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aaf0010@mix.wvu.edu

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Effect of Metacarpal Gloves on Pinch and Grip Strength

Aaron A. Fonner

Thesis submitted to the Benjamin M. Statler College of
Engineering and Mineral Resources at West Virginia University

In partial fulfillment of the degree of

Master of Science

In

Industrial Hygiene

Ashish Nimbarte, Ph. D. Committee Chairperson

Xinjian He, Ph. D.

Eduardo M. Sosa, Ph. D

Department of Industrial and Management Systems Engineering

Morgantown, West Virginia

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Abstract

Effect of metacarpal gloves on pinch and grip Strength

Aaron Fonner

Hand Injuries are common in industrial settings. In 2014 alone, there were 137,440 total cases of hand injuries in the United States that required days away from work. Hand injuries can be classified into six general categories: lacerations, fractures and dislocations, soft tissue injuries and amputations, infections, burns and high pressure injuries. Some of these injuries can be prevented with proper personal protective equipment. In recent times, metacarpal gloves are widely used to protect the workers against hand/metacarpal injuries in various industries including mining. The benefits of wearing metacarpal gloves for protection are unquestionable, but little is known about how these gloves can affect grip strength, pinch strength and the overall work performance. Therefore, the objective of this study was to determine if metacarpal gloves have an impact on user's gripping and pinching strengths. Five metacarpal gloves were evaluated using a sample size of 10 participants. Type of glove had a significant effect on the gripping strength. Use of glove, on an average, reduced the gripping strength by 20%. Between the gloves, the gripping strength varied in the range of 3% to 10%. The pinching strength was un-affected by the use of glove.

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Chapter 1: Background & Introduction

Hand injuries can be very taxing on employers and employees alike. In a lot of cases, hand injuries result in several days missed at work. In the United States, in 2016, the incidence rate was 315.9 per 10,000 full time workers and the number of cases that resulted in days away from work totaled 63,790 [2016 Survey Of Occupational Injuries and Illnesses Chart Data”, 2018]. In 2012-2013 the Australian Workers’ Compensation Statistics recorded 117,815 serious claims regarding the hands (Creagh 2018). In the Queensland mining industry, hand injuries are the second most common cause of lost work time. From 2007 to 2012 ~80% of all serious hand injuries fell under 4 categories: fractures (30%), lacerations, cuts and other open wounds (25%), crush injuries (15%) and traumatic injuries (9%) according to (Business Queensland, 2018).

Gloves can prevent many types of hand injuries such as: abrasions, punctures and breaks. However, gloves can inhibit movement of the hands which could cause a decrease in precision. Protective metacarpal gloves may also interfere with the ability to apply force on an object (Kovacs et al., 2002). The benefits of wearing gloves for protection are unquestionable, but we know very little about how they affect grip strength, pinch strength and the overall work performance. Metacarpal gloves in industrial settings like coal mining, are generally thicker work gloves constructed with leather or other synthetic materials and have additional protection on top of the metacarpal and finger zones. This thicker material used for glove construction causes the gloves to be stiff and rigid. “Knowledge of the effects of gloves on grip strength can help

workers, managers, and safety professionals make decisions about glove selection and use in the workplace”, (Wimer et al.,2010). This knowledge can also be useful to create a better design for future metacarpal gloves.

Workers in industrial settings such as coal mines are required to wear gloves for many reasons, the most important being safety. When determining the appropriate set of gloves for a task, an employer has a lot to consider when giving workers the proper set of gloves. Their gloves have to provide the worker with the right amount of protection, making sure the gloves aren't too thick to reduce tactile senses and making sure the gloves don't inhibit the worker's ability to apply the correct amount of force needed for a task. Some of the results of this study could be used to make that choice easier for employers.

Gripping, finger/thumb pinch are amongst most common tasks in gloves in industrial work places. There are a few studies that have analyzed the effect gloves can have on the users' force exertion ability, especially during gripping and pinching. Tsaousidis & Freivalds, (1998) examined the effect of cotton gloves and double cotton glove which was wearing 2 pairs simultaneously on maximum force and the rate of force in pinch. The researchers found that the influence from the gloves decreased pinch force development by 30% to 70%. They also discovered that there was a significant deterioration in grip force (15% - 20%). In a study by Rock et al, (2001) the authors found an 8% average decrease in pinch force while wearing leather gloves compared to no gloves in 45 healthy male and female volunteers. In that same study, there was an

average 23% decrease in grip strength with a leather glove compared to the no glove tests.

In a study conducted by the University of Nebraska, the effect of two types of work gloves, deer hide and leather from cow hide, on the human performance capabilities was examined. The hypothesis was that the grip force would be impaired and so would other human capabilities. The researchers found that there was a reduction in maximum static grip force. The grip force decrement for the deer hide glove was ~11% and the leather glove caused a 10% decrease in grip force (Bishu et al., 1987).

Hallbeck & McMullin, (1993) studied the effect of 5 different types of work gloves: cotton, knit, reinforced knit, combination of cotton and knit, and combination of cotton and reinforced knit on peak pinch force. They found that on average for all the gloves combined that there was a 4% decrease in pinching force from wearing the work gloves.

In a study that was interested in maximum pinch and grip forces, the authors had subjects wear military grade leather work gloves to complete tasks. The participants' mean power grip strength decreased by 28% and the mean power pinch strength decreased by 13% when glove condition was compared to an ungloved condition (Torrens, G.E. and Newman, A., 2000).

In an all-female study by Sung (2014), the effect of protective glovebox gloves on hand performance was examined. The gloves were fabricated from butyl, CSM/hypalon and with neoprene materials and three thicknesses: single, double and triple thickness.

Hand performance actually increased with the thin single glove but decreased with the other two thicknesses.

Chapter 2: Study Rationale

Personal protective equipment is mandatory by law. Nearly every industrial task involves use of one's hands so it is essential to keep them protected. In coal mines and steel mills, workers are required to wear gloves with extra protection over top of the metacarpals and fingers. The gloves provide ample protection, but they may compromise the ability to apply force while gripping and pinching. The unquestioned need for hand safety and the unknown performance compromise warrants further investigation into a relationship between the amount of protection provided and the hand performance.

2.1 Problem Statement

Safety should be the number one priority of any company. Grip strength and pinch strength are important in any industrial job that requires working with your hands. Coal miners are an excellent example of this. Every day, miners have to perform tasks that will be directly affected by pinch or grip strength like using chainsaws and drilling strategically placed bolts and plates into the roof to assure stability (Carrel 2018). During such industrial activities, bulky metacarpal gloves can ensure workers' safety but may hinder their ability to apply grip and pinch force, which may lower their overall performance. Very little is known about how metacarpal gloves can affect grip strength, pinch strength and the overall work performance.

2.2 Objective and Hypotheses

The objective of this study was to determine how metacarpal gloves affect workers' hand performance while gripping and pinching compared to working bare handed. To reach the objective of this study, a set of experiments were designed and conducted on 5 types of metacarpal gloves typically used in the mining industry. Metacarpal gloves are very thick and work well for protecting against lacerations, burns and abrasions but they may compromise the ability to apply gripping and pinching force. The following hypotheses were tested in this study:

Null hypothesis 1: Grip force of participants will not be affected by the use of metacarpal gloves

Alternative hypothesis 1: Grip force of participants will decrease with the use of metacarpal gloves

Null hypothesis 2: Pinch force of participants will not be affected by the use of metacarpal gloves

Alternative hypothesis 2: Pinch force of participants will decrease with the use of metacarpal gloves

Chapter 3: Methodology

A laboratory-based study was conducted to determine exactly how much a metacarpal glove can affect workers' hand performance. Maximum key pinch (Figure 1) and power hand grip (Figure 2) strengths were measured.



