Project Report – Thomas Young

1. Introduction

Knee anatomy directly influences joint mechanics and the potential for injurious loads (5). Any injury to the lower extremity can cause a cascade of effects that make it difficult to control landing in sport. Jumping and landing is included and used in various ways such as education, sport, and recreation, and in biomechanics to evaluate the joint kinematics and kinetics (3). Therefore, it is important to identify parameters for safe landings in sport. It's also important to determine potential predictors of functional instability of the knee and ankle joints (4). Athletic trainers and human performance staff in the military setting are often faced with the challenge of developing injury-prevention programs based on the most current evidence (2). This will allow coaches, clinicians, and other injury prevention staff to be educated in prescription and rehabilitation. Jumping and landing occur frequently during sporting events and can be soft or rigid/stiff (4). In several studies landing techniques and joint loading are assessed using drop jumps from raised platforms compared to countermovement jumps (1). In this study, we take a similar approach and examine the landing of two separate jumps: broad jump (standing long jump) and the countermovement jump (vertical jump). The mechanics of the standing long jump is that the subject is projecting their body horizontally from one place to another as far as possible from the takeoff point, in our case for the purpose of researching the effects of landing in this jump the subject jumped from a maximum distance possible to reach the AMTI force plate. In a countermovement jump, the subject starts in a standing position, performs a downward movement as a loading mechanism, and explodes into an upward movement that results in a takeoff from the ground. The countermovement jump is a simple movement that allows a softer landing, and the standing long jump/broad jump occurs with more of a stiffer loading which also affects the difference of joint angles in the knees during both conditions. A number of studies have examined the ground reaction forces (GRF) and the knee joint kinematics for these landing techniques (6). The purpose of our study is to identify areas of improvement for landing from a countermovement jump and broad jump by examining the following: knee joint angles, velocities, moments, power, and ground reaction forces. Our hypothesis is the following: We expect higher knee range of motion, max knee flexion, max knee moments and higher ground reaction forces in the broad jump trials compared to the countermovement trials (right leg only).

2. **Methods**

Subjects: We only had one participant in the study who qualified for participation. He identified as a 23-year-old male and had no prior lower extremity injuries prior to the study. His height and weight were recorded as 1.75 meters and 75 kilograms respectively. The other recruited participant did not meet the inclusion criteria by having two lower extremity injuries in the last 5 years. Prior to research the approval of the study came from Dr. Songning Zhang. **Experimental Design:** There were 11 trials completed with the first trail being our static trail. Reflective markers were placed on four locations of the body specific to the truck, thigh, leg, and foot. This four-segment model involves placing six reflective markers on each of the following locations: acromial process, greater trochanter, femoral epicondyle, lateral malleolus, heel, and fifth metatarsal. The purpose of the calibration trail was to get all the anatomical markers of the subject correct before collecting data. However, once calibrated these bony locations are no longer needed so they are removed, and the tracking makers remain. The first 5 experimental trials were called countermovement trials (vertical jumps). This meant the subject started on force platform 1 and 3. Was told “go”. And then three seconds of data was collected from jumping and leaving the platform for max height (straight up) and then returned to the platform in a balanced position. We had to re-do a few of these when the foot was not entirely on the force platform. The participant was given 30 seconds in between each trial to catch his breath. The second 5 trials were called broad jump in which the subject started in a stationary position and then was told “go”. The subject then leapt about 6.5 feet to the force platform landing on the heel and rolling to the toe to complete the movement. The subject walked off afterwards instead of holding for max flexion.

Kinematic Analysis: Data collection was performed using the Vicon and Nexus software along with 2 AMTI force platforms. Once data was smoothed over with a 4th order Butterworth low pass filter, it was transferred to the computer lab. Kinematic Analysis was performed in the Visual3D software provided by the University of Tennessee Knoxville in the Biomechanics Lab. **Statistical Analysis**: Statistical Analysis was performed in Excel. A successful trial was defined as the subject making complete foot contact with the force plate and was also defined as the start of the landing phase. The end of the landing phase was defined as max knee flexion. Range of motion was defined as the difference between max knee flexion and knee contact angle with the force plate. Mean and standard deviation were the primary objective of analyzing the following x-component variables: knee range of motion, max knee flexion, and max knee moment. The z-component looked at was max ground reaction force normalized to body weight.

3. Results

Figure 1: Collected data from trails represented by ensemble curves for force platform 3.

