The Physics Behind Weight Lifting:

A Look into the Effect of Technical Equipment on the Three Major Compound Lifts

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Abstract

The objective of this study is to test the effectiveness of the weightlifting belt, technical shoes, and wrist wraps to see if they improve the form, safety, and performance of lifting. The most popular technical equipment within the weightlifting community includes the usage of, weight belts, technical shoes, and wrist wraps. The weight lifting belt claims to support the lifter's spine helping them maintain a straight back allowing them to lift heavier weights. Technical shoes claim to keep the lifter's feet in the most optimal position so the lifter can push the weight with the heel of their foot offering them an increase in their maximum lifts for squat and deadlift. The wrist wraps claim to keep the lifters straight and supported, offering that their bench press will have the straightest and overall shortest path increasing their maximum lift. The purpose of this experiment is to test these claims by measuring the velocity of the barbell and comparing the two velocities to see if the technical equipment increased the velocity. If the velocity of a lift increases from not wearing any technical equipment lifting the same weight as when wearing technical equipment, then this would indicate an increase in the performance of that lift.

Introduction

With the rise of technology, the ability to measure different aspects of weightlifting has increased. Weightlifters now have more information on techniques and form to maximize results and their safety. Many products have been invented to improve performance and safety in weight lifting such as the use of technical shoes, weight belts, and wrist wraps.

The weight lifting belt claims to support the lifter's spine, helping them maintain a straight back allowing them to lift heavier weights. The squatting shoes claim to keep the lifter's feet in the most optimal position so the lifter can push the weight with the heel of their foot offering them an increase in their maximum lifts for squat and deadlift. The wrist wraps claim to keep the lifters straight and supported, offering that their bench press will have the straightest and overall shortest path increasing their maximum lift.

The lifter will perform three compound lifts known as the Conventional Squat, the Convention Deadlift, and the Benchpress. The acceleration of the barbell while performing the compound lifts will be measured using an accelerometer. While the mobile app *My Lift: Measure Your Strength* will measure the deterioration of the lifter's form and the velocity of the barbell, which will be compared to the calculated velocity from the measured acceleration. The app also offers backup data if a problem with the accelerometer were to arise.

Theory

The design of the experiment is to use an accelerometer to measure the acceleration of a barbell. From the acceleration, one will be able to determine the net force that the lifter is applying to the barbell using Newton's second law[1]

$$F = ma_y + mg \tag{1}$$

The human body and the barbell are two separate systems but when the lifter engages the barbell it becomes a one-body system. In the case of the deadlift and bench press, the force is being applied with the lifter's hands. In the case of the squat, the lifter will have the barbell on their back but their feet will be experiencing the full force of the weight.

The difference in acceleration while performing the squat, deadlift, and bench press will allow us to calculate the velocity of the barbell. The velocity will allow us to track the speed of the barbell and determine if the lifter is moving the weight at a faster rate. A higher velocity indicates increased performance as the lifter is more easily able to move the weight. If velocity is increased with the belt, tech shoes, or wrist wraps that means that they have a positive effect on the lifter's performance. [1]

$$v = \int a \, dt \tag{2}$$

To determine if the differences in velocity are significant between treatments, a two-tailed ANOVA test will be run on the velocities under different conditions.

The app *My lift: Measure Your Strength* will track the lifter's movement and the path of the barbell. The app will connect lines to the joints of the lifters such as their hips, knees, and neck. This will allow us to see if the lifter's form is deteriorating. The deterioration of the form will indicate that the lift is becoming more unsafe and the lifter has a higher chance of injury.

Methods

This study will include the three major compound lifts: squat, deadlift, and bench press. For each of the lifts, test subjects will perform each lift under different conditions. The control is the lift performed while barefoot. This represents the person's natural form. Then, the lift will be performed with technical shoes. Following this, with a weight belt/wrist wraps. Then, both the technical shoes and the weight belt/wrist wraps.

