# BE 436 - Biomechanics of Human Movement

# Lab #3: Biomechanics of Vertical Jumps

**May 6th, 2022**
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**Group Monday - B2**

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**Introduction:**

The goal of this lab was to analyze the biomechanics of jumping, one leg jump, and a running jump. These three exercises are all lower body exercises and should display some similarities in the forces produced while being performed. To complete this lab, we assigned one member to be the motion capture subject, two members to operate the computer, and the rest to help place the markers on the subject and take pictures.

Using the same motion capture suit and marker placement as the last lab, we collected data points corresponding to the human body while performing the selected exercises. Due to the movement of the exercises, the markers moved on the suit which created noise in our data. This noise can lead to noticeable outliers in the graphs, even after removing any clear erroneous data points.

Despite the noise, we were able to show similarities and differences in the ground reaction forces, heights and linear speed generated by a standing jump, one leg jump and a running jump.

**Methods:**

1. Begin the lab by completing basic setup tasks
    a. Start the Vicon Motion Capture software
        i. Create a folder to collect data, which was stored under a database, then the following folders: Courses, be436, be436_sp22, Group 13, Experiment 3, Patient 1, and finally, Session 1.
    b. Assist one group member in putting on the motion capture suit
        i. Attach velcro motion trackers to the motion capture suit by following the Marker Placement Guide on UBLearns
2. Calibrate the motion capture software
    a. Allow the test subject to stand in the viewing area to confirm that the software is accurately tracking the motion of the subject, and all markers are visible
    b. Have the test subject move towards each outer bound of the viewing area until the software begins to lose sight of suit markers. Place some type of marker on the border of each viewing area to denote where the motion capture cameras begin to lose sign of the test subject
    c. Use the Auto Initializing Labeling pipeline for the calibration
3. Begin analysis of exercises
    a. Once data collection has started, perform five vertical jumps while maintaining the same general position. Stop data collection after the completion of the five jumps. Label this data “Jump 1”.
    b. Repeat the previous step to record the second set of data for the jumps trial. Label this data “Jump 2”.

    c. Repeat steps 3A and 3B for one leg jump and running jump and label them respectively. When complete, you should have two sets of data for each motion totalling to six total datasets.
4. Process and save recorded data
    a. Once all data is collected, save and apply the Export pipeline to all six trials
    b. Upload collected data to UBBox and share with the group.

**Results:**

In this section, we will be using the data we have obtained from the motion capture lab to calculate the linear speed, ground reaction forces, and jump height of our subject. These calculations will be done for each trial, jump, one leg jump, and running jump.

## Section 1 - Linear Speed

We first calculated the linear speed of our subject. We did this by using the sternum marker of our subject, estimating this to be their center of mass. For each exercise– jump, one leg jump, running jump– we did our calculations using only one of the trials. For jumps and one leg jump we used the second trial, while the running jump used the first trial.

We took the x, y and z positions for the sternum marker and converted these to meters by multiplying by 0.001. After we had that data converted, we took the difference from each data point to the next and then divided that by our time interval of 0.01 seconds. This gave us our subject's speed. The example equation is for the x axis speed.

$$v_x = \frac{x_2 - x_1}{0.01s} \qquad \text{Equation 1.1}$$

We then graphed linear speed in each direction, as well as the magnitude of the linear speed for each exercise. Figures 1.1-1.3 display this data. To get a better grasp on our data, we calculated the maximum and averages for the speed in each direction, using the built-in functions in Excel ( “max()” and “average()” ).

**Jump: Linear Speed**

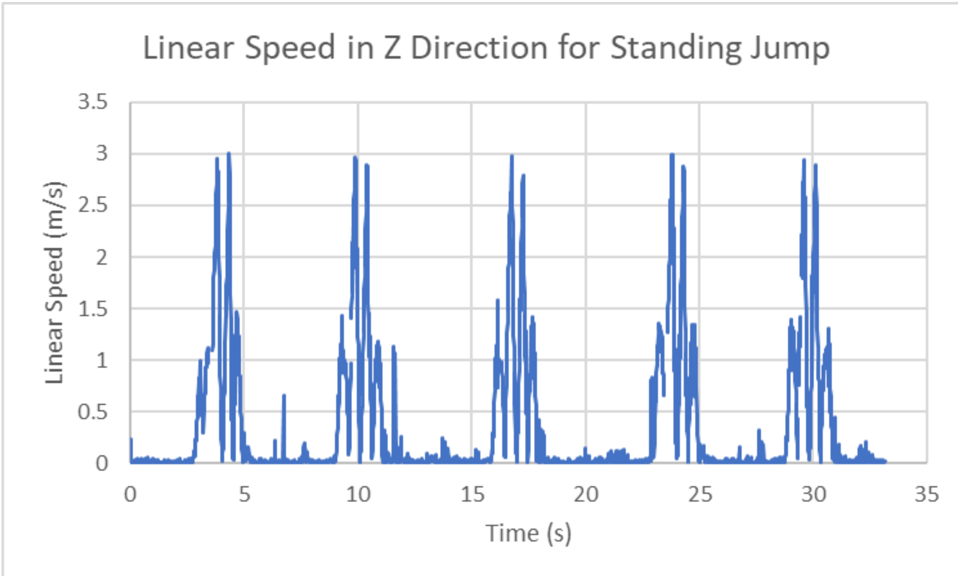


*Figure 1.1 - The linear speed of the center of gravity in the Z direction during the second jump trial.*