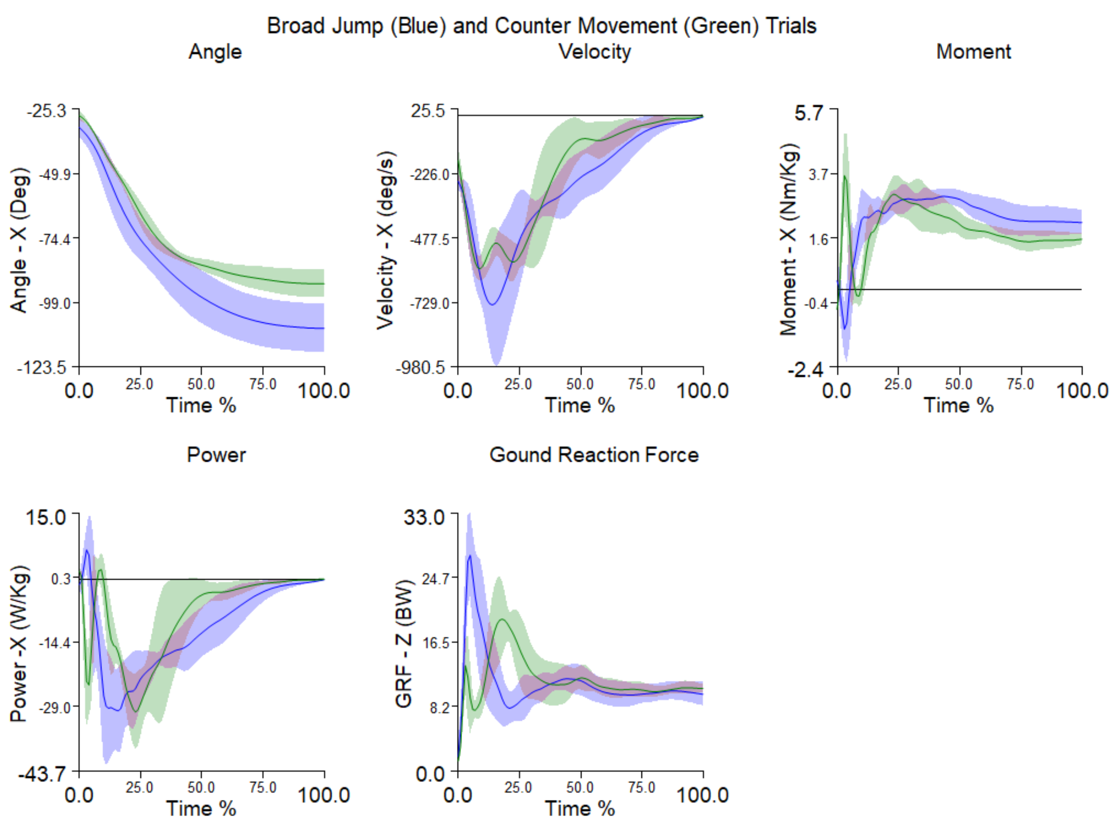

Table 1: Broad Jump (BJ) and Countermovement (CM) Trails
Mean and Standard Deviation (SD) for the four measured variables of the Knee Joint

Variable	CM	BJ
ROM - X	-64.14 (5.17)	-76.67 (6.44)
Max Flexion - X	-91.89 (5.29)	-108.88 (9.20)
Max Moment - X	4.38 (1.19)	3.30 (0.22)
Max GRF - Z	2.26 (0.25)	2.90 (0.57)

Both mean and standard deviation were higher for the broad jump trials for the variables: Range of Motion – X, Max Flexion – X, and Max GRF - Z. There was a higher max knee extension moment for the countermovement trials for both the mean and the standard deviation.

4. Discussion

The objective of this study was to look at the differences in landings between a countermovement jump and a broad jump for a healthy participant for the following variables: knee range of motion (x-component), max knee flexion (x-component), max knee moment (x-component), and max ground reaction force normalized to body weight for the z-component for the right leg only. As expected, there were higher forces that were exhibited in the broad jump compared to the countermovement jump. However, we were correct in three out of the four variables in our hypothesis. The countermovement trials had a higher max knee extension moment average compared to the broad jump trial average as seen in Table 1. The result indicate there are several differences to be pointed out from the graphs and variables we looked at. Starting with Figure 1: Angle, there was a higher average flexion angle in the x component for the broad jump trials compared to the countermovement trails. It we think about the movement being performed; this is a good sign we the data was collected correctly as there would be higher flexion exhibited in the landing portion of the broad jump for the x-component. In Figure 2: Velocity, there was also a higher max velocity performed by the broad jump trails from the start of the landing phase to the mid-landing. From mid-landing, both conditions steadily decreased and were both positive at the end of the landing phase. After a person lands, the participant must stabilize themselves to avoid injury, which is indicated here since the velocity is steadily decreasing. In Figure 3: Moment;