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During each lift, an accelerometer will collect data on the acceleration of the bar. The acceleration will then be used to calculate the force and velocity of the barbell. The calculated velocity will allow us to compare the speed of the barbell under different conditions. The faster movement of the barbell will be correlated with better performance.

In addition to the accelerometer, the lifter will be recorded by the *My Lift: Measure Your Strength* app to track bends in their body to examine safety and form. The bends that are going to be measured will be in their back, neck, and hips. The back, neck, and hips are the three points of the body that will determine if the lifter's form is deteriorating. The lifters will perform squat, deadlift, and benchpress, with just the barbell, to set a baseline for their form.

To ensure safety and increase the amount of data, the lifters will begin with just the barbell then increase to twenty-five percent, sixty-five percent, and eighty-five percent of their one-rep max. The recommended rest periods between lifts are two to four minutes, two minutes for the lighter lifts, and scaling up to four minutes closer to the lifter's max lift.[2] The rest periods will ensure that muscle fatigue does not affect the acceleration and velocity of the barbell. To decrease the uncertainty from muscle fatigue, the lifters will be taking three recovery days to ensure their bodies have enough time to fully recover. Three days of recovery is the recommended period. [3]

During the rest day, it is important that the lifters stay hydrated because dehydration can decrease strength by upwards of ten percent, since we are performing exercises that will further dehydrate the lifters; it is recommended a liter for every one thousand calories burned. [4] To ensure that the lifters have a consistent amount of energy throughout the data collection process, eat two servings of oatmeal. Oatmeal is a slow-digesting carbohydrate and will provide a consistent amount of energy to collect accurate data.

In order to keep the percentages of the one-rep max accurate, retesting of the one-rep maxes for the three compound lifts every two weeks. This was done to combat the issue of muscle growth and to try to keep the data as consistent as possible.

The lifters will also be performing warm-up lifts with just the barbell and from the warmup. One will be able to see the lifter's natural form while at the same time, preventing injury and lowering the risk of uncertainty by loosening up the lifter in order to get the best possible data. Comparing the lifter's natural form from the warmups to their form as the weight progressively gets heavier will allow one to determine how much the lifter’s form has deteriorated.

The proper form for performing a conventional deadlift is to stand shoulder-width apart and grab the barbell just outside of your feet. Once the lifter has properly set up for the deadlift they will drop their butt down while keeping their back straight and pulling the barbell to their shins. From the bottom position, the lifter will push through their feet to lift the barbell. To ensure the safety of the lifter, it is very important that they keep their back straight and do not round their back throughout the lift.[5] Figure 3 shows a good depiction of the form throughout the entire lifting process for the deadlift.

The proper form for performing a squat is to place the barbell on their trapezius and step back from the squat rack. Once the lifter has stepped back from the rack, they will position their feet directly under them and place their feet shoulder-width apart. The lifter's toes can be pointing straight forward or slightly outward depending on which is more comfortable for the lifter. Once they are in the top position, the lifter will bend from the knees while maintaining a straight back, to the parallel position. The parallel position is when the quadriceps are directly behind the knee. Figure 1 shows the proper form for squatting in the top and bottom positions.

From the parallel position, the lifter will push through their heels until they are in the upright position. Just like the deadlift, it is important to get the back straight and not rounded throughout the entire lift.[6] The proper form for performing a bench press is for the lifter to lay down on the bench press with their eyes directly under the barbell. Once the lifter is properly laid down they will grab the barbell with both hands shoulder-width apart. Once the barbell is in the lifter's hands they will bring the weight down to just above the nipple line on their chest, tapping their chest. From there, they will push the barbell in a straight line back to the starting position. It is important for the lifter to control the weight on the way down to make sure the path of the barbell is straight.[7] Figure 2 illustrates very well what the proper form is for the top and bottom positions while performing the bench press.

