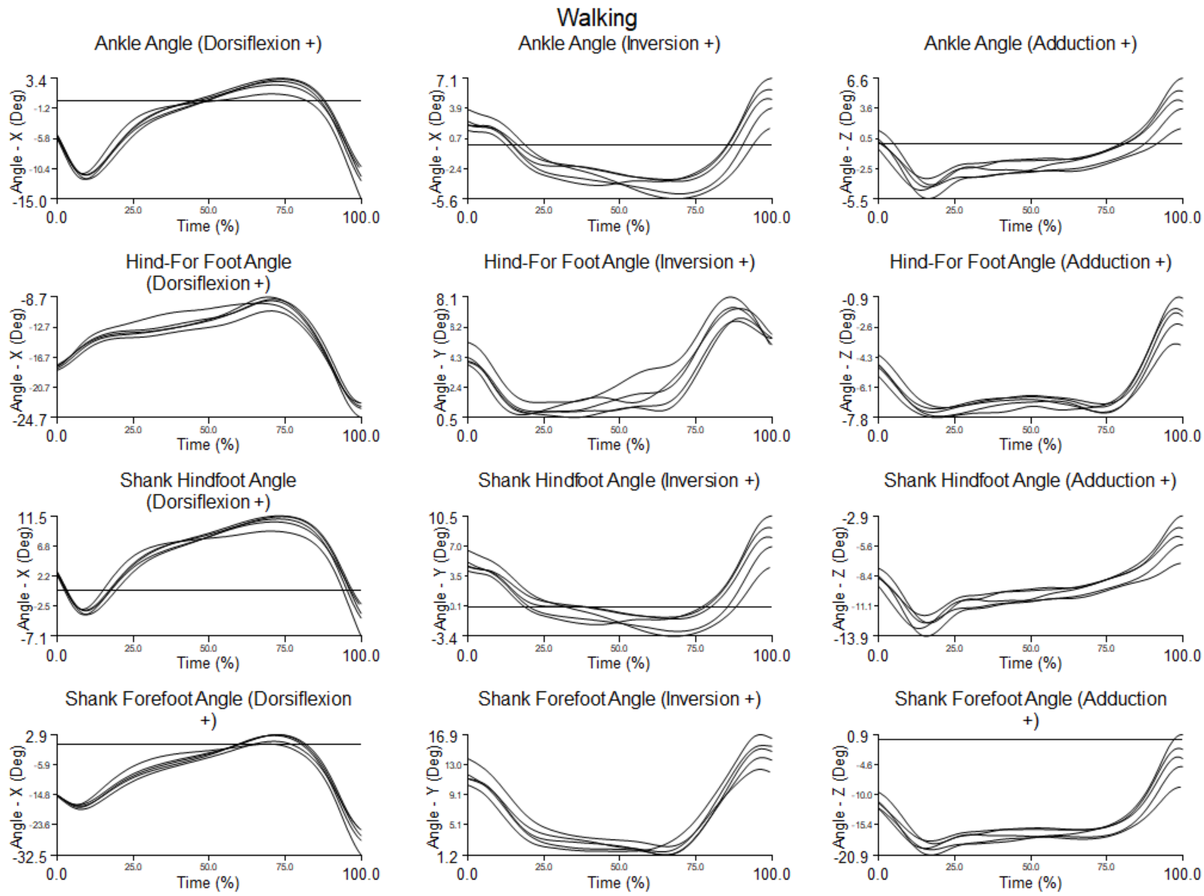

Table 1: Walking Condition: Hind foot metrics read as mean ± standard deviation

Table 1: Hind Foot Metrics - Walking					
	Mean	Std		Mean	Std
Max - X	-9.406	0.712	ROM - X	8.652	0.573
Min - Y	0.877	0.354	ROM - Y	-3.399	0.256
Max - Z	-7.531	0.198	ROM - Z	-2.708	0.374

