3D Kinetics and Center of Pressure (COP) – Thomas Young

Question: Are there differences between center of pressure displacement, peak moment, peak power, work, and range of motion performed by the left ankle and knee for the following two conditions: walking and ascending stair?

The equipment used for this project was the following: two force platforms (1200 Hz, BP600600, OR6-7, AMTI), AMTI instrumented staircase, 3D motion analysis system (240 Hz, VICON), and Nike Pegasus lab shoes. Reflective markers were placed on the trunk, pelvis, thigh, leg, and foot on both sides. Specifically, anatomical markers were placed on each side of the body on the following bony locations: acromial process, greater trochanter, lateral epicondyle, medial epicondyle, lateral malleolus, medial malleolus, 1st metatarsal, 5th metatarsal, and 2nd toe. Tracking markers in groups of 4 were placed on the back of the pelvis (posterior pelvic cluster), one on each thigh (4 in cluster), one on each shank (4 in cluster), and one on each posterior heel (posterior lateral heel cluster). Once a static trial was collected and reflective markers labeled, anatomical markers were removed, and dynamic trials began. Condition 1 was called walking and 5 trials were collected. Data collection occurred only with one participant from the graduate school. The participant was instructed to walk at normal walking pace and asked to land her right foot on force platform 1 and left foot on force platform 2. Condition 2 was called stair ascent and 5 trials were collected. The participant was instructed to walking up the stairs with her left foot hitting the first and third step at normal walking speed and to stop at the top of the staircase. Data processing was completed with Visual3D (C-Motion, Inc.) in the biomechanics computer lab at The University of Tennessee Knoxville.

Table 1: Variables for each condition with average and standard deviation

	Condition 1		**Condition 2**	
Variables	Average	SD	Average	SD
GRF Max - Z	1.0485	0.0250	1.1285	0.0589
Ankle Moment Min - X	-1.5275	0.0519	-1.2022	0.0775
Ankle Power Max - X	2.8733	0.2834	2.4100	0.1016
Knee Moment Max -X	0.6564	0.1615	1.2925	0.0320
Knee Power - X	-0.6950	0.0137	2.9646	0.4956
COP Disp - X	0.0255	0.0031	-0.0415	0.0086
COP Disp - Y	0.2589	0.0043	0.1618	0.0071
Ankle Work Pos	0.2388	0.0320	0.3056	0.0526
Ankle Work Neg	-0.2064	0.0137	-0.0158	0.0047
Knee Work	-0.0586	0.0043	0.6412	0.0265
ROM ankle - X	-24.6169	1.7986	-26.6996	3.1018
ROM knee - X	-45.6032	1.8801	-53.7795	4.9360

The first slightly different number is the peak vertical reaction force with respect to z. The walking trial experienced a slightly lower value than the ascent trial, which is to be expected since both motions are slow (and values are only separated by less than $1/10^{th}$).

Peak ankle sagittal moment was slightly larger in walking and stair ascent. A minimum was taken here as the peak exerted was predominately negative. A maximum was taken for ankle power and was seen to be larger in the walking condition. This is slightly larger but makes sense as a larger weight shift is seen walking for plantarflexing rather than ascending stairs. The sagittal knee moment max in condition 2 was twice as high as the walking condition. Gravity is working against the knee more while climbing stairs compared to walking. Sagittal knee power minimum was seen to be higher in stairs compared to walking. This makes sense as the force being generated comes primary from the knee muscles rather than the ankle muscles**.** For condition 1, ankle work positive and ankle work negative are almost the exact opposite of each other. This is a good sign the trails were performed correctly. However, the same could not be said for the stair condition and this is probably due to only having two trials to average. Knee work was negative for walking and positive for stairs. This is another good indication data was collected appropriately as the ankle will do more work walking and the knee will do more ascending stairs.

Center of pressure for X is slightly negative for the stair condition compared to the walking which is slightly positive. This is different for the center of pressure with respect to Y as this value is higher for walking when compared to condition 2. This relationship makes sense as when walking a person normally goes in a straight line and will have less medial / lateral movement compared to stairs. However, more displacement will happen in the anterior / posterior direction for walking as the foot will go a larger distance walking rather than going up a stair. Both condition 1 and condition 2 have positive COP Y values which is another good check that calculations were done correctly.

The GRF force vector for the sagittal plane can correspond with the knee sagittal plane graphs. The GRF X graph, with respect to the knee, and knee moment X graph in both conditions exhibit an initial dip into the negative values and follow a peak before the midstance. From midstance there exhibits a second peak followed by a drop in the force back to zero. This can correspond with the knee experiencing a primary extensor moment (positive values) with the force vector being located behind the knee joint center.

There are a few variables that seem to be sensitive to look at between the two conditions. The first one is knee power as the peaks are defined differently. A minimum is needed to capture the most negative value in walking while a maximum is needed to capture the most positive value in stair ascent. This is why it is important to look at the graphs to see where a peak occurs in order to acquire the correct data. Ankle and knee moments follow this same trend as the highest value is a negative value so taking a minimum as the peak is required instead of a maximum. Center of pressure with respect to X seems to be sensitive as well. This is due to the tiny values acquired as they are in captured with values only as large as 0.01 (one hundredths). The same could also be said for ankle work negative (tiny values).