The data velocities will be compared using a two-tailed t-test and ANOVA test. The t-test will be a more broad data analysis. The t-test will compare the velocities of no technical equipment to velocity with technical equipment. This test will show if there is any correlation between performance and technical equipment using the mean values. The ANOVA test will allow us to test different aspects of the technical equipment and tell us with the p-value if we can accept or reject the null hypothesis from different technical equipment.

It is important to note that the velocities under fifty percent of the lifters' one rep max will be affected by the placebo effect of technical equipment. The lifts under fifty percent of the lifter's one rep max will experience a mean average increase of 0.8 meters per second [8].

The original plan was to use the accelerometer to measure the acceleration of the barbell but when it came into contact with the barbell it made the data unusable. In order to fix that issue, a free app was downloaded called *WatchForce,* this app converts any apple watch into an accelerometer and can be used to measure the acceleration.

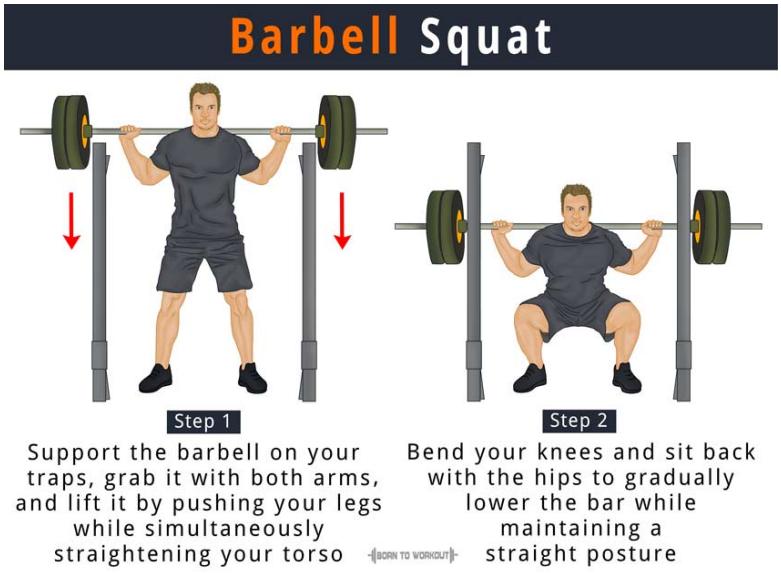


Figure 1: Proper Form for Squat

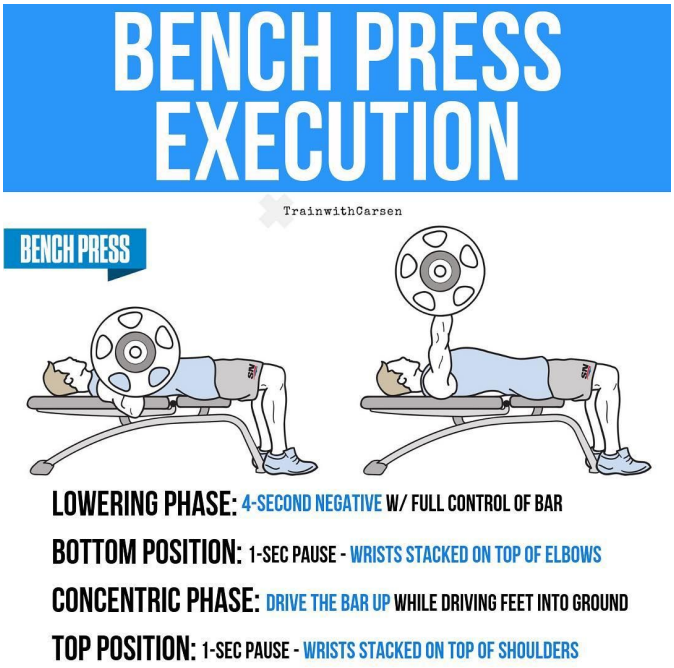


Figure 2: Proper Form for Bench Press

Figure 3: Proper Form for Deadlift

Data

Table 1: Average Velocities for Bench Press

	Without Wrist Wraps	With Wrist Wraps
25% of One Rep Max	1.602666667	1.819333333
65% of One Rep Max	0.7566666667	1.006666667
85% of One Rep Max	0.4753333333	0.5613333333
Total of Average Velocities	0.9448888889	1.129111111