Figure 2: Ankle, Hind-For Foot, Shank Hindfoot, and Shank Forfoot Angle in x, y, and z direction

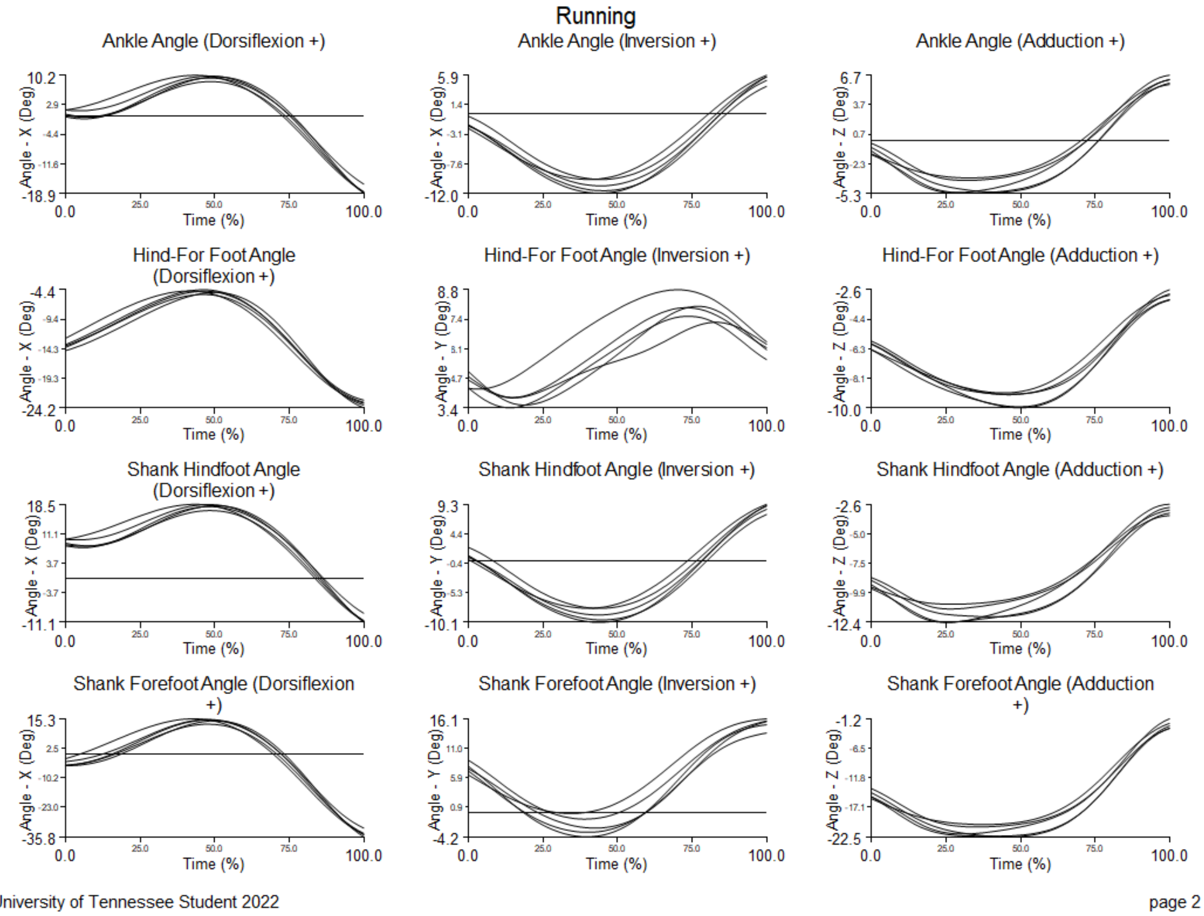

Table 2: Running Condition: Hind foot metrics read as mean ± standard deviation

Table 2: Hind Foot Metrics - Running					
	Mean	Std		Mean	Std
Max - X	-4.768	0.296	ROM - X	8.980	0.674
Min - Y	3.743	0.338	ROM - Y	-0.856	0.539
Max - Z	-9.470	0.465	ROM - Z	-3.386	0.488