**One Leg Jump: Linear Speed**

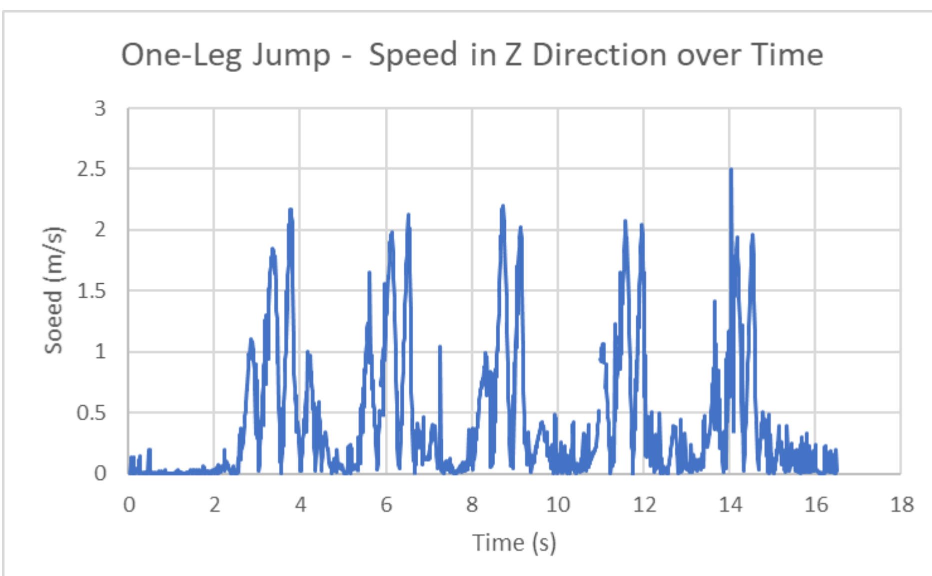


*Figure 1.2 - The linear speed of the center of gravity in the Z direction during the second one leg jump trial.*

**Running Jump: Linear Speed**

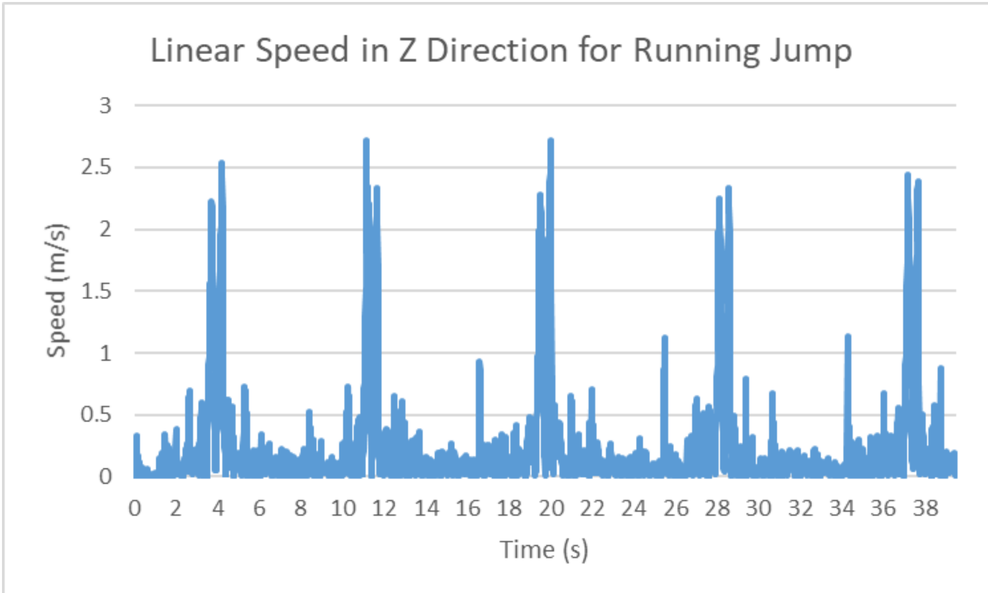


*Figure 1.3 - The linear speed of the center of gravity in the Z direction during the first running jump trial.*

Below is a table summarizing the maximum and average linear speed for the jump, one leg jump, and running jump trials.

| | *Jump* | *One leg jump* | *Running Jump* |
|---|---|---|---|
| *Max Linear Speed (m/s)* | *2.999* | *2.498* | *2.720* |
| *Average Linear Speed (m/s)* | *0.345* | *0.411* | *0.222* |

**Section 2 - Ground Reaction Forces**

In this next section, we calculated the acceleration, and found the ground reaction forces by multiplying acceleration and the mass of our subject. Using the speed from the previous section, we took the difference between two speed data points and divided that by 0.01 seconds, to get acceleration in each direction of each trial. The example equation is for the x axis acceleration.

$$a_x = \frac{v_{x2} - v_{x1}}{0.01s} \quad \text{Equation 2.1}$$

We performed this calculation for every direction and for each exercise and then used Equation 2.2 to calculate the ground reaction force. The mass of the subject used was 45.4 kg.

$$Ground\ Reaction\ Force = mass\ of\ subject * acceleration(m/s^2) \quad \text{Equation 2.2}$$

We then graphed our results for these ground reaction forces. Figures 1.4-2.5 are the results for each direction (x, y and z), for jump, one leg jump, and running jump respectively. For all the datasets, we used the sternum marker as our center of gravity. Additionally, we found the maximums, minimums and averages for the ground reaction forces in each direction for every exercise. This allows us to get a better understanding of our data.

