The Effects of Bat Grip Type on Baseball Hitting Performance

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ABSTRACT

INTRO: The success of a hitter for the longest time was defined by batting average but in today's game success is more focused on performance metrics such as bat speed, attack angle, and exit speed. One aspect of hitting that has been shown to have a potential effect on performance is the way you grip the bat. The palmar hamate grip which is becoming more popular across baseball is believed to increase performance. Prior research in regards to the palmar hamate grip and its effect on performance is limited and includes a major limitation of not accounting for grip preference. Additionally, if there is some type of performance benefit, it would be valuable to investigate the mechanism or explanation for the improvement in performance. With the wrist being near the bat and slight movements potentially affecting the orientation of the bat, changes in wrist kinematics could explain potential performance benefits from the palmar hamate grip. **PURPOSE:** The main purpose of this study was to analyze the effect of the palmar hamate grip on baseball hitting performance in comparison to the conventional grip, accounting for grip preference. The secondary purpose of this study was to analyze the effect of the palmar hamate grip on wrist kinematics in comparison to the conventional grip, also accounting for grip preference. **METHODS:** Twenty-one high school and collegiate right-handed hitters (ages 16-22) participated and were separated into two groups based on grip preference (conventional, n = 14; palmar hamate, n = 7). The study consisted of two conditions: in the first, participants completed 5 maximal effort swings off a tee with their preferred grip; in the second, participants completed 5 maximal effort swings off a tee with their non preferred grip. Bat speed and attack angle were measured via Blast Motion sensor, exit speed was measured via Stalker Sport 2 radar gun, and smash factor was calculated by dividing exit speed by bat speed. Wrist kinematics were measured via 12 camera Qualisys 3D motion capture system and then calculated in V3D. **RESULTS:** Statistical significances were found for attack angle and smash factor but not for bat speed or exit speed. For attack angle, a significant difference was found between the palmar preferred and conventional preferred group in the preferred grip condition (8.57 ± 4.29° vs. 4.37 ± 4.13°, $p < 0.05$). Additionally, within the palmar preferred group a significant difference was found between the preferred and non-preferred grip conditions (8.57 ± 4.29° vs. 7.14 ± 5.00°, $p < 0.05$). For smash factor, the only significant difference found was between the preferred and non-preferred grip conditions within the conventional preferred group (1.16 ± 0.03 vs. 1.18 ± 0.03, $p < 0.05$). Wrist kinematic variables that showed significance included: left wrist flex. / ext. angle at contact, left wrist pro. / sup. angle at contact, left wrist flex. / ext. ROM, left wrist uln. / rad. ROM, left wrist flex. / ext. angular velocity at contact, and left wrist flex. / ext. maximum velocity. **CONCLUSION:** The findings of this study indicate that the palmar hamate grip has some meaningful influence on attack angle, but not bat speed, exit speed, or smash factor. Given that the changes in attack angle acutely were modest, the findings suggest long term training with the palmar hamate grip would be needed to improve attack angle. Also, the palmar hamate grip had no clear effect on wrist kinematics, suggesting the change in attack angle seen could potentially be due to other body kinematics.

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CHAPTER 1: INTRODUCTION

Hitting a baseball is known to be one of the most difficult things to do in all of sports (Laughlin et al., 2016). It approximately takes 400-500 milliseconds from when the pitcher releases the ball to when the pitch crosses the plate (Gray, 2009). During this time the hitter must evaluate the pitch (trajectory, speed, and spin), decide to swing, and then actually complete the swing. With the decision to swing taking about 100-150 milliseconds and the time to set the motor program taking approximately the same amount, that leaves only 150-200 milliseconds for the hitter to swing the bat (Gray, 2009). Therefore, a hitter will do or try anything to increase their performance.

The importance of hitting in the game of baseball is self-evident. To win games, you must be able hit and produce runs as a team. As a hitter, the type of contact made with the ball can play a major role in the outcome. Being able to hit the ball hard can increase your likelihood of getting a hit, which gives your team a better opportunity to score runs and win games. This notion of hitting the ball hard has led to a shift in view of success as a hitter in today's game. For the longest time, success as a hitter was defined by batting average but in today's game the view on success is more focused on metrics associated with hitting the ball hard such as bat speed. (Jacob, 2019).