Figure 1: Key pinch grip using a Jamar pinch grip sensor.



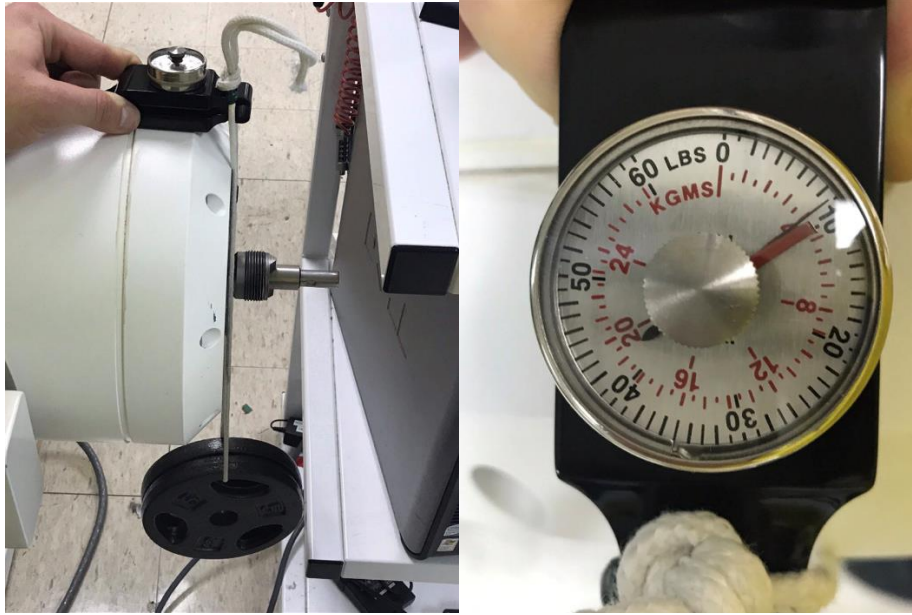
Figure 2: Power hand grip using Jamar hand dynamometer.

3.1 Participants

A total of 10 college-aged males (24-26) were recruited for the research. The subjects had a mean height of 71.4 inches with a standard deviation of 2.6 inches. The mean age of the subjects was 24.9 years old with a standard deviation of 0.5 years. The mean weight of the subjects was 184.5 pounds with a standard deviation of 14.9 pounds. There were 9 right handed subjects and 1 left handed subject. Participants had to sign a Only Minimal Risk Consent Information Form (without HIPAA), which can be found in the Appendix 2: Consent Form. The primary inclusion criteria for this research required that all participants be free from any neurological symptoms, previous cardiac problems or any musculoskeletal disorders that would affect grip/pinch strength.

3.2 Equipment

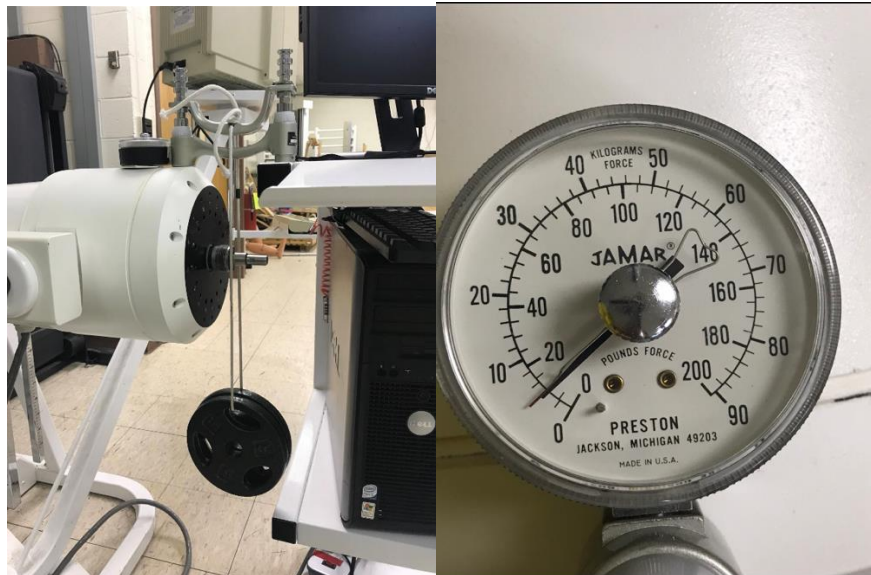
A Jamar pinch meter and Jamar hydraulic hand dynamometer (JLW Instruments., Chicago IL) were used to measure the maximum strengths. Before and after each participant, 10 pounds of weight was hung from each device to ensure that the calibration was still correct as shown in (Figure 3) respectively.



(A)

(B)

Figure 3: (A) Known weight of 10 pounds hung from the pinch meter; (B) The reading from the weight hung from the meter. (10 pounds).



(A)

(B)

Figure 4: (A) A known weight of 10 pounds hung from the hand dynamometer; (B) The reading from the weight hung from the meter (10 pounds).

3.3 Metacarpal gloves

Five different metacarpal gloves were tested in this study. In (Figure 5), glove 1 is a glove produced by West Chester Protective Gear. It is a split cow hide leather work glove with an elastic wrist band. Glove 2 is produced by Wells Lamont. It is the High-Vis Linebacker model. It has a synthetic leather palm with anti-slip finger patches for gripping. Glove 3 is produced by Meta Miner. These gloves are widely used in many mines located across the country. The palm is made of thermo plastic rubber (TPR) and has a padded hand and knuckle strap on the top. Glove 4 is produced by Ringers gloves. They are a high-visibility glove that have cut and puncture resistant materials on the dorsal side of the glove. Glove 5 is produced by Superior glove. This glove is made of goat skin leather and has impact protection from added gel padding on the dorsal side of the glove.



Figure 5: Five gloves tested in this study: (1) Glove produced by West Chester Protective Gear; (2) Glove produced by Wells Lamont; (3) Glove produced by Meta Miner; (4) Glove produced by Ringers Gloves; (5) Glove produced by Superior Glove.

3.4 Postures

The gripping and pinching strengths were measured using 2 different postures. The first posture is standing, with the shoulder adducted and neutrally rotated and elbow in full extension (elbow at 90 degrees) as shown in (Figure 6). The second posture is standing as well and the arm was in full abduction with the bicep muscle close to the participant's ear and as close to 150 degrees as possible, as shown in (Figure 7). Subjects were asked to look at the ceiling where they were simulating overhead work. An angle of 150 degrees was chosen so that the participant was not uncomfortable looking straight up during the duration of the experiment.



(A)

(B)

Figure 6: (A) Posture 1 using a Jamar hand dynamometer; (B) Posture 1 using a Jamar pinch sensor.



(A)

(B)

Figure 7: (A) Posture 2 using a Jamar hand dynamometer; (B) Posture 2 using a Jamar pinch sensor.

3.5 Experimental design

Each participant performed 72 experimental trials, comprised of: 2 types of force exertions (pinch and grip), 2 postures, 6 glove conditions and 3 repetitions. Each maximum force exertion trial involved applying the force slowly and steadily without a jerking motion, until maximum force is reached. Verbal cues were used to ensure slow and steady exertions by counting the following cadence (1, 2 Maximum 4, maintain, 6 and relax), for a seven second count every trial. For each subject and each trial, they were

encouraged to exert maximum strength through verbal reinforcement. Three trials of maximum strength measurements were collected. In the cases where variability was >10% between trails, a 4th trial was performed and the average of the highest 3 values was considered to be the representative pinch/gripping strength of the participant. The duration of the study for each participant was approximately three hours long. This long duration was due to a 2 minute long rest period in between each trial. Posture, grip/pinch and glove type were randomly selected using an Excel spreadsheet.