**Jump: Ground Reaction Force**

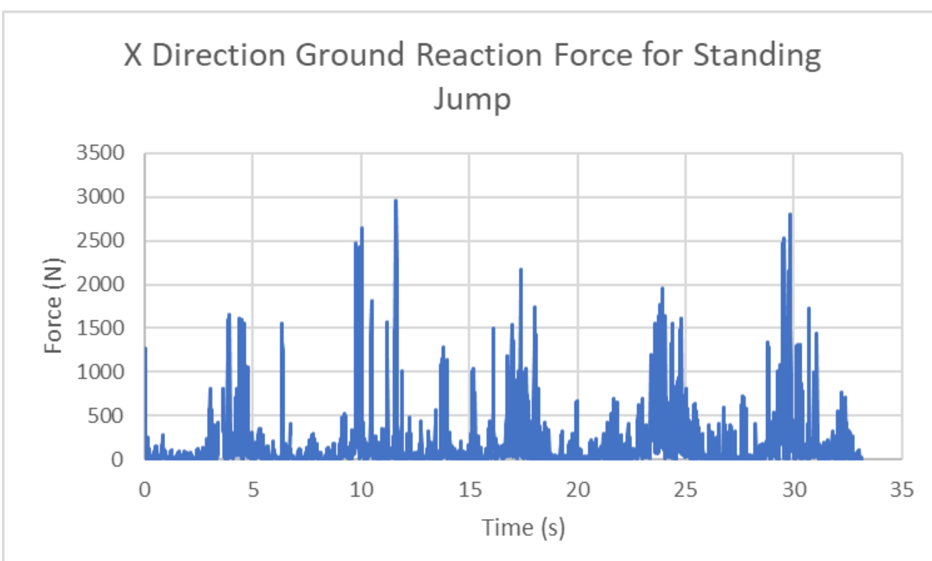


*Figure 2.1 - The ground reaction force in the X direction during the second jump trial.*

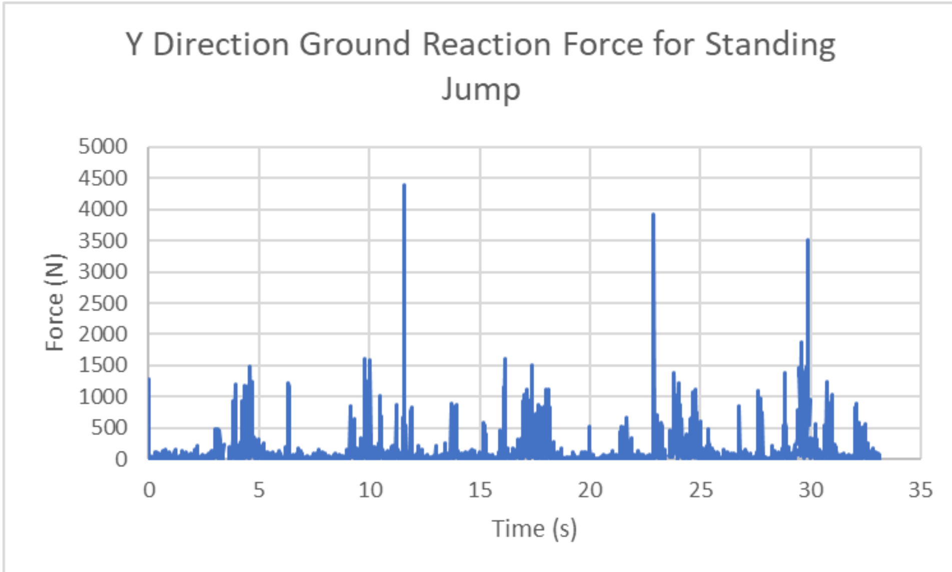


*Figure 2.2 - The ground reaction force in the Y direction during the second jump trial.*

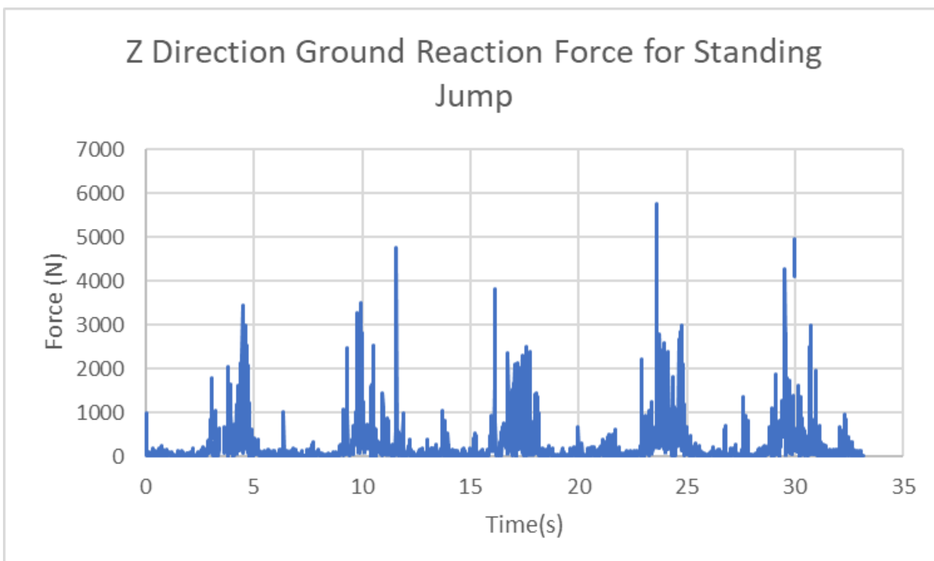


*Figure 2.3 - The ground reaction force in the Z direction during the second jump trial.*