Discussion: As a preface, trial 1 was excluded from both conditions due to data corruption so the above data represents trials two through six and can be found in the attached excel spreadsheet. The second row in figure 1 is of importance. Hind-for foot had a peak at 25% of the stance phase and at 75% of the stance phase for the walking condition with respect to x. For the y direction of walking, there as a minimum at 25% of the stance phase and around the 75% portion of the stance phase. For the z direction, there was a peak right at the start and end of the stance phase. Since injuries mainly occur when landing, we will focus on the first half of the stance phase which is described in table 1. This is how range of motion was calculated by either taking the maximum value in the first half of the stance phase or the minimum value in the first half of the stance phase. For the x direction, hind-for foot had a positive degree change by about 8.6 degrees indication dorsiflexion. For the y direction, hind-for foot had a negative degree change by about 3.4 degrees indication eversion. For the z direction, hind-for foot had a negative degree change by about 2.7 degrees indication abduction. Compared to the Steepens paper, the values collected from the experiment displayed on the table 1 were lower than the results found in table 3 (default column) of the 2006 paper for all 6 metrics. This could be due to the fact there were 15 individuals to average in the Steepens paper when the current experiment only had a single participant. There is not any data of the height and weight of the participants of the Steepens paper, but it does mention the subjects are children with an average age of 9.5 years. The subject in the current study was very tall and identified as a young adult which could be a potential bias.

However, figure 1 showed similarities to the Steepens paper, but are shifted laterally about 25%. Specifically looking at figure 2 on the Steepens paper, the hindfoot internal rotation can be compared to row two column two of figure 1. The data collected from the lab shows an initial dip after initial contact and a minimum at 25% followed by a slight increase and then another slight dip for a second minimum right after 50%. From here, there is a sharp increase to a peak right after 75% followed by a decline. The Steepens paper shows identical characteristics from 0-70% of the gait cycle, but then continues down to another minimum before the foot comes off the force plate. The description of the graph does explain there is an offset from visits below figure 2 in the 2006 paper. According to Steepens, “Within subject standard deviations were lowest in the sagittal plane (between 2°and 4°). The highest variability was in the transverse plane at the hindfoot … with standard deviations of 8° and 7°, respectively”. This is less comparable as we only have subject and STDs are related to the within-trial variables. The second row in figure 2 is of importance as well, but is for the running condition. Hind-for foot had a peak around the 50% point of the stance phase with respect to x. For the y direction of running, there as a minimum around the 25% mark of the stance phase and around the 75% portion of the stance phase. For the z direction, there was a peak right at the start and end of the stance phase. Again, only the first half of the stance phase was looked at for running since injuries occur mainly when landing. Table 2 displays the metrics of max and min for the calculation of range of motion. For the x direction, hind-for foot had a positive degree change by about 8.9 degrees indication dorsiflexion. This is slightly larger when compared to the walking condition. For the y direction, hind-for foot had a negative degree change by about 0.8 degrees indication eversion. This is significantly smaller when being compared with the walking condition. For the z direction, hind-for foot had a negative degree change by about 3.3 degrees indication abduction. This is larger than when compared to the walking condition. Compared to the Steepens paper, the values collected for the running condition cannot be compared since the researchers in 2006 only implemented a walking condition. However, table 1 trends are similar to table 2 trends with running having overall higher values for peaks and lower values for minimums. This makes sense as the body would be exerting a higher force output while running compared to walking due to gravity and distance covered. This is also a good check to see if this new multi-foot model would produce comparable forces.

References:

Stebbins, J., Harrington, M., Thompson, N., Zavatsky, A., & Theologis, T. (2006). Repeatability of a model for measuring multi-segment foot kinematics in children. *Gait and Posture*, *23*(4), 401–410. https://doi.org/10.1016/j.gaitpost.2005.03.002