Table 1 is the averages of the velocities for bench press for each of the trials twenty-five, sixty-five, and eighty-five percent. The total is the average of all the velocities measured for the bench press. The values in table 1 are the values used to create graph 1.

Table 2: Average Velocities for Deadlift

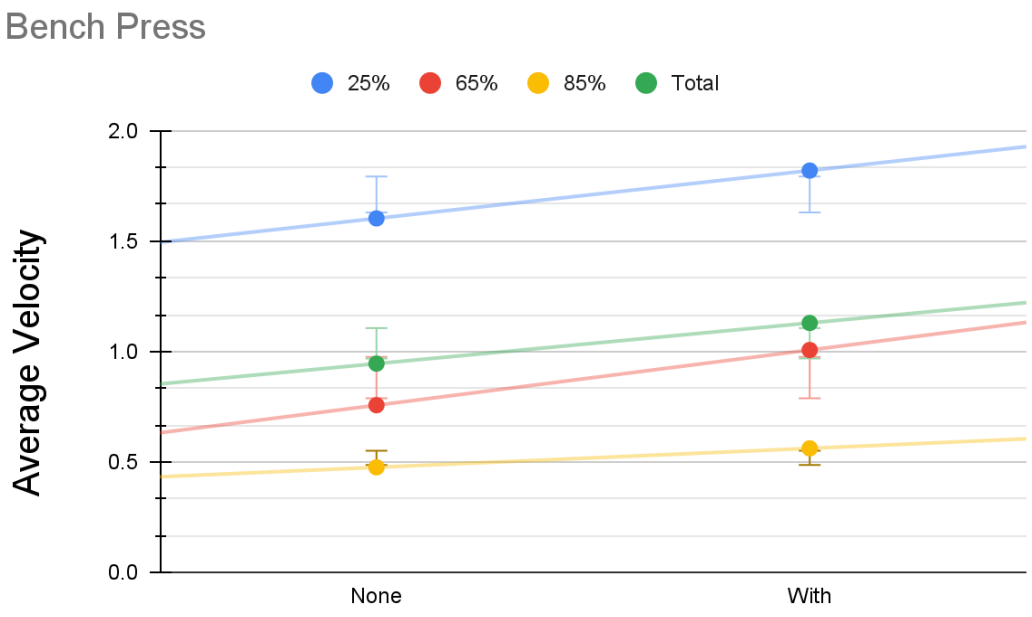
	Without Tech Shoes and Weight Belt	With Tech Shoes and Weight Belt
25% of One Rep Max	2.375333333	2.41
65% of One Rep Max	1.362	1.443333333
85% of One Rep Max	0.9386666667	1.048
Total of Average Velocities	1.558666667	1.633777778

Similar to table 1, table 2 is the averages of the velocities for each of the trails but for the deadlift. The values in table 2 are the values to create graph 2.