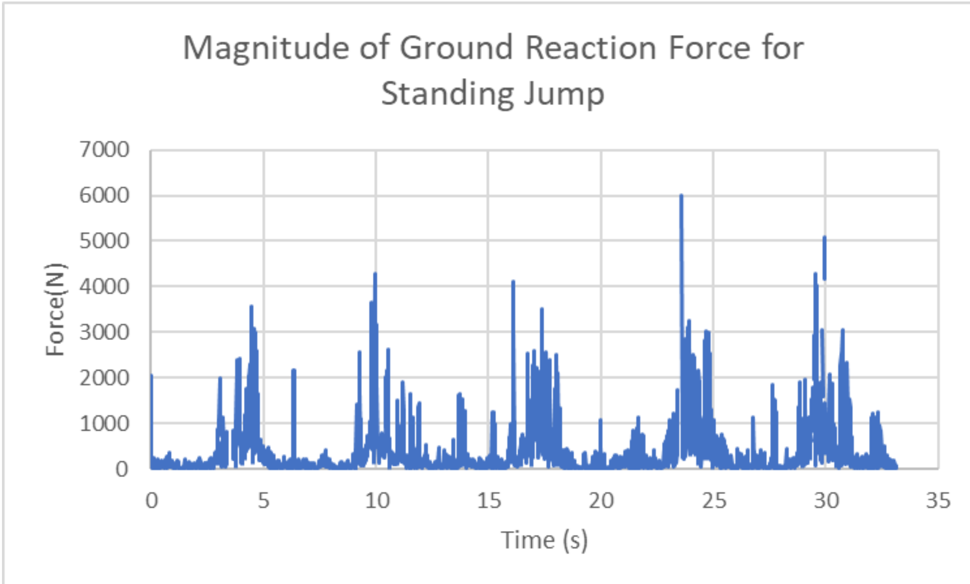


*Figure 2.4 - The total magnitude of ground reaction force during the second jump trial.*

Below is a table summarizing the maximum and average linear speed for the jump trial in the x, y, and z directions as well as the total magnitude.

| | *x* | *y* | *z* | *Magnitude* |
|---|---|---|---|---|
| *Max Ground Reaction Force (N)* | *2959.70* | *1874.57* | *5762.09* | *5987.29* |
| *Average Ground Reaction Force (N)* | *170.74* | *109.36* | *249.24* | *358.65* |

**One Leg Jump: Ground Reaction Force**

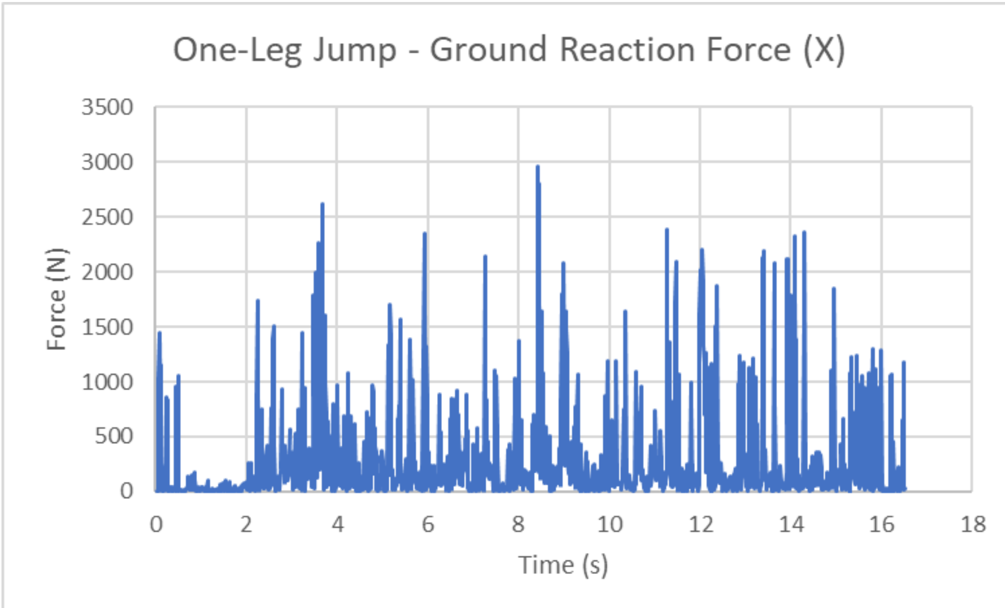


*Figure 2.5 - The ground reaction force in the X direction during the second one leg jump trial.*

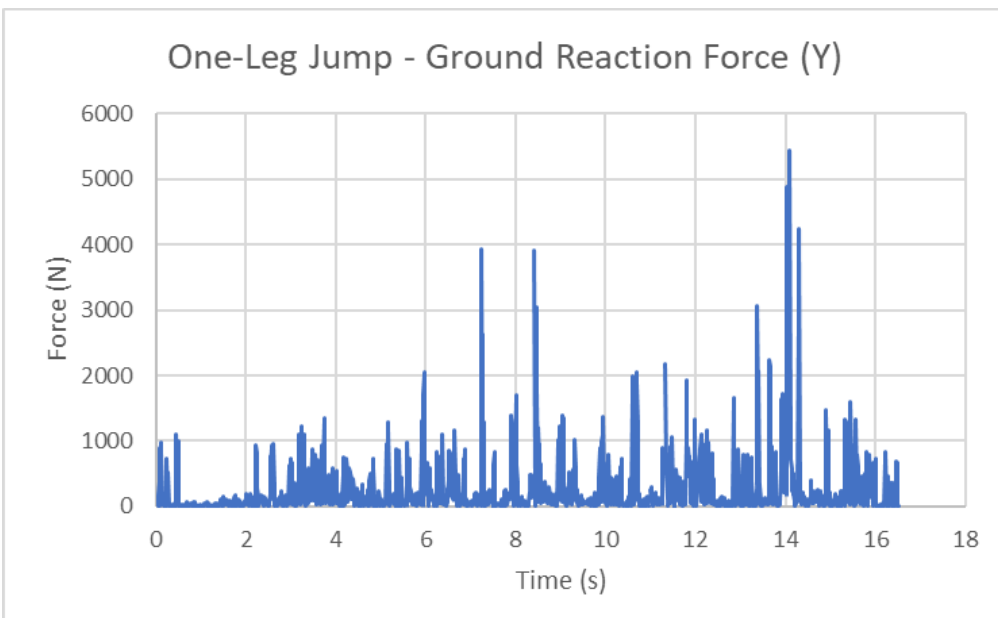


*Figure 2.6 - The ground reaction force in the Y direction during the second one leg jump trial.*