An increase in bat speed can be vital for having success as a hitter. How fast you can swing the bat determines how fast the ball comes off the bat after contact (Baseball, 2019; Smith, 2018; Szymanski et al., 2009). The measurement of the speed of the baseball as it comes of the bat after contact is known as exit velocity ("Exit Velocity (EV) | Glossary," n.d.). A ball with a higher exit velocity can have a higher probability of success because first the defense has less time to react, and second the ball can travel further in the air. When a ball is hit in the air, just a 1 mph increase in bat speed will increase exit velocity by 1.2 mph, resulting in 7ft increase in distance (Baseball, 2021). This is significant because this could be the difference between a ball caught on the warning track for an out or a homerun.

Another important performance metric when it comes to having success as a hitter is attack angle. Attack angle is the measurement of the angle of the bat path at ball contact in relation to the ground ("Blast Connect | Metrics," n.d.; "Hand Positions and Hitting," 2020). As a hitter being able to produce a bat path that is on the same plane as the ball coming in is vital to making solid contact ("Blast Connect | Why is Attack Angle important?," n.d.). Also attack angle has been associated with launch angle ("Hitting Biomechanics," 2022), a metric which measures the vertical angle at which the ball leaves a player's bat after contact ("Launch Angle (LA) | Glossary," n.d.). Therefore, the angle of your bat at contact can dictate the direction of the ball after contact which can have a major impact on success.

One aspect of hitting that has been shown to have a potential effect on both bat speed (Escamilla et al., 2009; "Hand Positions and Hitting," 2020) and attack angle ("Hand Positions and Hitting," 2020) is the way that you grip the bat. The grip, although often overlooked could arguably be one of the most important factors in a baseball swing. It is essentially the only point of contact that your body has with the bat. Therefore, the way a baseball player grips a bat can affect the swing as well as the outcome (Academy, 2020; "Baseball Bat Grip and Angle," 2020; "Gripping A Bat," 2023; "How to hold a baseball bat the right way," n.d.; baseballbysanom, 2023).

There are a few common ways that a baseball player can grip the bat. The most common is the "conventional grip" (aka normal grip) in which all fingers of the bottom hand are in contact with the handle and above the knob of the bat (Figure 1A). Another way to grip the bat is by “choking up” which consists of the hands being further away from the knob (Figure 1B). A third way is termed the “palmar hamate grip” (aka pinky or pinky off grip) in which the knob of the bat rests in the palm of the bottom hand over the hamate bone with pinky resting on the knob or completely off the bat (Figure 1C).

Figure 1: Baseball bat grip types. (A) conventional (“2023 Fantasy Baseball Outfield Player Spotlight,” n.d.) (B) choked-up (Carr, 2019) (C) palmar hamate (Reuter, n.d.).

The situation a hitter is in could dictate the type of grip used. It is common to hear the phrase “choke up with two strikes” as a hitter when you have two strikes. This is due to the belief that choking up promotes better control and accuracy, giving you a higher likelihood of making contact and putting the ball in play (Rhee et al., 2021; “Why You Should Or Shouldn’t Choke Up On A Bat | JustBats,” n.d.). On the other hand, with less than two strikes it is believed that using a more conventional or palmar hamate grip style grip is better because it creates a longer lever which allows for more bat speed and power (“Why You Should Or Shouldn’t Choke Up On A Bat | JustBats,” n.d.).

There has been some evidence suggesting the palmar hamate grip is not the best grip to use as it can increase the likelihood of a hamate fracture (Alexeev et al., 2021; Flynn et al., 2021). This injury occurs due to either a direct blow or repetitive blows on the hamate bone. The palmar hamate grip has been of concern because the knob of the bat sits right over the hamate bone resulting in greater pressure over that area (Alexeev et al., 2021; Flynn et al., 2021). With this increased pressure over the hamate, the likelihood of injury is greater.

Although hamate fractures are not season ending injuries, they can still result in substantial time away from the game. On average players are out for 51.5 days or roughly 7 weeks for a hamate fracture (Rhee et al., 2021). This could be critical depending on how far along a player is in a season. If this injury occurs towards the end of the season, it could have a major impact on a team's postseason success. However, the good news is that around 80% of players that sustain a hamate fracture can return to the same level of play before the injury occurred (Erickson et al., 2020).

The palmar hamate grip although associated with an increased likelihood of injury (Alexeev et al., 2021; Flynn et al., 2021), is becoming more popular across baseball. This is due to the belief that the palmar hamate grip can help improve your swing (Reida, 2017). Many skilled Latino players in the Atlanta Braves organization are being taught this grip in belief that it helps maximize power and control when batting (Alexeev et al., 2021).