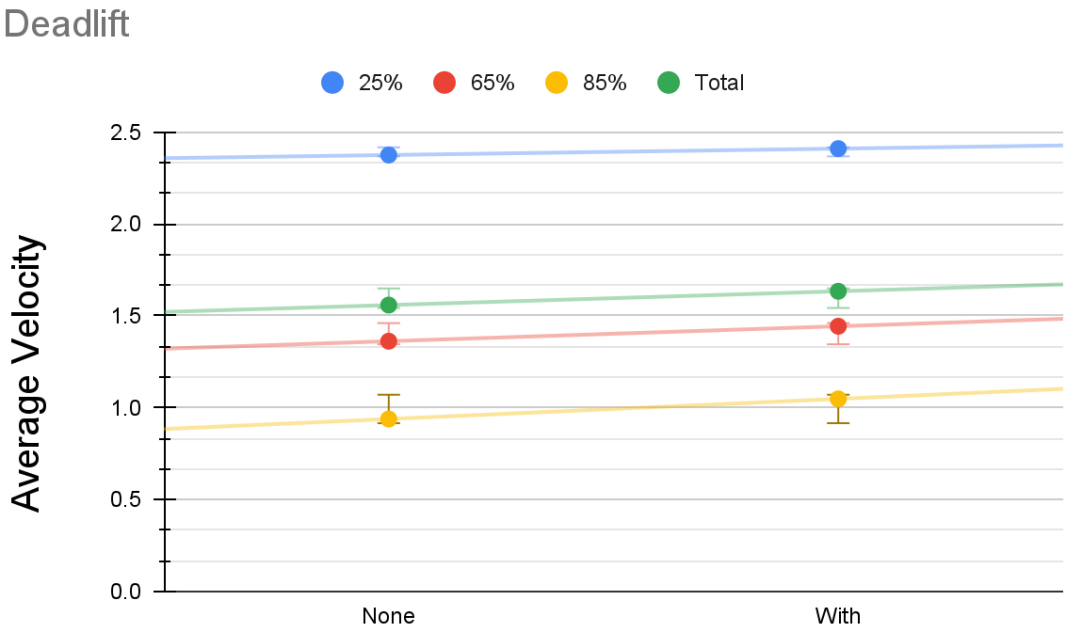
Table 3: Average Velocities for Squat

	Without Tech Shoes and Weight Belt	With Tech Shoes and Weight Belt
25% of One Rep Max	1.248	1.384
65% of One Rep Max	1.193333333	1.365333333
85% of One Rep Max	0.9826666667	1.062666667
Total of Average Velocities	1.141333333	1.270666667

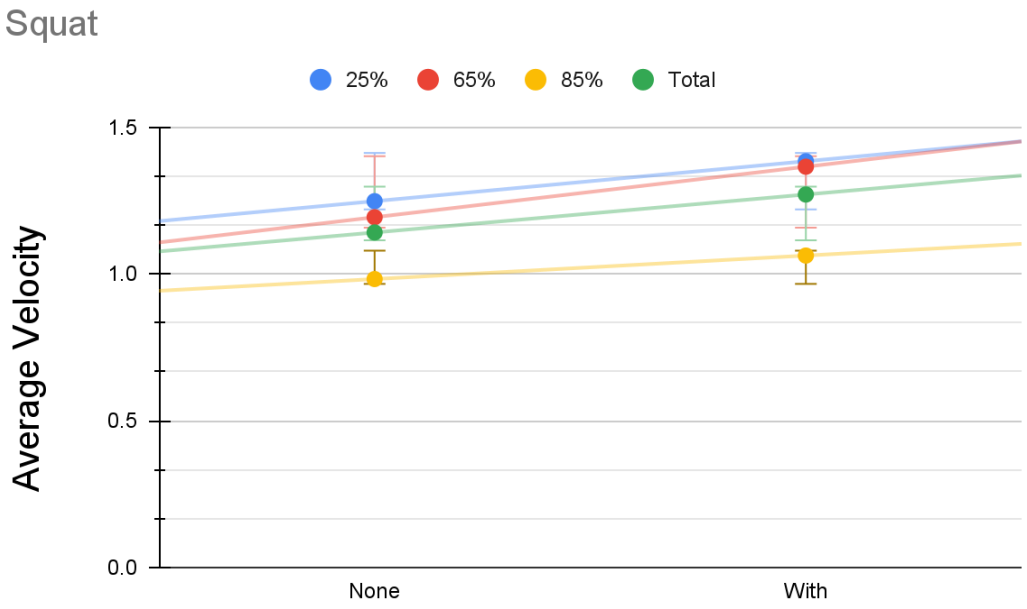
The average velocities show that with the technical equipment for all three of the compound lifts is higher than without the technical equipment. But this was not enough to reject or accept the null hypothesis and claim that the technical equipment increased performance for any of the three compound lifts.