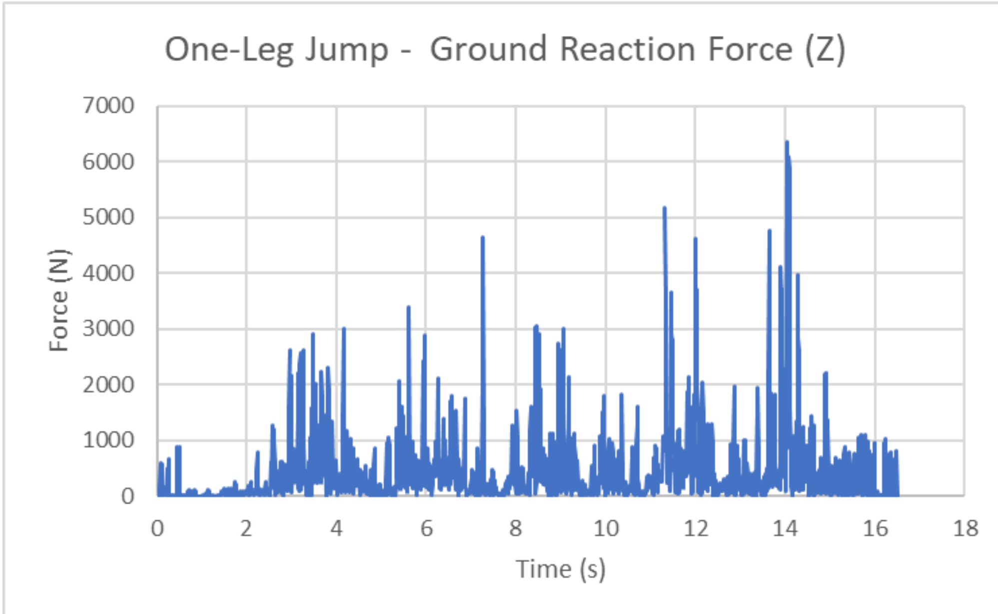


*Figure 2.7 - The ground reaction force in the Z direction during the second one leg jump trial.*

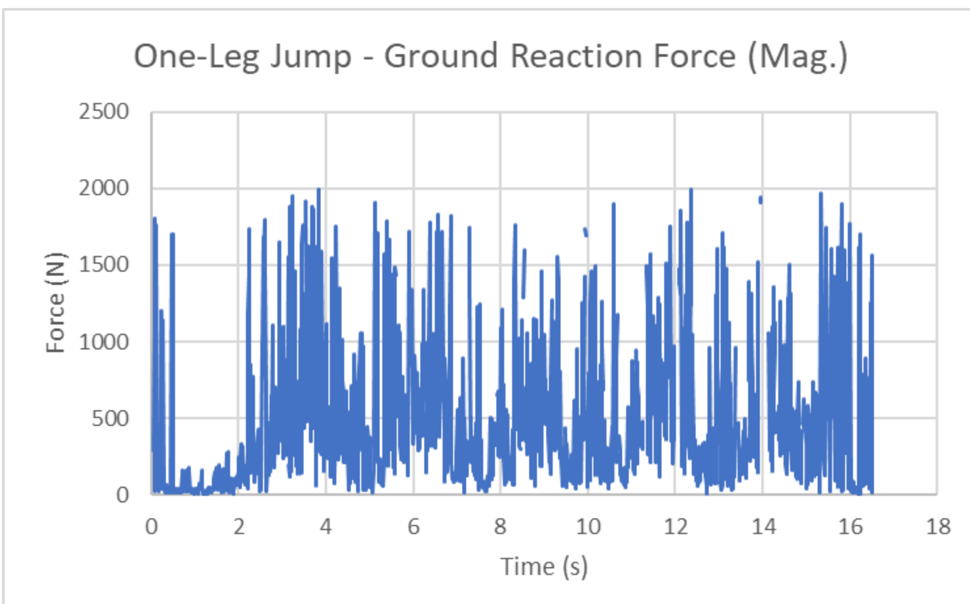


*Figure 2.8 - The total magnitude of ground reaction force during the second one leg jump trial.*

Below is a table summarizing the maximum and average linear speed for the one leg jump trial in the x, y, and z directions as well as the total magnitude.

| | *x* | *y* | *z* | *Magnitude* |
|---|---|---|---|---|
| *Max Ground Reaction Force (N)* | *2959.42* | *5427.27* | *6362.28* | *1996.09* |
| *Average Ground Reaction Force (N)* | *285.68* | *253.99* | *464.82* | *438.17* |