3.6 Statistical analysis

A two-factor general linear ANOVA was performed to evaluate the effect of posture and glove type on the grip and pinch strengths. Posture was treated as a fixed factor at two levels, 150 degrees overhead and 90 degrees to the side. Glove type was treated as a fixed factor at six levels, no glove, glove 1, glove 2, glove 3, glove 4 and glove 5. The participant was treated as a random factor. Significance level was set to 5%, ($P=0.05$). The significant main and/or interaction effects were further evaluated by conducting the comparisons between means using Tukey's HSD all-pairwise comparison test. The equality of variance test using a multiple comparison test showed that the assumption of an equal variance condition was valid in (Appendix 1). Furthermore, the adequacy of the linear model was confirmed by normal probability plots of the residuals between the actual and fitted value. Minitab 18 software (Minitab Inc., Pennsylvania, USA) was used to perform the statistical analysis.

Chapter 4: Results

4.1 Grip Strength

Descriptive statistics for Grip Strength are shown in Tables 1 and 2. In general, the mean Grip Strength in pounds was higher for the no glove condition (106.78 pounds) compared to the with glove conditions ranging from (83.95 pounds-92.65 pounds) for the different glove conditions. Among the five gloves, the mean grip strength was the highest for glove type 4 (92.65 pounds) and the lowest for glove type 1 (83.95 pounds). As summarized in (Table 1), mean grip strength for posture 2 was found to be higher than posture 1.

Table 1: Means and Standard Deviations (SDs) of Grip Strength for different glove conditions.

Variable	Glove type	Mean (Lbs)	SD (Lbs)
Grip Strength	0	106.78	16.37
	1	83.95	12.32
	2	90.03	16.46
	3	88.77	16.21
	4	92.65	15.67
	5	90.08	14.12

Table 2: Means and Standard Deviations (SDs) of Grip Strength for different postures.

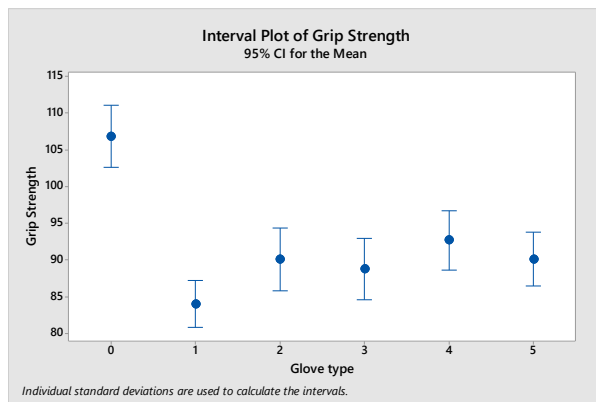
Variable	Posture	Mean (Lbs)	SD (Lbs)
Grip Strength	1	89.63	15.56
	2	94.46	17.55

Table 3: Result of Analysis of Variance (ANOVA) for the effect of glove type and posture on grip strength.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Glove type	5	18095	3618.92	67.23	0.000
Posture	1	2100	2100.08	39.02	0.000
Participant number	9	61701	6855.65	127.36	0.000
Glove type*Posture	5	446	89.23	1.66	0.144
Error	339	18248	53.83		
Lack-of-Fit	99	15798	159.57	15.63	0.000
Pure Error	240	2450	10.21		
Total	359	100589			

The main effect of glove type on the grip strength was statistically significant (Table 1). In (Figure 8 A), it can be seen that the highest mean grip strength was for the no glove condition. The results of the Tukey HSD all-pairwise comparison test showed that mean grip strength without a glove is different from the means with a glove (Figure 8 C). Among the five gloves, mean grip strength for glove 4 is different from glove 3. Mean grip strength for glove 1 is different from the other four gloves. Results of the Tukey HSD all-pairwise comparison test showed that mean grip strength for posture 1 was different from posture 2. The interaction effect of glove type and posture on the grip strength was statistically not significant (Figure 10).

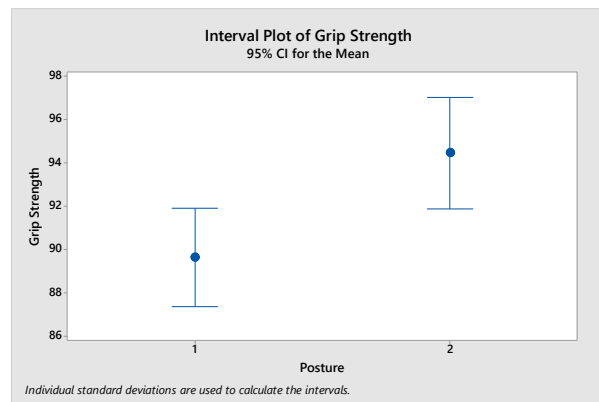
Results of ANOVA (Table 3), and Tukey HSD all-pairwise comparison test conclude that the null hypothesis 1 is rejected and alternative hypothesis 1 is accepted, meaning that glove use and type of glove had an effect on participants' grip strength.



(A)

Glove type	N	Mean (Lbs)	Grouping
0	60	106.78	A
4	60	92.65	B
5	60	90.08	B C
2	60	90.03	B C
3	60	88.77	C
1	60	83.95	D

(C)



(B)

Posture	N	Mean (Lbs)	Grouping
2	180	94.46	A
1	180	89.63	B

(D)

Figure 8: Main effect of glove type (A) and posture (B) on grip strength. Results of Tukey HSD all-pairwise comparison test for glove type (C) and posture (D); means that do not share a letter are significantly different.

4.2 Pinch Strength

Descriptive statistics for Pinch Strength are shown in Table 4 and Table 5. In general, the mean pinch strength was slightly higher under the glove conditions compared to no glove condition. Among the five gloves, mean pinch strength was the highest for glove type 2 and the lowest for the bare hand condition. Mean pinch strength for posture 1 was found to be higher than posture 2.

Table 4: Means and Standard Deviations (SDs) of Pinch Strength for different glove conditions.

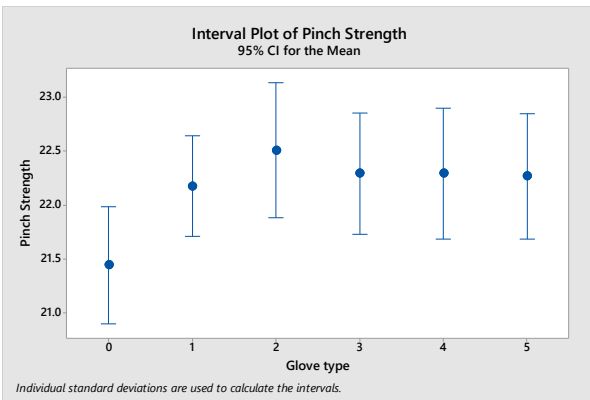
Variable	Glove type	Mean (Lbs)	StDev (Lbs)
Pinch Strength	0	21.4	2.1
	1	22.2	1.8
	2	22.5	2.4
	3	22.3	2.2
	4	22.3	2.3
	5	22.3	2.2

Table 5: Means and Standard Deviations (SDs) of Pinch Strength for different postures.

