Exploring how the pressure of a soccer ball affects its bounce height and how they are related

[redacted]

Introduction:

This investigation will be focused around the idea that as a soccer ball's internal pressure increases then the bounce height of the ball will increase. The reasoning behind the investigation is mainly due to the importance of soccer in my life. I have played for the past 13 years of my life and plan to continue playing for as long as I can. Over the past year my curiosity of how the sport is played has increased with a primary focus on the physics behind a soccer ball. I wanted to conduct an experiment that would help explain why a soccer ball must have a certain pressure reading in order to be played with. The investigation will answer the question of how the pressure of a soccer ball affects its bounce height when dropped, which will provide me with experimental results to explain why a certain pressure in a soccer ball is required for it to be played with in a soccer game.

The main physics focus will be around the inelastic collision between the ground and the soccer ball and the transfer of energy as the soccer ball is dropped during the experiment. In an inelastic collision kinetic energy of the two colliding objects is not conserved, meaning that there is a loss of energy as the collision occurs. This is obviously seen as a soccer ball will never bounce back up to the initial drop height not only due to this loss of energy, but also the effect of gravity on the soccer ball. By releasing air and thus changing the pressure of the soccer ball, the time of contact between the ground and the soccer ball is increased. The time of contact increase is due to a decrease in pressure which allows the soccer ball to compress more when it comes in contact with the ground. The compression then leads to a greater amount of kinetic energy from the soccer ball being transferred to the ground which subsequently decreases the soccer ball's bounce height.

I hypothesize that the increase of a soccer ball's pressure will have a linear direct correlation to the bounce height of the soccer ball when graphed because the increase of pressure will be consistent and no outside factors will affect the soccer ball.

Question:

How does the pressure of a soccer ball affect its bounce height when dropped from a consistent height?

Hypothesis:

If a soccer ball of consistent size is dropped from a height of 250 cm, then as the pressure inside of the soccer ball is increased the bounce height of it will also increase because there will be less compression of the soccer ball as it hits the ground. Due to a smaller amount of compression, the soccer ball will be in contact with the ground for a shorter period of time, meaning that more momentum and energy will be conserved in the soccer ball.

Independent Variable:

The independent variable will be the pressure of the soccer ball. I will be increasing the pressure by 2 PSI after every five trials to ensure that my data is accurate. This will be measured using a pressure gauge with 1 PSI precision.

Dependent Variable:

The dependent variable is the bounce height of the soccer ball and this will be measured after every trial of the experiment by using video recordings of the soccer ball's bounce along meters sticks stacked on a wall.

Controlled Variables:

The controls will include the drop height of the soccer ball, 250 cm, the surface that the soccer balls are dropped onto, concrete, and the experiment will be conducted indoors so that wind, temperature, and air pressure do not affect the results

Procedure:

1. Three meter sticks must be lined up against a wall in order to observe the soccer ball bounce height.
2. The pressures of the soccer ball range from 4 PSI to 16 PSI due to the fact that a soccer ball with a pressure lower than 4 PSI does not have a high enough bounce that can be accurately observed. A pressure of 16 PSI was chosen as the maximum because the

Fédération Internationale de Football Association (FIFA) recommends that a soccer ball is not pressurized above 16 PSI.

3. A scientist should now hold the soccer ball at the desired drop height of 2.5 meters. The soccer ball should be held from the sides to avoid a force being applied to the ball as it is dropped. Two and a half meters was chosen as the drop height because the differences between bounce heights of differently pressured soccer balls was sufficient for the experiment.
4. A second scientist should be standing by the meter stick in order to record and observe the bounce height of the soccer ball based on the upper most point of the ball. A phone with slow motion recording capabilities was used to easily observe the bounce.