**Running Jump: Ground Reaction Force**

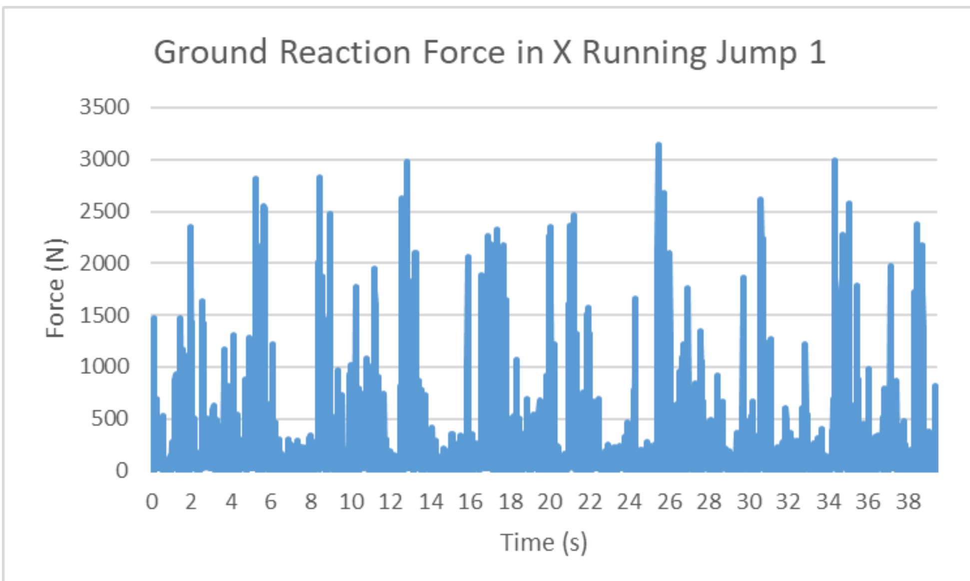


*Figure 2.9 - The ground reaction force in the X direction during the first running jump trial.*

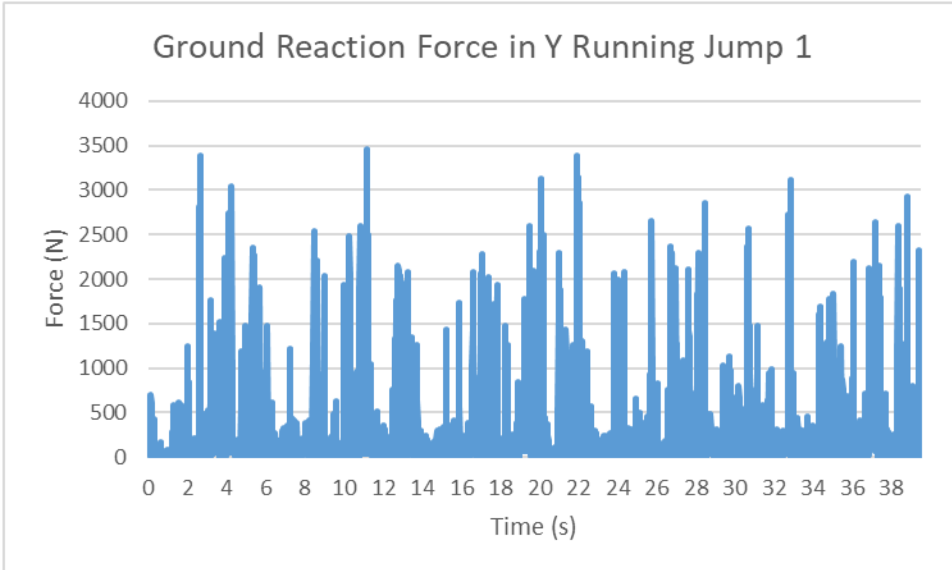


*Figure 2.10 - The ground reaction force in the Y direction during the first running jump trial.*

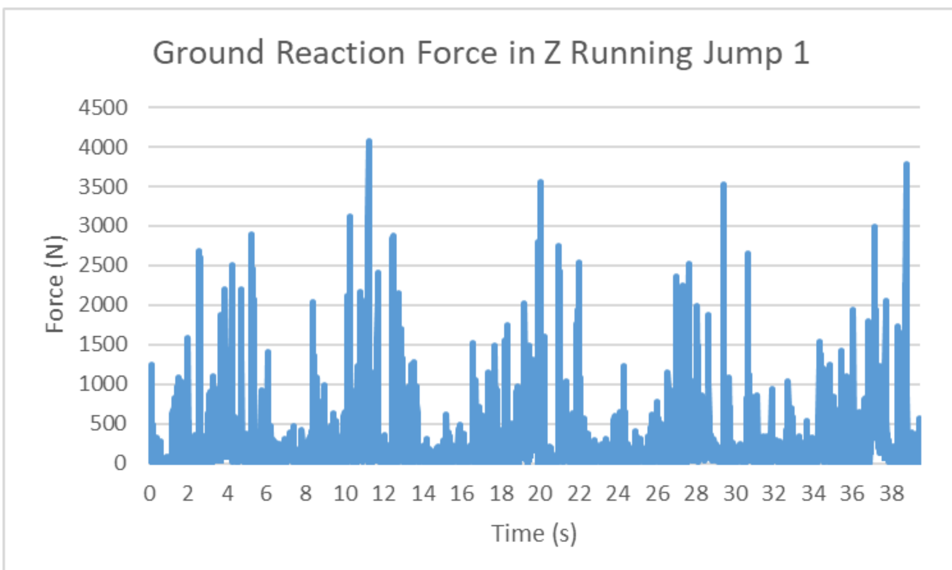


*Figure 2.11 - The ground reaction force in the Z direction during the first running jump trial.*