The effect of the palmar hamate grip on hitting performance has been significantly understudied. There has been only one study that has investigated the palmar hamate grip and its effect on performance, but it is not a peer reviewed or published study. Also, the study did not consider grip preference, therefore it is inconclusive whether the results found were because of grip type or if grip preference was a factor. Therefore, additional research needs to be done regarding the effect of the palmar hamate grip on hitting performance, taking grip preference into account.

If an improvement in performance is seen with the palmar hamate grip, then the obvious question to ask is what is the mechanism behind it? Could there be a potential biomechanical change that occurs when using this grip that could explain an increase in performance? There is little to no knowledge of the effects of grip type on body kinematics, especially in regards to the wrist. The wrist being an important joint due to its proximity to the bat. Slight movements of the wrists can change the orientation of the bat leading to different swing outcomes. Therefore, with the palmar hamate grip, it would be interesting to see if gripping the bat around the knob changes the kinematics of the wrist.

The main purpose of this study was to analyze the effect of the palmar hamate grip on baseball hitting performance in comparison to the conventional grip, accounting for grip preference. The secondary purpose of this study was to analyze the effect of the palmar hamate grip on wrist kinematics in comparison to the conventional grip, also accounting for grip preference.

Delimitations

Listed below are the delimitations of the study.

1. Participants are from the Greenville, NC area.
2. Potential findings only apply to a baseball swing.

Limitations

Listed below are the potential limitations of the study.

1. Participants hitting off a tee.
2. Participants level of play is limited to high school and college level.
3. Limited number of participants who use palmar hamate grip.
4. Participants swung with preferred grip first then non-preferred grip.

Assumptions

Listed below are the assumptions of the study.

1. Participants swing with maximum effort.

Definitions

For the proposed study, the following terms are defined:

- Conventional grip: In regards to the bottom hand, all fingers are on the handle and above the knob of the bat.
- Palmar hamate grip: In regards to the bottom hand, the knob sits over the palm and the pinky is either resting on the knob or completely off the bat.
- Bat speed: Measurement of how fast the "sweet spot" (6 inches below the distal end) of the bat is moving at ball contact.
- Exit speed: Measurement of how fast the ball comes off the bat immediately after contact has been made.
- Attack angle: Measurement of the angle of the bat path at ball contact in relation to the ground. Zero-degree angle = parallel to the ground; Positive angle = swinging up; Negative angle = swinging down.
- Launch angle: The vertical angle at which the ball leaves the bat after contact.

- Smash factor: Measurement of collision efficiency or how much energy is transferred from the bat to the ball. Smash factor = exit speed / bat speed.
- Kinematics: Mechanics concerned with the motion of objects without reference to the forced which cause motion.
- Wrist angle: The position of the hand in relation to the forearm.
- Wrist angular velocity: The angular rate of change of the wrist angle.
- Wrist flexion: Moving the palm of your hand towards to the anterior surface of the forearm
- Wrist extension: Moving the back of the hand towards to the posterior surface of the forearm.
- Wrist pronation: Rotation of the hand and forearm so that the palm faces backwards or downwards.
- Wrist supination: Rotation of the hand and forearm so that the palm faces forwards or upwards.
- Wrist radial deviation: Tilting the hand and wrist toward the thumb and radius.
- Wrist ulnar deviation: Tilting the hand and wrist toward the pinky and ulna.
- Hamate bone: A carpal bone located towards the medial side of the wrist below the fourth and fifth metacarpals

CHAPTER 2: REVIEW OF THE LITERATURE

In this chapter there will be a discussion of literature mainly focused on topics regarding baseball bat grip types. However, due to limited literature related to baseball grip types, literature related to grip types in golf and tennis, which like baseball has multiple two-handed grip types, will also be discussed. To begin this chapter there will be a discussion on the importance of hitting and how it impacts success followed by a discussion about common grip types seen in baseball, golf, and tennis. General knowledge on the effect of grip along with research related to the effect of grip type on performance will then be discussed. The chapter will end with a discussion about one baseball grip type and its association with injury.

Impact of Hitting on Success

Hitting is obviously an important aspect of baseball. To not only have individual success but to have success as a team, being able to hit plays a major role. The ability to hit increases your chances of reaching base and gives your team a better opportunity of winning. To win games, you must score more runs than your opponent. Runs can be scored in a multitude of ways but most of the time runs are scored due to hitting. Without having the ability to hit and score runs the likelihood of winning decreases.