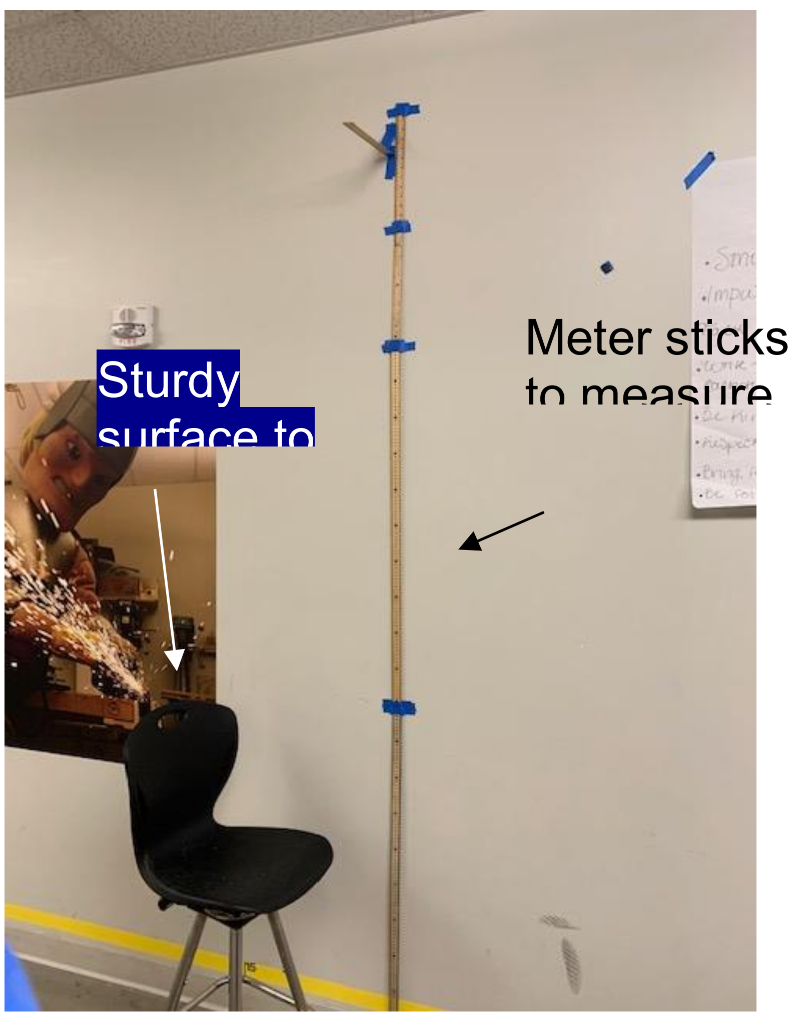


Fig. 1 - Picture of Lab Set up

5. The experiment should begin with a soccer ball at a pressure of 4 PSI being dropped five times in order to acquire an average bounce height which will reduce percent error between drops.
6. Once five trials have been completed for the current pressure, the pressure should be increased by 2 PSI. Another five trials should be taken for the new pressure.

7. Steps 5 and 6 should be repeated for each different pressure of the soccer ball up to 16 PSI. This will provide the desired data to be analyzed.

Safety Concerns:

With this experiment there are very few safety concerns, however one concern would be to ensure that no living beings are in the area where the soccer ball is being dropped. This may lead to injuries such as a concussion. In addition, the scientist dropping the soccer balls should stand on a well secured platform to ensure that he or she does not fall and receive severe injuries.

Data:

	Height of Bounce (cm)					
Pressure (PSI) ± 0.5 PSI	**Trial 1 ± 1 cm**	**Trial 2 ± 1 cm**	**Trial 3 ± 1 cm**	**Trial 4 ± 1 cm**	**Trial 5 ± 1 cm**	**Average (cm)**
4	133	132	129	129	135	132 ± 3
6	137	146	140	141	143	141 ± 5
8	146	145	147	143	147	146 ± 2
10	148	149	154	159	158	154 ± 6
12	154	160	161	164	165	161 ± 6
14	165	160	172	169	171	167 ± 6
16	173	176	173	173	171	173 ± 3

Uncertainty:

- By using an analog pressure gage that measured to every 1 PSI, my uncertainty is ± 0.5 PSI because that is the least count on the meter.
- The bounce height uncertainty of ± 1 cm was determined from human error when reading the measurement on the meter stick which measured every 1 cm.
- Average uncertainty calculation: 4 PSI results used as example

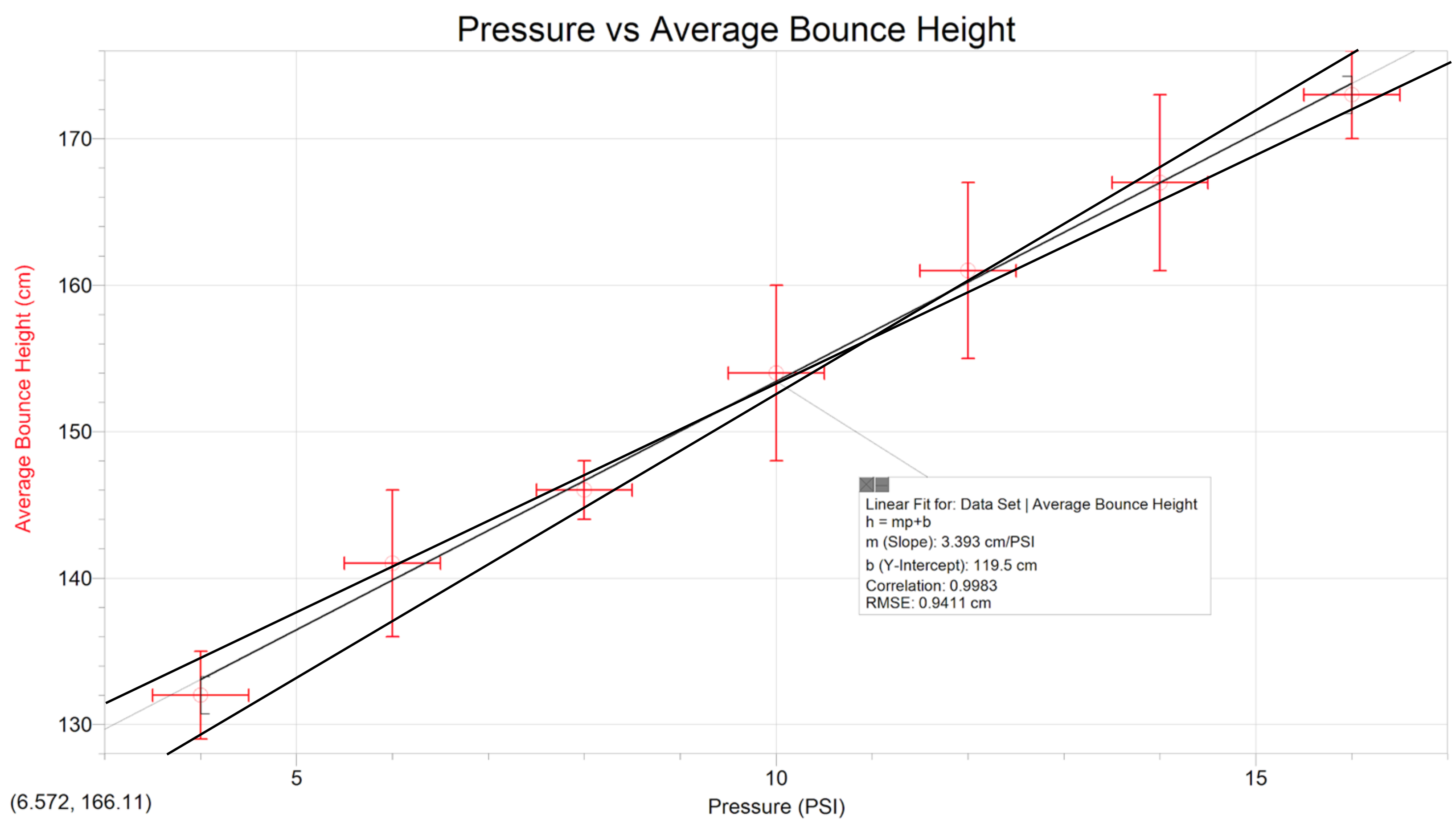
$$Uncertainty\ =\ (max\ -\ min)\ /\ 2$$

$$Uncertainty\ =\ (135\ -\ 129)\ /\ 2$$

$$Uncertainty\ =\ (6)\ /\ 2$$

$$Uncertainty = \pm 3\ \text{cm}$$

Graph: Pressure (PSI) against Average Bounce Height (cm)



Data Analysis:

The results of my experiment support my hypothesis that as the pressure of a soccer ball is increased the bounce height will increase proportionally due to the decreased amount of kinetic energy lost during the collision. Starting from a soccer ball with a pressure of 4 PSI allowed me to have a wide range of pressure values without exceeding the recommended max pressure of 16 PSI. The bounce height of the soccer ball at the lowest pressure (4 PSI) was on average 132 $\pm$ 3 cm and the maximum pressure of 16 PSI had a bounce height of 173 $\pm$ 3 cm. A

41 cm increase is seen between the lowest and highest values of pressure which had a range of 12 PSI. By dividing the increase of bounce height by the increase in pressure it is seen that the bounce height increases by about 3.4 cm for every increase of one PSI in the soccer ball. This is supported by the graph as it is the slope of the linear fit line.

Error Analysis:

There were three main errors that could have impacted the results of my experiment. The first error could be a reason for inaccuracy in the data collection process. A phone with the capability of recording in slow motion was used to record the height of the soccer ball's rebound height. Although this did help minimize error by making it easier to read the measurements of the meter stick and see the height of the ball, there were still some improvements that could have been made. The camera was only able to slow down the ball's movement so much and a better, more frames per second could have helped to have a more accurate height for the soccer balls. In addition to this, the angle of the camera was different for some of the recordings which may have lead to some inconsistencies in the data collection process. The camera angle impacts the data because if it was perfectly perpendicular to the meterstick then it would allow the scientist to accurately observe how high the balls bounced, however, and uneven angle such as one from a more sideways view may make it hard to accurately observe how high the top moist point of the soccer ball went after it bounced.