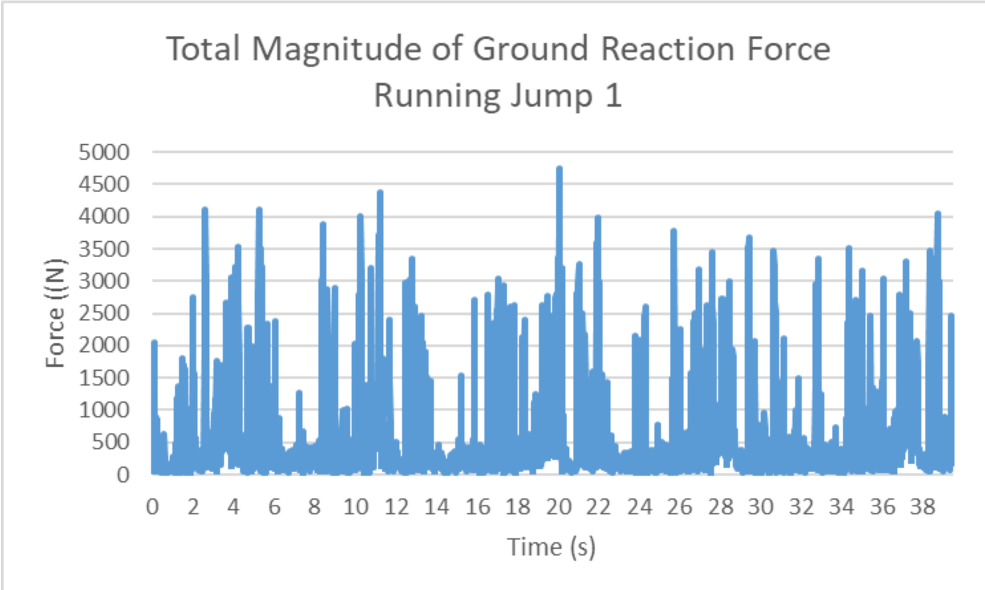


*Figure 2.12 - The total magnitude of ground reaction force during the first running jump trial.*

Below is a table summarizing the maximum and average linear speed for the running jump trial in the x, y, and z directions as well as the total magnitude.

| | *x* | *y* | *z* | *Magnitude* |
|---|---|---|---|---|
| *Max Ground Reaction Force (N)* | *3143.833* | *3460.475* | *4065.883* | *4744.839* |
| *Average Ground Reaction Force (N)* | *225.118* | *283.208* | *267.355* | *505.455* |

**Section 3 - Jump Height**

To determine the height of the jump for each trial, we utilized the sternum marker (STRN). The position of the sternum marker in the Z direction is graphed with respect to time in Figures 3.1-3.3. The baseline height of the sternum marker is 1.07 m.

**Jump: Jump Height**

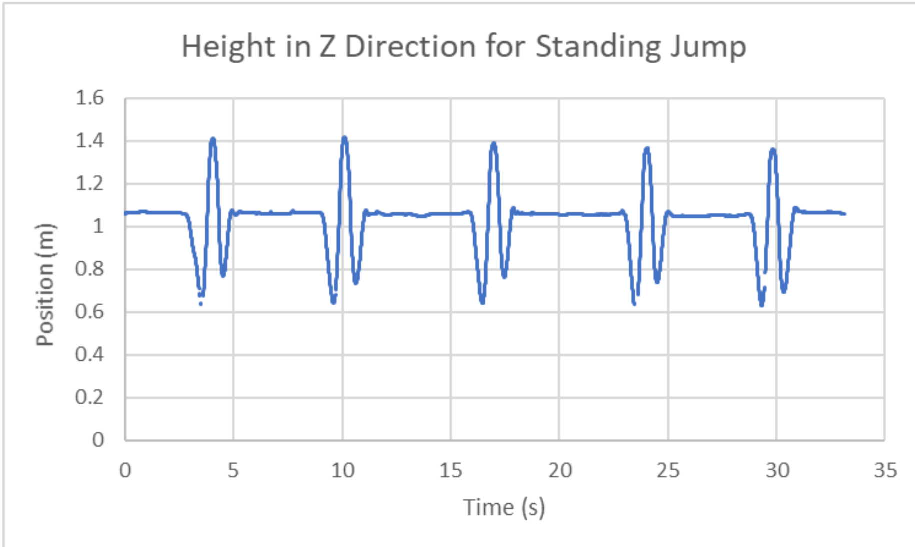


*Figure 3.1 - The jump height in the Z direction during the second jump trial.*

**One Leg Jump: Jump Height**

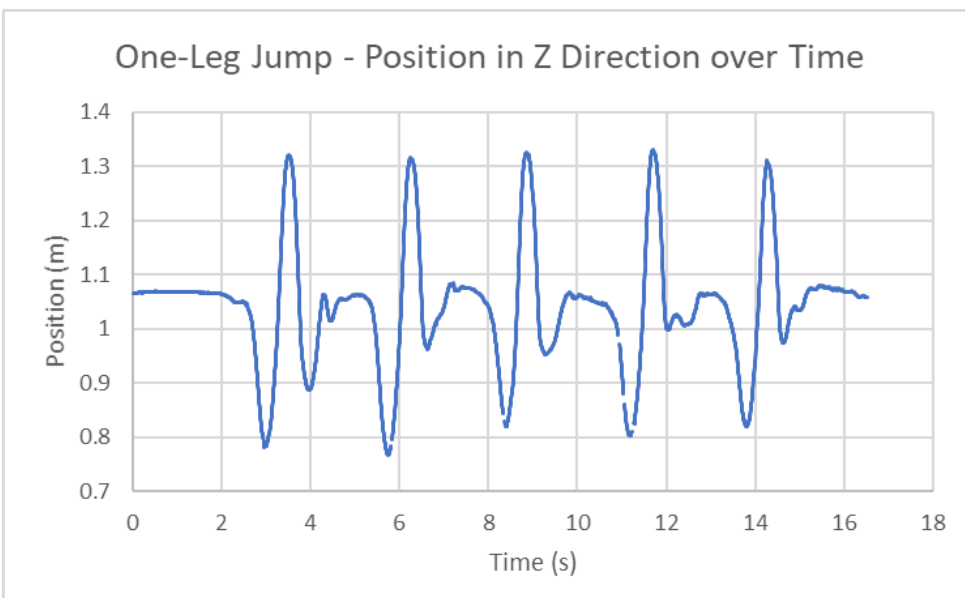


*Figure 3.2 - The jump height in the Z direction during the second one leg jump trial.*