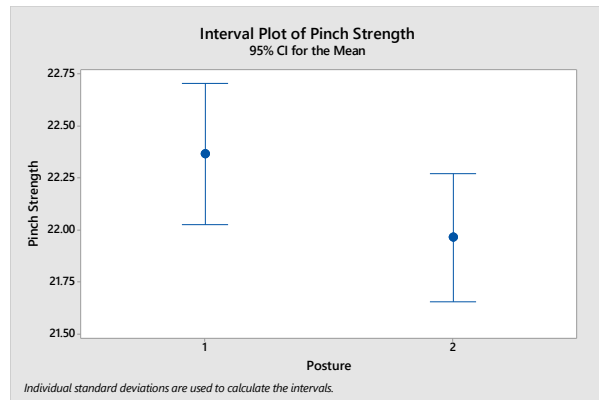
Variable	Posture	Mean (Lbs)	SD(Lbs)
Pinch Strength	1	22.4	2.3
	2	22.0	2.1

Table 6: Result of Analysis of Variance (ANOVA) for the effect of glove type and posture on pinch strength.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Glove type	5	41.01	8.203	6.39	0.000
Posture	1	14.60	14.601	11.38	0.001
Participant number	9	1195.92	132.880	103.58	0.000
Glove type*Posture	5	55.30	11.061	8.62	0.000
Error	339	434.91	1.283		
Lack-of-Fit	99	304.91	3.080	5.69	0.000
Pure Error	240	130.00	0.542		
Total	359	1741.74			



(A)



(B)

Glove type	N	Mean (Lbs)	Grouping
2	60	22.5	A
3	60	22.3	A
4	60	22.3	A
5	60	22.3	A
1	60	22.2	A
0	60	21.4	B

Posture	N	Mean (Lbs)	Grouping
1	180	22.4	A
2	180	22.0	B

(C)

(D)

Figure 9:: Main effect of glove type (A) and posture (B) on pinch strength. Results of Tukey HSD all-pairwise comparison test for glove type (C) and posture (D); means that do not share a letter are significantly different.

The main effect of glove type on pinch strength was statistically significant (Table 6). However, the difference in strength was in the range of a few pounds of force. A similar observation can be made for the effect of posture on the pinch strength and interaction effect of glove type and posture on pinch strength.

ANOVA (Table 6), and Tukey HSD all-pairwise comparison test show that glove type and posture and interaction were significant for pinch strength. All glove types performed the same, and were better than the no glove condition. Null hypothesis 2 is rejected and alternative hypothesis 2 is accepted, meaning that glove use had an effect on pinch strength, however the difference in the strength was minimal and not meaningful from ergonomics injury point of view.

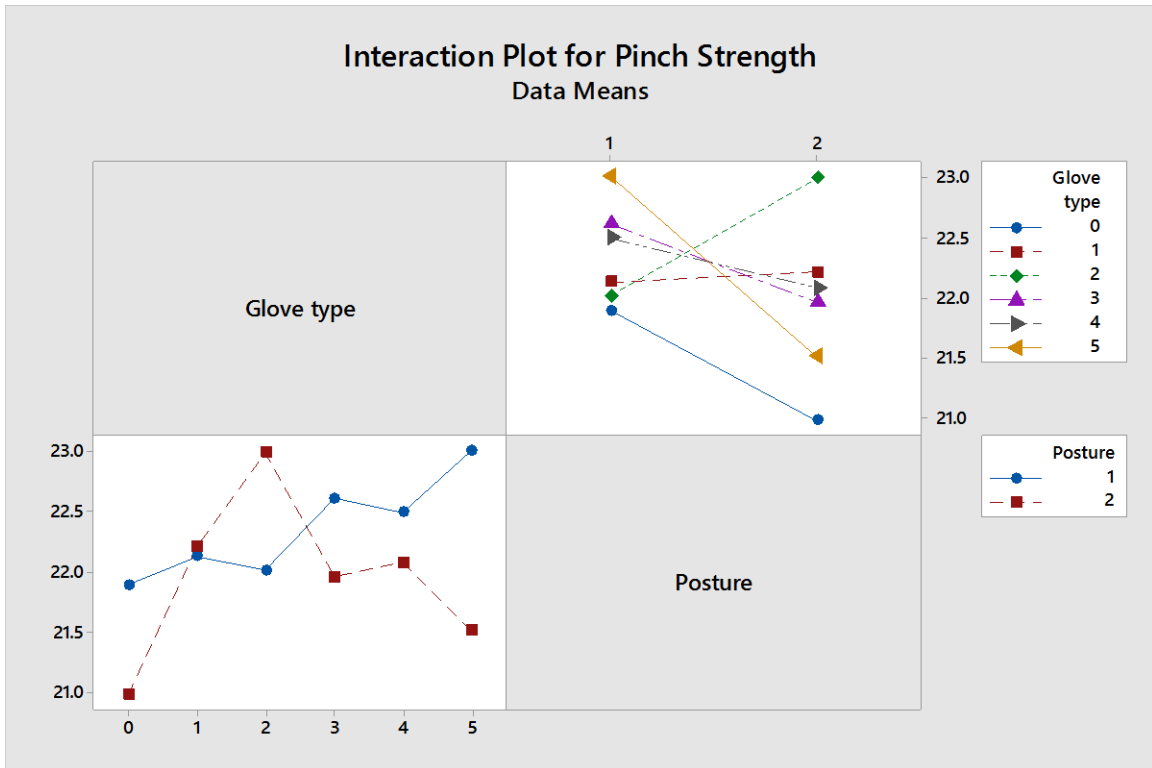


Figure 10: Interaction plot for glove type*posture on pinch strength.

On the Y axis in both graphs is force in pounds. Looking at the graph on the left it is seen that the ungloved condition has the lowest mean pinch strength of 21 pounds. Glove 1 had a mean pinch strength of 22.5 pounds. Glove 2 had a mean pinch strength of 23.0 pounds. Glove 3 had a mean pinch strength of 22.0 pounds. Glove 4 had a mean pinch strength of 22.0 pounds and glove 5 recorded a mean pinch strength of 21.5 pounds

Chapter 5: Discussion

The mean peak grip strength observed in this study under no glove condition was ~107 pounds and is very similar to values reported by Dodds et al., (2014), where they found that the male subjects' mean peak grip strength was 112.2 pounds. The mean pinch strength observed in this study under no glove condition was 21.4 pounds and is also comparable to a study by Dodds et al., (2014), where they found that the male subjects' mean peak pinch strength was 18 pounds. Unexpectedly, the pinch force was lowest when participants were not wearing gloves in (Table 4). It is possible that this was due in part to the added padding to the fingers that the gloves provided. The pinch meter is made of steel and becomes very uncomfortable to use after a few trials.

Researchers debate whether protective metacarpal gloves inhibit a worker's ability to perform pinching and gripping tasks while working. The study found that metacarpal gloves do negatively impact the ability to produce force when performing a gripping task, and is speculated that this is because of the thickness of the glove and the limited space in the hand dynamometer. Metacarpal gloves positively impacted the ability to produce force while performing a pinching task. There is a difference of 14-22 pounds between the no glove and glove conditions. Metacarpal gloves can have a negative impact on a worker's ability to produce gripping force but, there isn't enough of an impact to disregard wearing gloves. A forceful pinch can be uncomfortable. Gloves may help a worker produce more pinching force because it provides comfort during an otherwise

uncomfortable task. It was determined that these gloves decrease applied grip force, but it is unknown that if this decrease in force actually decreases performance. Future studies should quantify possible differences in ability to complete job-specific tasks between gloved and ungloved workers. If these future studies determine there really is no effect, then the obvious decision should be to choose the most protective gloves because it won't impact worker productivity.