there is a max positive moment around the 25% portion of the landing phase for the broad jump trials. This can be defined as the first max knee extension moment, but when analyzing data for injuries, we look at the second max knee extension moment. From this point, there is a steady linear decline until the end of the landing phase. In contrast, there is negative moment for the countermovement trials around the 25% portion of the landing phase. This indicates there is a knee flexion moment, which is odd since we don't see it that often in previous literature. There is a steady positive increase to about the middle portion of the landing phase. From mid-landing, there is a slightly positive increase to the end of the landing phase. In Figure 4: Power, positive power is defined as concentric and negative power is defined as eccentric. For the broad jump trials, there was a slight positive increase in power at the start of the stance phase and a negative drop from this peak to the 25% portion of the landing phase, which indicates power is absorbed. From here there was a positive increase in power to the end of the landing phase. For the countermovement trails, there was a sharp decrease in power with a peak at around the start of the landing phase, it then came back up to be a positive value before sharply decreasing to another peak at the 25% portion of the landing phase, which indicates power is absorbed. From here, there is a steady decrease in power to the end of the landing phase. In Figure 5: GRF, the z-component was looked at since that has the highest magnitude with landing. The broad jump starts in a neutral position and has a sharp acceleration peak before reaching the 25% portion of the landing phase. This is followed by a sharp deceleration until reaching the mid-landing. From here, there is constant acceleration until the end of the landing phase. In contrast, the countermovement jump did not see as high of a peak, but still exhibited an acceleration peak at the 25% portion of the landing phase. From the 25% portion of the landing phase, there still exhibited a deceleration until the mid-landing. From here, it was similar to the broad jump by not keeping constant acceleration until the end of the landing phase. **Limitations:** We encountered a few issues with the Vicon and Nexus systems when it came to lost tracking markers. When the subject landed on the force platform, especially for the broad jumps, the markers of the knee would get very close and switch points in the system. We manually had to go in and change them to reflect the model, but this still could cause human error when replicating the study. Testing for significance was not performed. This could lead to the researcher finding some correlations, but not being able to prove causation since not p-value was found or chi-squared values.

Future studies: More studies could be performed with a more in-depth analysis using a more advanced software than excel. We also only used one subject for this experiment so performing the same experiment with more people could also lead to better results. Different populations could be taken into consideration as well, such as older adults versus younger adults. The ground reaction force for the y component could also be looked at to get a better insight for the broad jump condition.

5. References

1. Baus, J., Harry, J. R., & Yang, J. (2020). Jump and landing biomechanical variables and methods: A literature review. *Critical Reviews in Biomedical Engineering*, *48*(4), 211–222. https://doi.org/10.1615/CritRevBiomedEng.2020034795

2. Heebner, N.R., Rafferty, D.M., Wohleber, M.F., Simonson, A.J., Lovalekar, M., Reinert, A., Sell, T.C., 2017. Landing kinematics and kinetics at the knee during different landing tasks. J Athl Train 52, 1101–1108. https://doi.org/10.4085/1062-6050-52.11.25

3. Hraski, M., Hraski, Ž., Prskalo, I., 2015. COMPARISON OF STANDING LONG JUMP TECHNIQUE PERFORMED BY SUBJECTS FROM DIFFERENT AGE GROUPS, BALTIC JOURNAL OF SPORT & HEALTH SCIENCES.

4. Kim, K., Jeon, K., 2016. Comparisons of knee and ankle joint angles and ground reaction force according to functional differences during single-leg drop landing.

5. McLean, S.G., Lucey, S.M., Rohrer, S., Brandon, C., 2010. Knee joint anatomy predicts high-risk in vivo dynamic landing knee biomechanics. Clinical Biomechanics 25, 781–788. https://doi.org/10.1016/j.clinbiomech.2010.06.002

6. Yeow, C.H., Lee, P.V.S., Goh, J.C.H., 2010. Sagittal knee joint kinematics and energetics in response to different landing heights and techniques. Knee 17, 127–131. https://doi.org/10.1016/j.knee.2009.07.015