The definition of success when it comes to hitting has changed throughout the years. In the past, success as a hitter was mainly defined by batting average. In today's game the definition of success has started to shift away from batting average and is now more associated with metrics such as bat speed and exit velocity (Jacob, 2019). The reason for the change is due to the flaws in the batting average statistic (crefio, 2016). A hitter one at bat can hit a ball softly and get a hit and then in the next at bat hit it hard right at someone for an out. The chance of a softly hit ball resulting in a successful outcome more often than a hard-hit ball is highly unlikely. Therefore, metrics associated with hitting the ball hard such as bat speed and exit velocity is a better way to define success.

Bat speed is an important factor for having success as a hitter (Szymanski et al., 2009), as higher bat speeds can increase decision time (Smith, 2018; Szymanski et al., 2009). During an at bat, a hitter must process multiple variables related to the incoming pitch. These variables include pitch type (fastball, curveball, etc.), pitch velocity, and pitch location. Once these variables have been processed then the hitter must decide on whether to swing. The time frame of the hitter processing variables related to the pitch and deciding to swing is called the decision time (Hay, 1985). For major league hitters, this is between 0.26 and 0.35 seconds (Breen, 1967). With an increased decision time, more information about the pitch can be collected, resulting in better timing and accuracy of the swing.

Another reason bat speed is important for hitting success is because higher bat speeds can decrease swing time (Szymanski et al., 2009). After a hitter has decided to swing, they then must physically swing the bat to contact the ball. The time from the start of the swing to contact is referred to as swing time (Breen, 1967; Welch et al., 1995). For major league hitters, this is between 0.19 and 0.28 seconds (Breen, 1967). Swing time is directly related to decision time, the less time it takes a hitter to swing the bat, the more time they have to make a decision about the pitch. With a decreased swing time, the hitter has more time to process information in regards to the pitch. This can increase the chances of making solid contact with the ball, increasing likelihood of a successful outcome.

Bat speed is also important for success as hitter because higher bat speeds can increase exit velocity (Baseball, 2019; Smith, 2018; Szymanski et al., 2009). Once a hitter makes contact with the ball, the speed at which the ball comes off of the bat immediately after contact is known as exit velocity (“Exit Velocity (EV) | Glossary,” n.d.). This can range from low 70’s to mid-80’s miles per hour (mph) in high school up to 90 mph and above in professional baseball (Pourciau, 2023). The faster the ball comes off the bat the less time the defense can react, making it more difficult to make a play, increasing the likelihood of a successful outcome.

Hitting the ball hard is important to having success as a hitter but the direction of the ball after contact also plays an important role. The direction of the ball after contact is dependent on both timing of the swing and bat path. The timing of a swing dictates where the bat contacts the ball in relation to the body. When contact is made further out in front of the body, hitters tend to pull the baseball, and when contact is made further back, the ball tends to go the opposite field. For a right-handed hitter, pulled means a ball that is left of second base and any ball to the right of second base is considered opposite field or backside. As mentioned before, increasing bat speed can help a hitter with their timing at the plate (Smith, 2018; Szymanski et al., 2009). However, bat speed does not have any influence on bat path, the other factor that influences direction of the ball. The path of the bat is important because it dictates both the height and distance of the ball after contact (“Blast Connect | Why is Attack Angle important?,” n.d.). Depending on the path of the bat at contact, this could result in ground ball or a ball hit in the air, which could be the difference between an out or a hit. So, hitting the baseball hard is important for having success at the plate but if the ball does not go in the desired direction, then success could be diminished.

A metric that is mentioned a lot in today’s game in regards to the path of the bat is attack angle. Attack angle is the measurement of the angle of the bat path at ball contact in relation to the ground, with a positive attack angle indicating that a hitter is swinging up, a negative attack angle indicating that a hitter is swinging down, and zero is parallel to the ground ("Blast Connect | Metrics," n.d.; "Hand Positions and Hitting," 2020). Typically, an attack angle of -15 to 0 degrees results in a groundball, 5 to 20 degrees a line drive, and 20 to 35 a ground ball (Lisle, 2018). An ideal attack angle is considered 10 degrees as professional hitters tend to have attack angles between 8 and 12 degrees (Lisle, 2018). This will give a hitter the best chance to make solid contact and get the ball in the air, maximizing success.