In a study conducted by (Ramadan, 2017), they used a Jamar hand dynamometer and a similar design. A no glove condition and 5 different gloves, none of which were metacarpal gloves. The results are very comparable to this study. For their no glove condition, the mean grip strength was 100.0 pounds. For their glove 1, the mean grip strength was 76.0 pounds. Glove 2 showed a mean of 73.6 pounds. Glove 3 had a mean of 71.5 pounds. Glove 4 had a mean grip force of 88.7 pounds. Finally, glove 5 had a mean of 66.2 pounds. They concluded in their study that glove use generally reduced grip strength applied to the Jamar hand dynamometer and that total glove thickness is a main factor that influences grip strength.

In another study by Sung,(2014), it was found that gloves have no significant effect on key pinch strength compared to bare hand. In a previous study by [Dianat et al.(2012)], is it stated that a thicker glove decreases tactile perception and manual dexterity but adds more comfort. This extra comfort allows more pressure to be put on the finger tips during forceful exertions. This is reflected by the results of the current

study because there is only a 1 pound difference between the different glove types and the no glove condition.

In the study there were higher force exertions in posture 2 for pinch and grip, (overhead posture). According to Parvatikar & Mukkannavar, (2009), this overhead position allows the proximal muscles to stretch beyond their normal length which would increase their ability to exert force. Also contributing to posture 2 having higher strength, there is more muscle recruitment according to Thigpen et al.,(2010).

When comparing the gloves, the thinner gloves produced higher strength values compared to thicker gloves. The no glove condition was the highest for strength values. Glove (1) produced the lowest strength value (83.95 pounds) and it is because the glove is constructed out of thick cotton and leather, making it the thickest glove that was tested. The other gloves are made out of leather and lighter synthetic materials which makes them lighter and more flexible.

For pinching strength wearing any of the tested gloves produced higher strength values compared to the no glove condition. Glove (2) produced the highest strength value (22.5 pounds). As mentioned before, the difference in strength values among different glove types was minimal. The pinch sensor is an uncomfortable device to use continuously, that's why there are slightly higher strength values for all the different glove conditions compared to the no glove condition. The type of material i.e., cotton and leather, or a leather and synthetic material seem to have little effect on the pinch strength.

5.1 Limitations

There are a few limitations in this study, with the most obvious being that the sample size is so small. Increasing the number of participants from 10 to perhaps 20 or 25 subjects would allow for more variability and could show more significant results.

Another limitation would be the devices themselves. Though these devices are standard when measuring grip and pinch forces, it is possible that they are not ideal for industrial testing due to the limited amount of space to grip the devices for testing. The space given on the devices can be constricting or limited when using a bulky metacarpal glove. There was no randomization factor for this study and there is always a possibility of human error when reading force devices. For future studies, it would be very beneficial to use all electronic force devices if possible. Another possible limitation is that subjects become anxious and fatigued during the 3-3.5 hour long testing.

5.2 Conclusions

The study shows that during gripping tasks a no glove condition can generate more force than when wearing a glove, but working in an industrial setting without a glove isn't practiced. So, even though maximum force max may not be attained while wearing metacarpal gloves, it is always a good idea to keep gloves on to provide protection. It was also found that wearing gloves has a positive impact on the ability to produce force while pinching compared to a no glove condition. This is credited to the added comfortability

that a glove provides while performing a pinching task. The overhead posture produced a higher force while gripping and this is caused by the positioning of the arm and the recruitment and lengthening of the proximal muscles used while performing the task.

5.3 Implications

Not many hand tools require ~106 pounds of gripping strength to operate so, each glove that I tested would be a good choice for workers performing gripping tasks. For pinching tasks, 20-23 pounds of pinch strength would be adequate for most tasks that would have to be performed. From this study, we can tell which gloves outperform others, but all of these glove would be a good choice for PPE.