Another improvement to the experiment could have been to check the pressure of the soccer ball after every trial to ensure that no pressure was lost. This was not done during the experiment due to the fact that the changes in pressure would have been so miniscule that they would not have drastically altered the bounce height, but a decrease in pressure of the soccer ball could have been a possibility after every trial, although there was now evidence of this occurring.

Lastly A force may have been applied to the soccer ball as it was dropped from the predetermined height of 250 cm. A way to ensure that there was a consistent amount of force applied to the soccer ball on each trial would have been to use a force gage that recorded the soccer ball's force on the ground due to gravity. This would have helped rule out errored and skewed trials and data values. All in all, there was a general consistency between each trial based on the data collected so it is safe to assume that the previously stated areas of potential error had little effect on the data collected during the experiment.

Conclusion:

In conclusion, there is a generally linear direct correlation between the pressure of a soccer ball and its bounce height after being dropped which supports my hypothesis that as the pressure is increased the bounce height will also increase due to the fact that the soccer ball does not compress as much in the collision when it has more pressure. The more that the soccer ball compresses the longer that it is contact with the ground or other colliding surface. This longer collision allows for more kinetic energy to be transferred from the soccer ball to the ground which leads to a lower bounce height. Many improvements could have been made to the experiment had higher end equipment been available such as a slow motion camera. Despite this the data was collected as accurately as possible.

An extension of this experiment could be to test how the bounce surface affects the height of a soccer ball's bounce. This would be done by again dropping a soccer ball from a consistent height onto a grass field, artificial turf, and different types of artificial turf / grass. This would provide the researcher with an understanding on how playing soccer on different surfaces could affect the game and its speed of play.