**Running Jump: Jump Height**

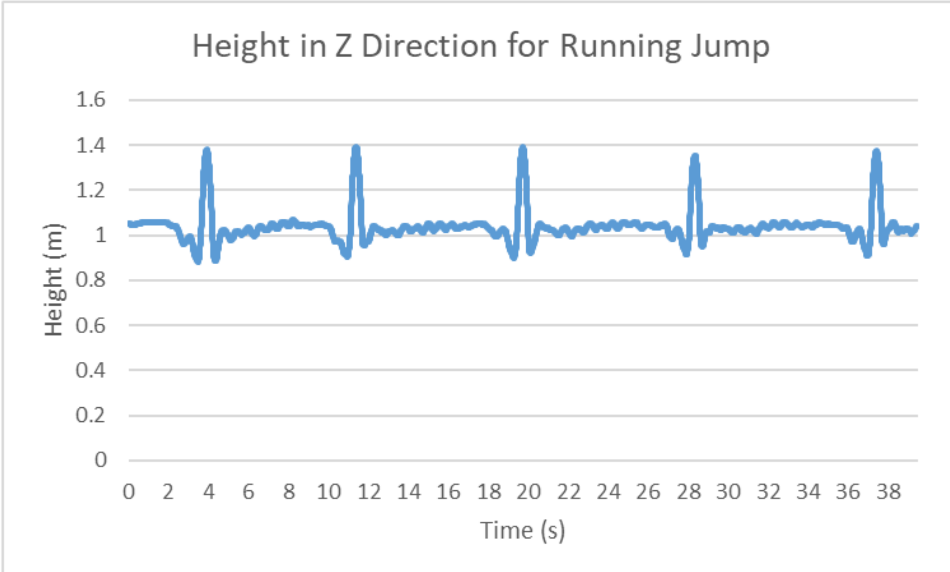


*Figure 3.3 - The jump height in the Z direction during the first running jump trial.*

To determine the height of the jump, we subtracted the baseline height (1.07 m) from the largest data value. Below is a table informing on the maximum and average values of jumping height for each trial. These values are each determined from data collected from the sternum marker in the Z direction.

| | *Jump* | *One leg jump* | *Running jump* |
|---|---|---|---|
| *Max Jump Height (m)* | *0.349* | *0.261* | *0.322* |
| *Average Jump Height (m)* | *0.320* | *0.250* | *0.308* |

**Discussion:**

*Linear Speed:*

Figures 1.1-1.3 shows the linear speed in the Z direction for jump, one leg jump, and running jump. In each graph you can see there are five sections which represent the five jumps performed. The linear speed was at its highest during the jump trial, with the value being 2.999 m/s, and lowest for the one leg jump, with the value being 2.498 m/s. The average linear speed was the highest for the one leg jump, with the value being 0.411 m/s , and smallest for the running jump, with the value being 0.222 m/s. The jump trial had less noise than the one leg jump and the running jump.

*Ground Reaction Forces:*

Figures 2.1-2.12 show the ground reaction forces in each direction as well as the magnitude of forces for each jumping method. For the standing jump and one-legged jump, the highest average ground reaction force was in the z direction, with those values being ~249N and ~465N, respectively. This is accurate because the subject is primarily moving in the z direction, so it would have the greatest forces in this direction. Additionally, the force in the one-legged jump is approximately twice the force in the two-legged jump. We found that the average ground reaction force for the running jump was greatest in the y direction, but it wasn’t too far off for the z direction, as these values are ~283N and ~267N respectively.

The average total magnitude of the ground reaction force was smallest in the standing jump and greatest in the running jump. It makes sense for the one-legged jump to have a greater force than the standing jump, since the force would be concentrated in one foot as well as it being more difficult to jump using just one leg. The running jump also had the greatest ground reaction force sense forces were generated in the x and y directions due to running.

*Jump Height:*

Figures 3.1-3.3 show the vertical height of the subject with respect to the sternum marker. As you can see in the graphs of the jump height with respect to time, there are five spikes in the data, representing when the jumps occur. Surrounding each spike, there are downward spikes that occur because the subject bends their knees before jumping and after landing. The horizontal portions of each graph represent when the subject is standing still between jumps.

The height of the subject's jump was measured by taking the maximum position of the sternum in the z direction for each jump and subtracting the at-rest position of the sternum. This rest value was measured to be approximately 1.07m, so the five maximum values from each jump, as well as the average of these values, were subtracted by 1.07m to get the height of the maximum and average jump height.

The maximum and average height of each jump is reported in the table in Section 3. From this table we can see that the jump height of the Standing Jump trial is the greatest, followed by the Running Jump and One Leg Jump trials respectively. It is likely that the Standing Jump was the greatest because the subject was able to bend their legs more than for the Running Jump. This can be seen when comparing the initial bending spikes in Figures 3.1 and 3.3. The subject bends further down during the Standing Jump than during the Running Jump. Additionally, the Running Jump involved a slightly forward-moving jump, instead of being purely vertical. The One Leg Jump has the lowest jump height likely because there is only the force of one leg pushing the body upward. This would result in a smaller jump height and may also be influenced by how much the subject was able to bend while balancing on one foot.

**Distribution of work:**

1. **Linear Speed**
   - Calcs: CC, MF, CB graph: CC, MF, CB max/min: CC, MF, CB, LMK
2. **Ground Reaction Forces**
   - Calcs: CC, MF, CB graph: CC, MF, CB max/min: CC, MF, CB
3. **Jump Height**
   - Calcs: CC, MF, CB graph: CC, MF, CB max: CC, MF, CB
4. **Introduction, Methods, and Formatting**
   - LMK, SS
5. **Discussion**
   - Everyone