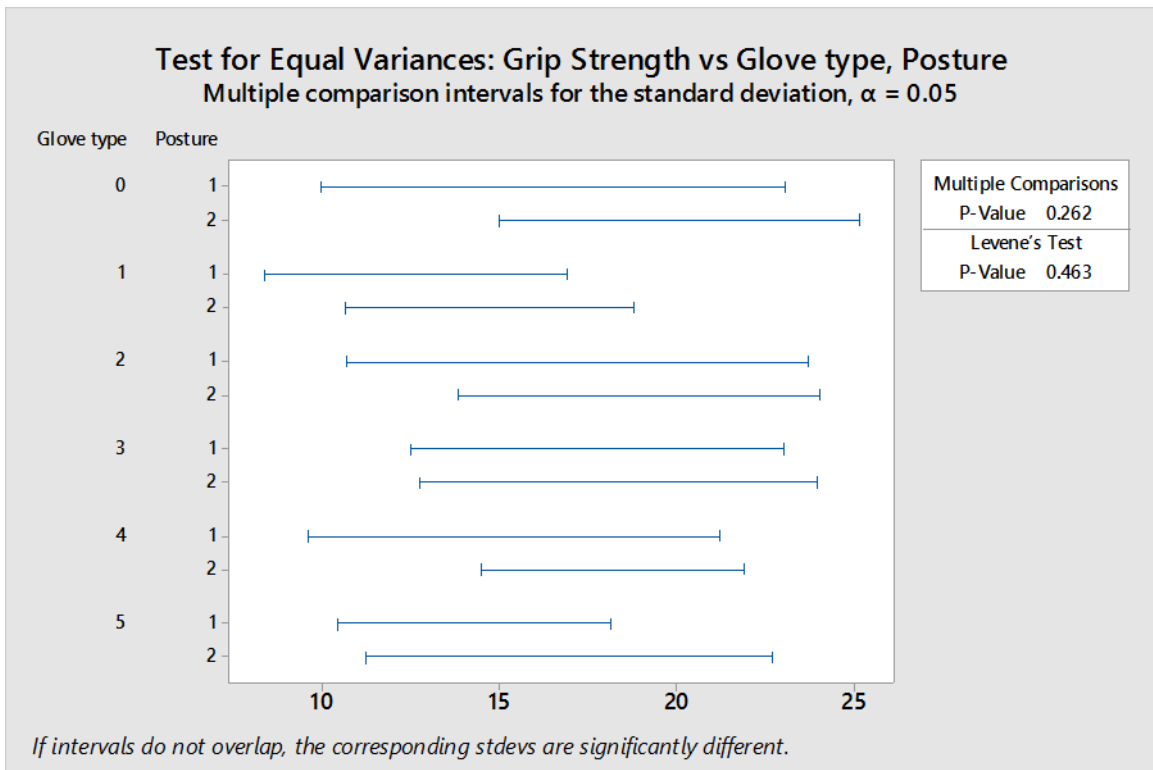
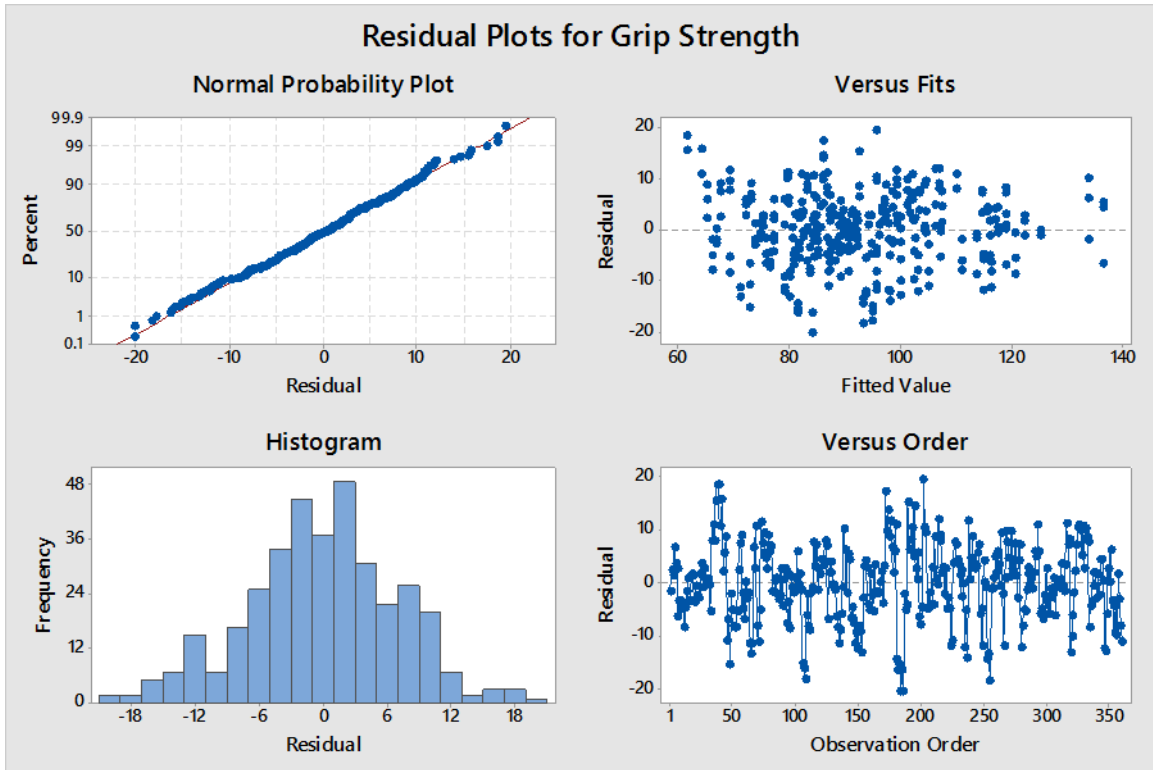
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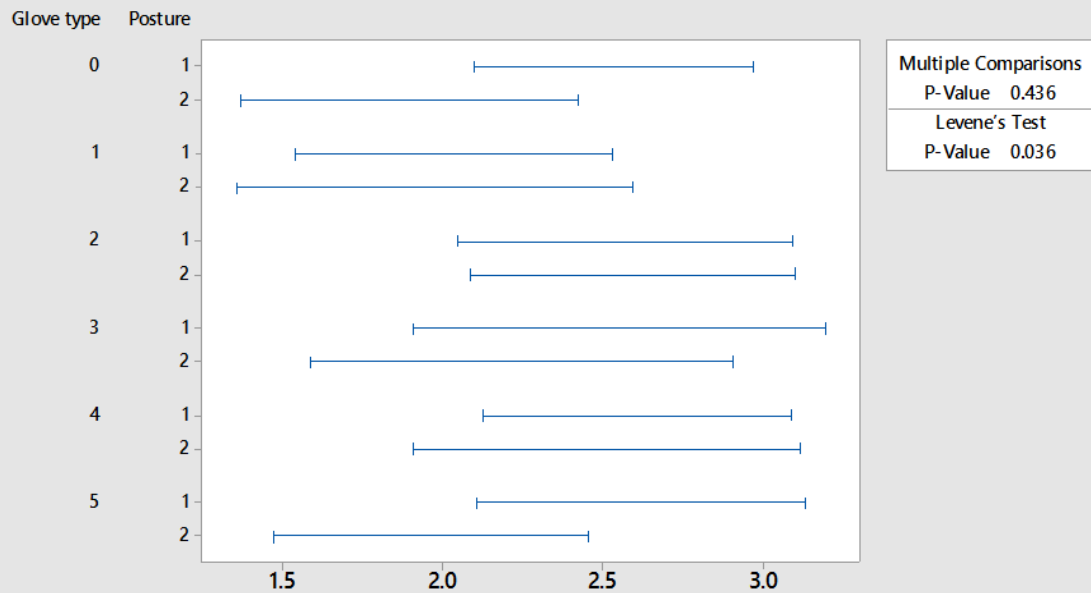
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Appendix 1: Residual Plots



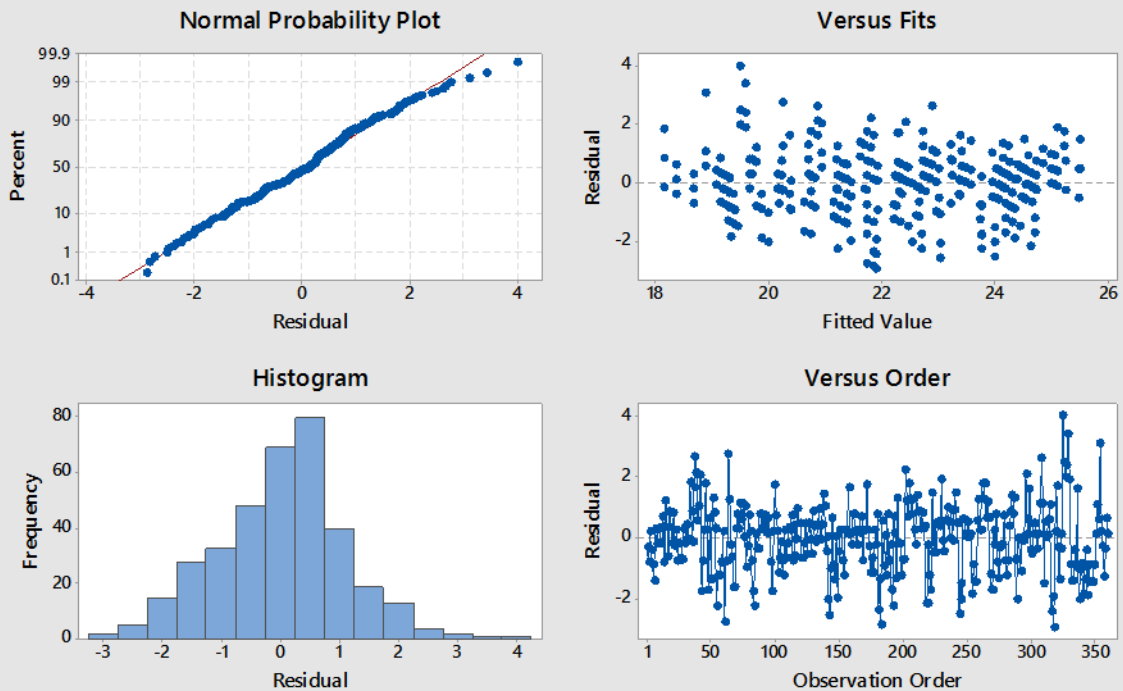
Test for Equal Variances: Pinch Strength vs Glove type, Posture

Multiple comparison intervals for the standard deviation, $\alpha = 0.05$



If intervals do not overlap, the corresponding stdevs are significantly different.

Residual Plots for Pinch Strength



Appendix 2: Consent Form

Only Minimal Risk Consent Information Form (without HIPAA)

Principal Investigator	Ashish Nimbarte PhD
Department	Industrial and Management Systems
Protocol Number	1810332591
Study Title	Effect of metacarpal gloves on pinch and grip strength.
Co-Investigator(s)	Aaron Fonner

Contact Persons

In the event you experience any side effects or injury related to this research, you should contact Dr. Ashish Nimbarte at (304)-293-9473. (After hours contact: Dr. Nimbarte at (304) 226-8813. If you have any questions, concerns, or complaints about this research, you can contact Dr. Nimbarte or Aaron Fonner at (304) 639-8643.

