Human Body Motion Analysis in Soccer Kicking

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Lab 3, Group 2

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Abstract

In this experiment, the motion of the leg that kicks a soccer ball was analyzed. With the use of tracker software and Arduino sensors, which allowed for the transmission of accelerometer data, the velocity and the acceleration of the kicking leg, and the velocity and momentum of the ball were measured. Ultimately, it was found that the experimental data aligned with the hypothesis and pre-existing scientific knowledge of natural phenomena. It was found that there is a 0.9614 m/s increase in ball velocity for every 1 m/s^2 increase in maximum leg acceleration of the kicking leg and a 0.5857 m/s increase in ball velocity for every 1 m/s increase in maximum leg velocity of the kicking leg. Although data points for both leg acceleration and leg velocity slightly varied per trial, using slope interpretation allowed for a relevant comparison of the maximum average acceleration for the leg acceleration and leg velocity when kicking a soccer ball.

Introduction

This study determined the effects of leg acceleration and leg velocity when kicking a soccer ball at different efforts. The first steps of the study required the setup of an Arduino and its appropriate sensors, including an accelerometer to measure proper acceleration of the kicking motion, as well as a cable to transmit sensor data. From here, calibration and distance limitations of the accelerometer were determined.

There were three discrete qualitative efforts in kicks, each having three trials, resulting in a total of nine trials conducted. The efforts were considered as “soft”, “medium”, and “hard”. The actual effort of the experimenter who kicked the ball and the average max accelerations for each effort were considered for differentiating between each effort.

$$x(t) = x_0 + v_0 t + (½)at^2$$

Equation 1. General equation of kinematic displacement.

$$\overline{v} = \frac{\Delta s}{\Delta t}$$

Equation 2. General equation of velocity.

$$\overline{a} = \frac{\Delta v}{\Delta t}$$

Equation 3. General equation of acceleration.

$$p = mv$$

Equation 4. General equation of momentum.

Methods

Equipment

A pink soccer ball was the main object used for the experiment. A distinct color was used in order for the tracker software to easily distinguish it from its background. A meter stick was also laid out next to the kicker's foot in the field of view in order to give the tracker software an accurate frame of reference. Tape was used to connect the Arduino sensor to the kicker's knee. This Arduino sensor contained an accelerometer and was wired to a computer for data collection and analysis. Additionally, an outdoor brick wall was used for a stopping catcher for the ball.

Setup

The Arduino sensor was taped to the kicker's knee and connected to a computer through wires. The kicker stood directly in front of the ball, where the kicker used their right foot to kick the ball. The kicker placed their left foot right next to the ball. This part of the setup is displayed in *Figure 1*. A wall (not pictured) was about ten feet away for the purpose to act as a catcher for the soccer ball after it was kicked.

Figure 1. Setup for kicking the soccer ball.

Procedure

There were nine trials conducted in this experiment. There were three kick trials for a "soft" effort kick, three kick trials for a "medium" effort kick, and three kick trials for a "hard" effort kick. The average maximum accelerations for the three different effort kicks were analyzed. These values are displayed in *Figure 2*. After every kick, data for the leg acceleration was sent from the Arduino sensor to the computer via connection and collected by the experimenters. Every kick was videotaped so tracker software could be used to collect and analyze data on the leg velocity and the ball velocity and momentum after the kick.

For each individual trial, the kicker swung their right leg back, keeping it as straight as possible, then swung the leg forward to make contact on the ball with the right hallux (commonly known as the big toe). This kicking motion is displayed in *Figure 3* and *4.* This was done to minimize error, as adding different leg snapping movements and different types of contacts with the ball (kicking with the inside or outside of the foot, for example) would cause a lot of variance in how the ball would react after the kick.

In analyzing the videotapes via the tracker software using the distinctly colored ball and meter stick for accurate results, the choice was also made to track the magnitude of the ball's velocity, instead of its horizontal and vertical components. This was done to reduce error, as in order for the software to separate the velocity into its components, the angle of a coordinate system had to be defined by hand in the software- which may have caused the components to be separated in an inconsistent manner. Especially in the case of the "slow kick" trials, the ball showcased hard-to-predict bouncing behavior when it came into contact with the ground.