Graph 1: Bench Press Average Velocities Vs None/With



Graph 2: Deadlift Average Velocities Vs. None/With



Graph 3: Squat Average Velocities Vs. None/With

Graph 1 and graph 3 are trending upwards with technical equipment, indicating that for the bench press the wrist wraps did have a positive effect on the performance. Also indicating

that for squat that the technical shoes and weight belt did have a positive effect on the performance. Graph 2 does have a very slight trend upwards, but is not significant enough to reject the null hypothesis, that the technical shoes and weight belt have a positive effect on the performance. One reason for this might be because, in this capstone, I rarely performed deadlifts and was not as comfortable performing deadlifts causing the data to be not as reliable.

ANOVA						
Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Percentage	22.42258667	2	11.21129333	126.6131541	0	3.105156608
With/None	0.7636011111	1	0.7636011111	8.623621045	0.004280591417	3.954568256
Interaction	0.1127022222	2	0.05635111111	0.6363932957	0.5317296663	3.105156608
Within	7.438	84	0.08854761905			
Total	30.73689	89				

Table 4: Bench Press Anova Results

ANOVA						
Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Percentage	31.05787556	2	15.52893778	376.7461423	0	3.105156608
With/None	0.1269377778	1	0.1269377778	3.079625843	0.08292499117	3.954568256
Interaction	0.02134222222	2	0.01067111111	0.2588908529	0.7725209064	3.105156608
Within	3.46236	84	0.04121857143			
Total	34.66851556	89				

Table 5: Deadlift Anova Results

ANOVA						
Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Percentage	1.532666667	2	0.7663333333	40.34614163	0	3.105156608
With/None	0.37636	1	0.37636	19.81471144	0.002604379389	3.954568256
Interaction	0.03224	2	0.01612	0.8486904782	0.4316114317	3.105156608
Within	1.595493333	84	0.01899396825			
Total	3.53676	89				

Table 6: Squat Anova Results

The p-value for both table 4 and table 6 are both less than the value for alpha which was 0.05. This indicates that the data was significant enough to reject the null hypothesis and that the technical equipment did increase the performance of bench press and squat. Table 5 has a p-value of 0.08 which is greater than the value of alpha of 0.05. This means that the data was not significant enough to reject the null hypothesis and that technical shoes and weight belts do not increase the performance of deadlift.

Discussion and Conclusion

Although two-thirds of my data were able to reject the null hypothesis, there are a couple of things that could be changed that would hopefully allow for one hundred percent rejection of the null hypothesis. The first thing I could have done differently would be during the first semester of capstone I would have practiced each of the compound lifts more so that my body was fully comfortable making those movements. The second thing that I would change would be the accelerometer. I definitely jumped the gun when it came to buying the accelerometer, more research would have been beneficial, and I could have found one that was more suitable for my project. After the first accelerometer did not work when it came into contact with the barbell and I found the *WatchForce* to replace it. I looked for other accelerometers and they make some that are specifically for measuring the velocity of barbells. Those ones are anchored to the floor and a string is attached to the barbell and it measured the velocity using a pulley system. Simplifaster.com has a large selection of accelerometers geared towards weight lifting, though they are significantly more expensive than the normal accelerometers.

One thing to add to make the data more appealing would be, to calculate the work done and compare the work done of twenty-five, sixty-five, and eighty-five percent of the one-rep

max. Some people have a hard time connecting velocity to performance when explaining the data. Showing that comparison of work done would make it easier for others to make that connection.

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