For information regarding your rights as a research subject, to discuss problems, concerns, or suggestions related to the research, to obtain information or offer input about the research, contact the Office of Research Integrity and Compliance at (304) 293-7073.

In addition if you would like to discuss problems, concerns, have suggestions related to research, or would like to offer input about the research, contact the Office of Research Integrity and Compliance at 304-293-7073.

Introduction

You, _____, have been asked to participate in this research study, which has been explained to you by Dr. Nimbarte or Aaron Fonner. This study is being conducted by Dr. Nimbarte and Aaron Fonner in the Department of Industrial and Systems Management at West Virginia University.

Purpose(s) of the Study

The purpose of this study is to determine whether protective metacarpal gloves restrict the ability to apply force when performing pinching and gripping tasks.

Description of Procedures

A laboratory-based study will be conducted to determine exactly how much a thick, protective metacarpal glove will negatively affect workers' hand performance. Participants will perform maximum forceful exertions of key pinch grip

10 male participants will be recruited to undergo this study. A Jamar pinch meter and Jamar hydraulic hand dynamometer (JLW Instruments., Chicago IL) will be used to measure the maximum strengths. The strengths will be measured using 2 different postures. The first posture is standing, and it is where the shoulder is adducted and neutrally rotated and elbow in full extension (elbow at 90 degrees). The second posture is also standing, the arm will be in full abduction with the bicep muscle close to the participant's ear as close to 180 degrees as possible. Six glove conditions will be tested – no glove and five metacarpal gloves. Each experimental condition will be repeated at least 3 times. Thus, an individual participant will perform 72 experimental trials, 2 types of force exertions (pinch and grip) x 2 postures x 6 glove conditions x 3 repetitions. Each maximum strength measurement trial will involve applying the force slowly and steadily without a jerking motion, until maximum force is reached. 3 trials of maximum strength measurement will be collected. In the cases where variability was >10% between trails, a 4th trial will be performed and the average of the best 3 values will be used to determine pinch/gripping

Discomforts

There are no known or expected risks from participating in this study.

Alternatives

You do not have to participate in this study.

Benefits

You may not receive any direct benefit from this study. The knowledge gained from this study may eventually benefit others.

Financial Considerations

There are no special fees for participating in this study.

Confidentiality

Any information about you that is obtained as a result of your participation in this research will be kept as confidential as legally possible. Your research records and test results, just like hospital records, may be subpoenaed by court order or may be inspected by the study sponsor or federal regulatory authorities without your additional consent.

Voluntary Participation

Participation in this study is voluntary. You are free to withdraw your consent to participate in this study at any time.

Refusal to participate or withdrawal will not affect and will involve no penalty to you.

In the event new information becomes available that may affect your willingness to participate in this study, this information will be given to you so that you can make an informed decision about whether or not to continue your participation.

You have been given the opportunity to ask questions about the research, and you have received answers concerning areas you did not understand.

Upon signing this form, you will receive a copy.

I willingly consent to participate in this research.

Signatures

Signature of Subject

Printed Name

Date

Time

The participant has had the opportunity to have questions addressed. The participant willingly agrees to be in the study.

Signature of Investigator or Co-Investigator

Printed Name

Date

Time

Appendix 3: Raw Data

Ryan	Trial 1	Trial 2	Trial 3	lbs
Po2HDG5	97	95	95	lbs
Po1HDG3	84.5	87.5	90	lbs
Po2HDG4	96.5	96	96	lbs
Po2HDG2	91	92	87.5	lbs
Po1PG5	20	19.5	19.5	lbs
Po1HDG5	91.5	93.5	89	lbs
Po2PG2	20.5	20	20	lbs
Po1PG3	20.5	19	21	lbs
Po1PNG	19.5	19	19	lbs
Po1PG4	20	19.5	20.5	lbs
Po2HDG3	89	89	94	lbs
Po2HDNG	118	112	118	lbs
Po1PG2	19.5	19	19.5	lbs
Po2PG4	19	19.5	18.5	lbs
Po2PG3	19.5	18.5	20	lbs
Po1HDNG	108	107	102	lbs
Po1HDG2	82	85	85	lbs
Po2PNG	20	19	18	lbs
Po1HDG4	92	87	90	lbs
Po1HDG1	83	87	86	lbs
Po2HDG1	94	91	90	lbs
Po2PG1	90	85.5	88	lbs
Po1PG1	19	18.5	19.5	lbs
Po2PG5	18	19	18.5	lbs

Brandon	Trial 1	Trial 2	Trial 3	lbs
Po2HDG5	60	58	60	lbs
Po1HDG3	64	61	58	lbs
Po2HDG4	71	74	69	lbs
Po2HDG2	62	66	57.5	lbs
Po1PG5	19	21	21	lbs
Po1HDG5	67	64	65	lbs
Po2PG2	23.5	22	20	lbs
Po1PG3	22	20	20	lbs

Po1PNG	20	19	19	lbs
Po1PG4	19	20	20	lbs
Po2HDG3	61	61	64	lbs
Po2HDNG	79	76	82	lbs
Po1PG2	19	20	21	lbs
Po2PG4	20	20	21	lbs
Po2PG3	22	21.5	21	lbs
Po1HDNG	91	87	95	lbs
Po1HDG2	67.5	71	74	lbs
Po2PNG	20	20.5	20	lbs
Po1HDG4	70	75	76.5	lbs
Po1HDG1	77	80	80	lbs
Po2HDG1	75	75	80	lbs
Po2PG1	21.5	22	23	lbs
PoPG1	22.5	23.5	23	lbs
Po2PG5	23	21.5	20	lbs

Rj	Trial 1	Trial 2	Trial 3	lbs
Po2HDG5	80	80	85	lbs
Po1HDG3	75	72	71	lbs
Po2HDG4	76	80	75	lbs
Po2HDG2	79	79	81	lbs
Po1PG5	23	22	24	lbs
Po1HDG5	76	74	73	lbs
Po2PG2	23	22	21.5	lbs
Po1PG3	23.5	23	23	lbs
Po1PNG	21.5	22	22.5	lbs
Po1PG4	24	23.5	24	lbs
Po2HDG3	75	80	73	lbs
Po2HDNG	80	79	77	lbs
Po1PG2	22.5	23.5	23	lbs
Po2PG4	23	23.5	23	lbs
Po2PG3	23.5	23.5	23	lbs
Po1HDNG	92	94	91	lbs
Po1HDG2	82	79	80	lbs
Po2PNG	21	20.5	22	lbs
Po1HDG4	76	78	77.5	lbs
Po1HDG1	81	77	79	lbs

Po2HDG1	78	77	75	lbs
Po2PG1	23	24	22	lbs
Po1PG1	24	23.5	24	lbs
Po2PG5	24	23	22.5	lbs

Jake	Trial 1	Trial 2	Trial 3	lbs
Po2HDG5	112	115	120	lbs
Po1HDG3	120	120	119	lbs
Po2HDG4	125	125	124	lbs
Po2HDG2	121	125	124	lbs
Po1PG5	25	25.5	26	lbs
Po1HDG5	110	108	105	lbs
Po2PG2	26	25.5	25.5	lbs
Po1PG3	24	24	24.5	lbs
Po1PNG	25	23.5	24	lbs
Po1PG4	25	24.5	24	lbs
Po2HDG3	127	126	112	lbs
Po2HDNG	136	143	142.5	lbs
Po1PG2	23.5	24.5	24	lbs
Po2PG4	25	24.5	24	lbs
Po2PG3	24.5	23.5	24.5	lbs
Po1HDNG	144	140	132	lbs
Po1HDG2	122.5	118	132	lbs
Po2PNG	142	141	130	lbs
Po1HDG4	119	121	119	lbs
Po1HDG1	105	109	103	lbs
Po2HDG1	105	112	113	lbs
Po2PG1	24.5	25	23.5	lbs
Po1PG1	23.5	24	24.5	lbs
Po2PG5	23.5	24	25	lbs