We additionally analyzed the velocity of the foot motion before it came into contact with the ball in order to compare it with the data taken from the arduino. Similar choices, such as isolating a distinctly colored portion of the kicker's shoe, as well as taking the magnitude of the velocity instead of its components, were made. The method of analyzing the data was by using Python, by which is further explained in the Analysis section later in the report.

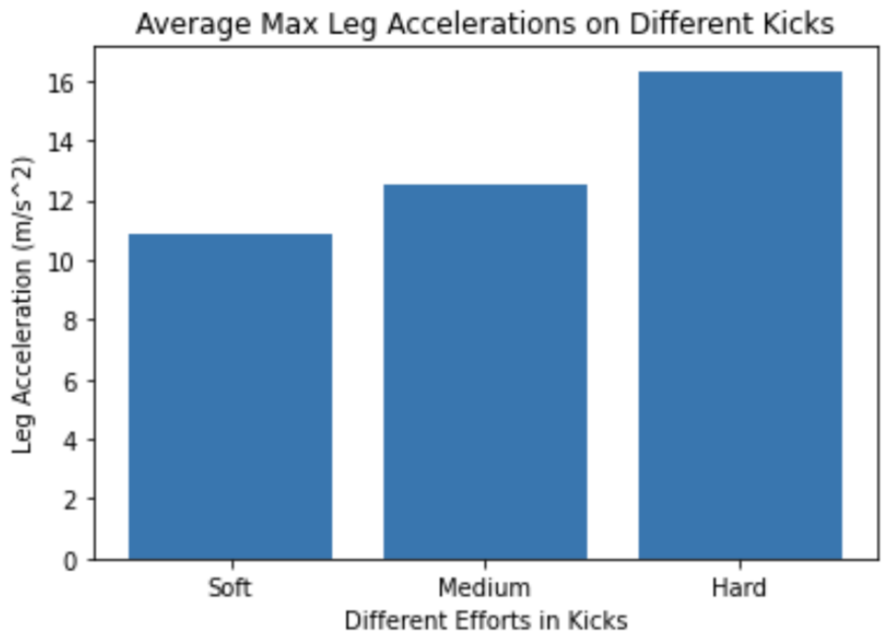

Figure 2. Average maximum leg accelerations on the different efforts of kicks.

Figure 3. Swing back motion of the kick.

Figure 4. Forward swing motion and movement of the ball after the contact from the kick.

Results

Tables:

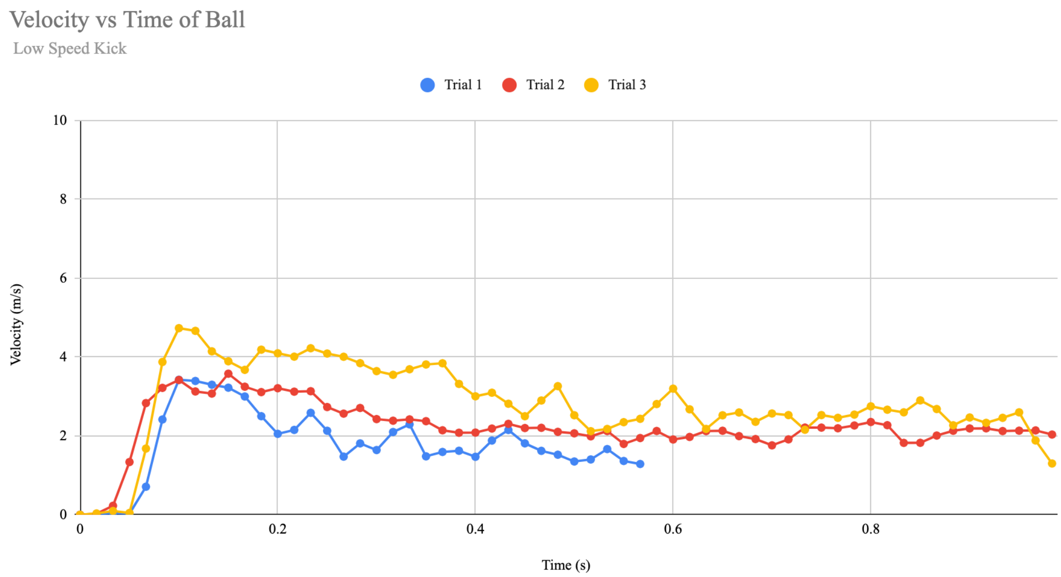

Figure 5: Velocity of Ball obtained from tracker analysis - Low Speed Kick

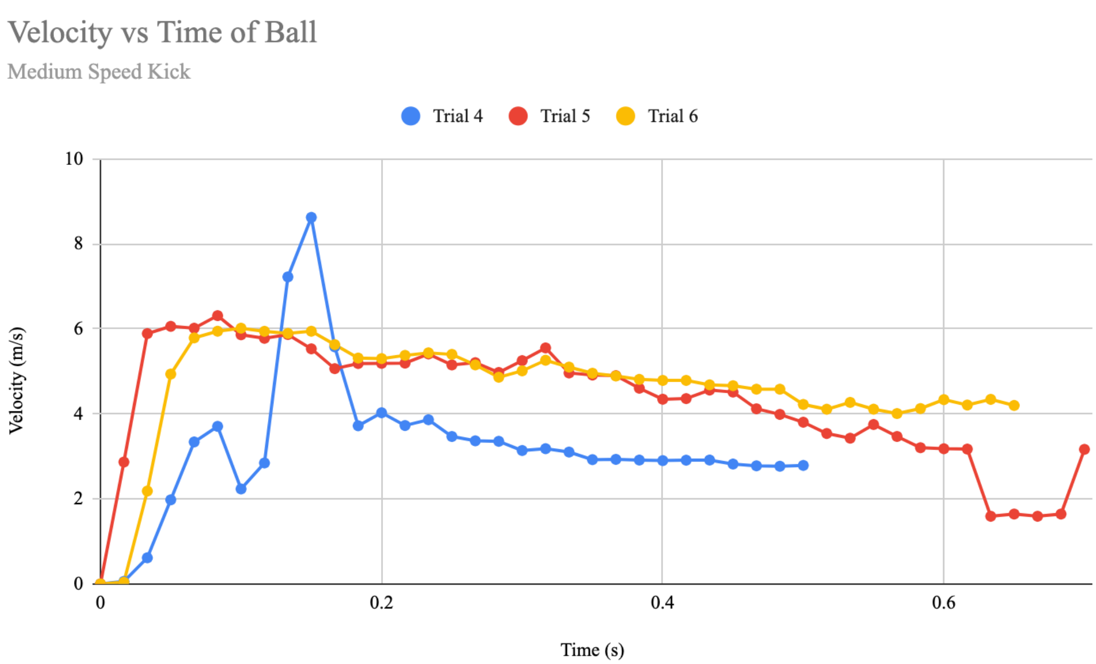

Figure 6: Velocity of Ball obtained from tracker analysis - Medium Speed Kick

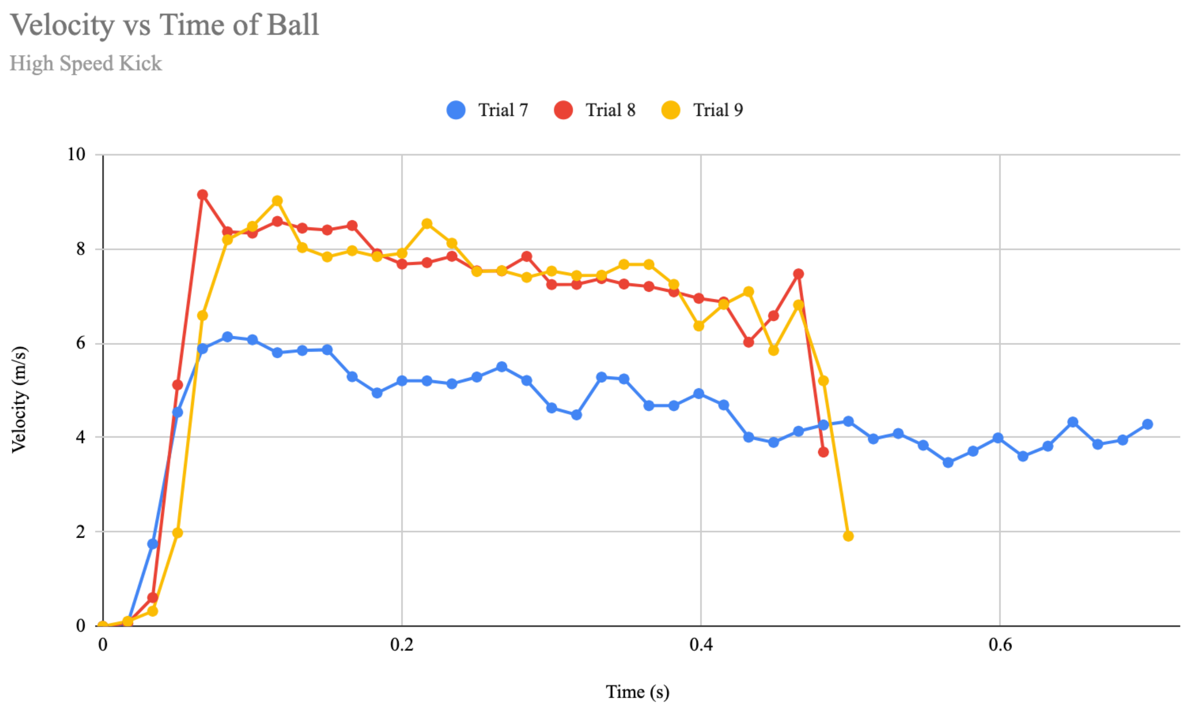

Figure 7: Velocity of Ball obtained from tracker analysis - High Speed Kick

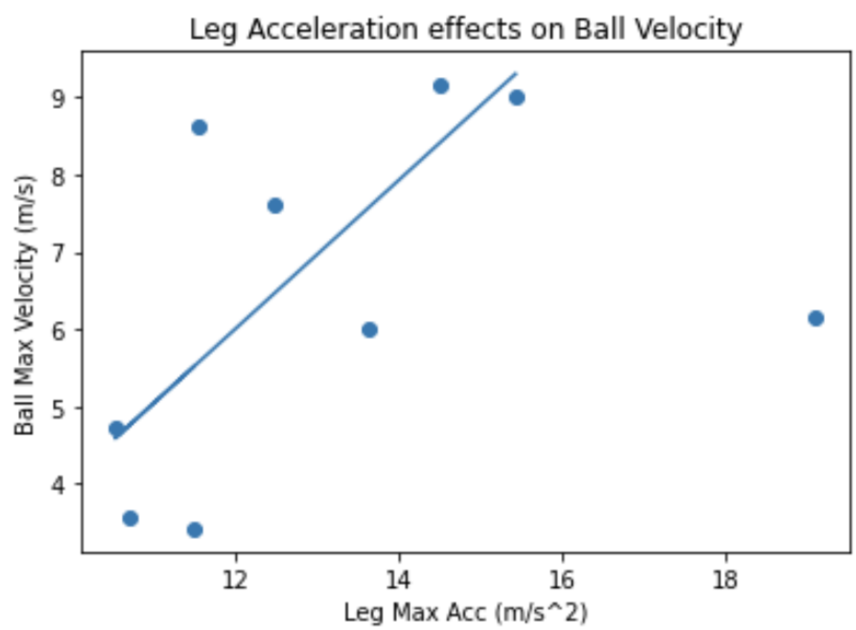

Figure 8: Effects of Leg Acceleration on Ball Velocity

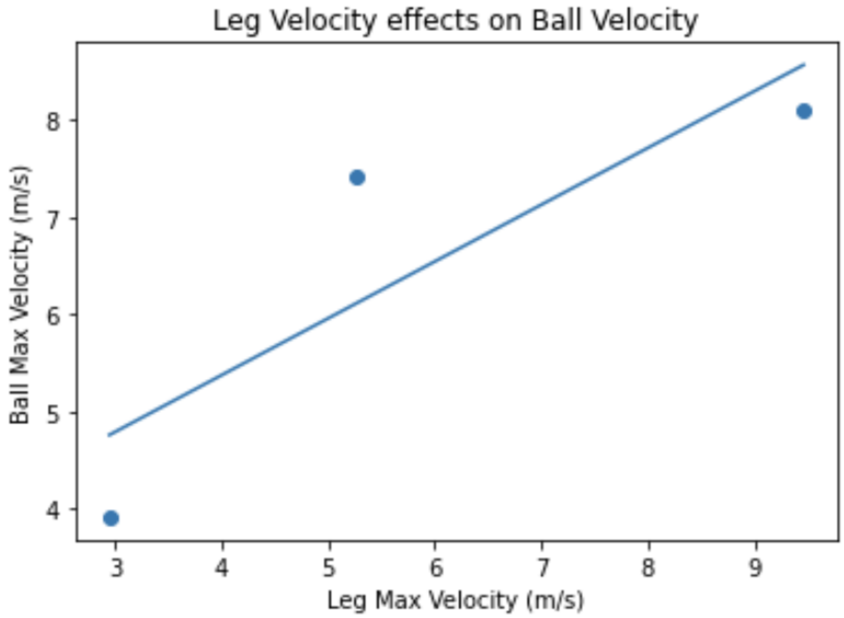

Figure 9: Effects of Leg Velocity on Ball Velocity

Analysis:

Compiling the ball velocity data into line graphs as in *Figures 5, 6 and 7* displayed what we had previously envisioned - that the ball would quickly reach a maximum velocity when kicked, and then slow down gradually. We then took these maximum ball velocity values for each kick level and compared them with both maximum Leg Acceleration and maximum Leg Velocity as shown in *Figures 8 and 9*. This allowed us to quantify a relationship between the motion of the kicker's leg and the motion of the ball by interpreting the slope of the graphs.

In *Figure 8*, we found a 0.9614 m/s increase in ball velocity for every 1 m/s^2 increase in max Leg Acceleration owing to the graph's slope of 0.9614. Next, we found a 0.5857 m/s increase in ball velocity for every 1 m/s increase in max Leg Velocity owing again to a slope of 0.5857 in *Figure 9*. This tells us that per increment, (m/s^2 or m/s), leg acceleration was a more influential factor in increasing ball velocity.