Byan	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	103.5	96	100		lbs

Po1HDG3	84	77	76	lbs
Po2HDG4	89	89	91	lbs
Po2HDG2	85	91	92	lbs
Po1PG5	21.5	22.5	22.5	lbs
Po1HDG5	84	78	85	lbs
Po2PG2	21	22.5	22.5	lbs
Po1PG3	22	23.5	22	lbs
Po1PNG	20	20.5	20	lbs
Po1PG4	22	21.5	22	lbs
Po2HDG3	86	82	79	lbs
Po2HDNG	104	108	113	lbs
Po1PG2	21.5	21.5	20.5	lbs
Po2PG4	21.5	22	22	lbs
Po2PG3	21	22	22	lbs
Po1HDNG	108	111	106	lbs
Po1HDG2	72	71	67	lbs
Po2PNG	20.5	20	21	lbs
Po1HDG4	86	81	81	lbs
Po1HDG1	70	72	69	lbs
Po2HDG1	68	70	67	lbs
Po2PG1	21.5	19.5	21	lbs
Po1PG1	22	20.5	20	lbs
Po2PG5	22.5	21	20.5	lbs

Michael	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	87	94	87		lbs
Po1HDG3	96.5	91	100.5		lbs
Po2HDG4	115	106	105		lbs
Po2HDG2	108	99	101		lbs
Po1PG5	24.5	24	23.5		lbs
Po1HDG5	82	82	85		lbs
Po2PG2	22.5	21	20.5		lbs
Po1PG3	23	22.5	21		lbs
Po1PNG	23	22.5	22.5		lbs
Po1PG4	21	21.5	21.5		lbs
Po2HDG3	92	90	95		lbs
Po2HDNG	119	116	115		lbs
Po1PG2	20.5	22.5	21		lbs

Po2PG4	24	23	22.5		lbs
Po2PG3	23	21.5	21.5		lbs
Po1HDNG	113	105	104		lbs
Po1HDG2	83	80	81		lbs
Po2PNG	21	21.5	21		lbs
Po1HDG4	81	79.5	83		lbs
Po1HDG1	67	55	66	52.5	lbs
Po2HDG1	64	68	64		lbs
Po2PG1	22.5	21	22		lbs
Po1PG1	19.5	20.5	19		lbs
Po2PG5	22.5	21.5	21		lbs

Josh M	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	105	107.5	109		lbs
Po1HDG3	101	100	98		lbs
Po2HDG4	118	107	111		lbs
Po2HDG2	107	111	110.5		lbs
Po1PG5	27	26	26		lbs
Po1HDG5	106	101	100		lbs
Po2PG2	25	26	26		lbs
Po1PG3	25.5	27	25		lbs
Po1PNG	25	25	24.5		lbs
Po1PG4	26	21.5	25	24	lbs
Po2HDG3	97.5	102.5	100		lbs
Po2HDNG	122	118	117		lbs
Po1PG2	26	24	25		lbs
Po2PG4	25.5	24.5	25.5		lbs
Po2PG3	24	25	25		lbs
Po1HDNG	109	110	103		lbs
Po1HDG2	91	74	85	87	lbs
Po2PNG	23.5	24	23.5		lbs
Po1HDG4	86	93	84		lbs
Po1HDG1	94	95	90		lbs
Po2HDG1	97.5	90	92		lbs
Po2PG1	24.5	23.5	23		lbs
Po1PG1	25	22.5	22.5		lbs
Po2PG5	21.5	22.5	22		lbs

Kyle	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	91	95	98		lbs
Po1HDG3	96	86	99		lbs
Po2HDG4	112	115	109		lbs
Po2HDG2	108	104	114		lbs
Po1PG5	25	25	26		lbs
Po1HDG5	96	103	106		lbs
Po2PG2	27	26.5	27		lbs
Po1PG3	25.5	26	25.5		lbs
Po1PNG	24.5	25	25.5		lbs
Po1PG4	25	24.5	25.5		lbs
Po2HDG3	111	109	106		lbs
Po2HDNG	122	119	120		lbs
Po1PG2	25.5	24.5	24.5		lbs
Po2PG4	23.5	23	24		lbs
Po2PG3	23	22.5	22.5		lbs
Po1HDNG	111	115	118		lbs
Po1HDG2	102	99	103		lbs
Po2PNG	24	24.5	22.5		lbs
Po1HDG4	100.5	109	102		lbs
Po1HDG1	79	80	75		lbs
Po2HDG1	95	95	97		lbs
Po2PG1	23	23	25		lbs
Po1PG1	24.5	22.5	23.5		lbs
Po2PG5	23	22.5	23		lbs

Josh D	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	98	94	95		lbs
Po1HDG3	76	79	76		lbs
Po2HDG4	90.5	92	95		lbs
Po2HDG2	86	85	91		lbs
Po1PG5	23.5	24	24.5		lbs
Po1HDG5	82	81	86		lbs
Po2PG2	23.5	25	23		lbs
Po1PG3	22.5	18	23.5	22.0	lbs
Po1PNG	22.5	24	22		lbs
Po1PG4	24	25.5	24		lbs
Po2HDG3	84	83	86		lbs

Po2HDNG	101	105	110	lbs
Po1PG2	22.5	24.5	23	lbs
Po2PG4	21	23	22.5	lbs
Po2PG3	22.5	22	22.5	lbs
Po1HDNG	87	90	94	lbs
Po1HDG2	75	76	74	lbs
Po2PNG	20	21	20.5	lbs
Po1HDG4	77	83.5	83	lbs
Po1HDG1	76	79	83	lbs
Po2HDG1	85	91	86	lbs
Po2PG1	21.5	22.5	22.5	lbs
Po1PG1	20.5	22.5	22.5	lbs
Po2PG5	19.5	20	19	lbs

Devin	Trial 1	Trial 2	Trial 3	Trial 4	lbs
Po2HDG5	86	85	80		lbs
Po1HDG3	86	83.5	86		lbs
Po2HDG4	81.5	81	88		lbs
Po2HDG2	82.5	86.5	87.5		lbs
Po1PG5	19.5	19.5	20.5		lbs
Po1HDG5	87.5	75	91	89.0	lbs
Po2PG2	20	19.5	22		lbs
Po1PG3	19	18	19		lbs
Po1PNG	19.5	19	18		lbs
Po1PG4	19.5	18	19		lbs
Po2HDG3	84.5	89	85		lbs
Po2HDNG	102	97	94		lbs
Po1PG2	18.5	18	18		lbs
Po2PG4	18	18	18		lbs
Po2PG3	18.5	17.5	18		lbs
Po1HDNG	96	92.5	104		lbs
Po1HDG2	93.5	92	91		lbs
Po2PNG	18	19	18.5		lbs
Po1HDG4	90	90	86		lbs
Po1HDG1	90	90.5	89.5		lbs
Po2HDG1	87.5	93	85		lbs
Po2PG1	22	23	21.5		lbs
Po1PG1	23.5	22	21.5		lbs

Po2PG5 23 22.5 22 lbs