In order to calculate the two slopes in the paragraph above and analyze the data to reach those slopes, we used Python. Notably, we used NumPy in order to load and process the accelerometer data read in from the Arduino. From there we used NumPy to break the data into windows, corresponding to the different trials. For each trial, we used NumPy to calculate the max and min values reached for Leg Velocity and Leg Acceleration, so that we could make a range of increase from min to max. Using this increase value for each trail along with the level of kick (soft, medium, or hard) we were able create a scatterplot using Matplotlib and fit a slope to the data using NumPy's polynomial fit module.

Conclusion

The purpose of this experiment was to determine whether increasing the leg acceleration or the leg velocity when kicking a soccer ball would increase the velocity and momentum of the ball after the kick more effectively. The found experimental results ended up backing up the hypothesis, as there was a 0.9614 m/s increase in ball velocity for every 1 m/s^2 increase in maximum leg acceleration of the kicking leg and a 0.5857 m/s increase in ball velocity for every 1 m/s increase in maximum leg velocity of the kicking leg.

To improve on this experiment and to better support the stated hypothesis, it would be best to use more advanced technology in addition with more effective ways of kicking a soccer ball. The kicking form performed in this experiment was one of the least efficient and accurate ways of kicking a soccer ball. For example, all higher level soccer players use the inside of the foot to pass a soccer ball, which is similar to the scenario performed in the experiment. Also, higher level players perform a knee snapping motion to put different amounts of power in kicking the ball. These two main techniques of kicking a ball were not used in the experiment. The reason the experiment was done in a simpler way was because when using different forms of kicking a ball, it creates a greater surface area of contact, which can change the result of the ball in a myriad of ways. Additionally, the setup was not the most comfortable because of the sensor being taped to the kicker's knee.

With more advanced software and experimental setups, analysis on the conservation of momentum and kinetic energy can be conducted. Other athletic movements can be studied to determine the most important biomechanical factors in transfer of momentum, such as the optimal time to exert maximum effort in a lift for a powerlifter, or the best jump shot technique for a basketball player.