Attack angle is important when it comes to success as at hitter because first matching up the bat path with the pitch path increases the hitter's chances of making contact ("Blast Connect | Why is Attack Angle important?," n.d.) and second it affects the vertical direction of the ball after impact ("Blast Connect | Why is Attack Angle important?," n.d.; "Hand Positions and Hitting," 2020; Lisle, 2018). Due to the pitcher being on the mound which is an elevated surface, the ball comes across the plate at a downward angle. As a hitter, being able to match that angle is crucial as it gives you a better chance of making solid contact with the ball. After contact the vertical angle at which the ball leaves the bat is known as launch angle, another popular performance metric in today's game. As a guideline, launch angles that are less than 10 degrees will result in a ground ball, 10 to 25 degrees a line drive, 25 to 50 degrees a fly ball, and greater than 50 degrees a pop up ("Launch Angle (LA) | Glossary," n.d.), with an ideal launch angle on average being between 17-20 degrees (Lisle, 2018). To produce an ideal launch angle, you must have a positive attack angle. Having a positive attack angle will increase the chances of the hitter getting the ball in the air (positive launch angle) and maximizing distance ("Blast Connect | Why is Attack Angle important?," n.d.). Therefore, attack angle plays a major role in the outcome of the swing and the potential success of a hitter.

Grip Types

In baseball there are three common ways to grip the bat. These include the conventional grip (aka normal grip), choke-up grip, and the palmar hamate grip (aka pinky or pinky off grip). The conventional being the most common grip consists of all the fingers on the bottom hand being in contact with the handle and above the knob of the bat (Figure 2A). The choked-up grip is like the conventional grip but both hands are moved up the bat further away from the knob (Figure 2B). The palmar hamate grip, which is starting to become more popular across baseball, consists of the knob resting in the palm of the hand over the hamate bone and the bottom hand pinky off the handle (Figure 2C).

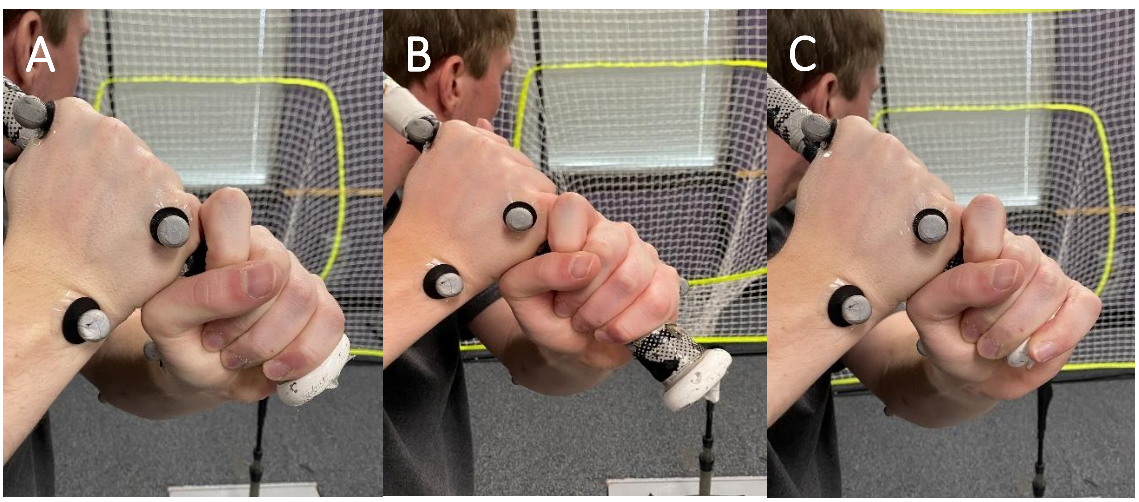

Figure 2: Demonstration of bat grip types. (A) conventional (B) choked-up (C) palmar hamate.

In golf the three main grip types include the neutral grip, strong grip, and weak grip. A neutral grip would consist of both hands around the center of the grip, not leaning to one side or the other. When looking down you should only see two knuckles on the lead hand and 1 to 2 knuckles on the trail hand (Figure 3A). With a strong grip both hands will be rotated around the shaft resulting in the lead hand more on top of the club and the trail hand more under the club

(Figure 3B). When looking down you should see three to 4 knuckles on the lead hand and none on the trial hand. A weak grip consists of both hands being rotated around the club the opposite way of the strong grip resulting in the trail hand to be more on top of the club. When looking down you should see only 1 knuckle on your lead hand and 2 to 3 knuckles on your trail hand (Figure 3C).

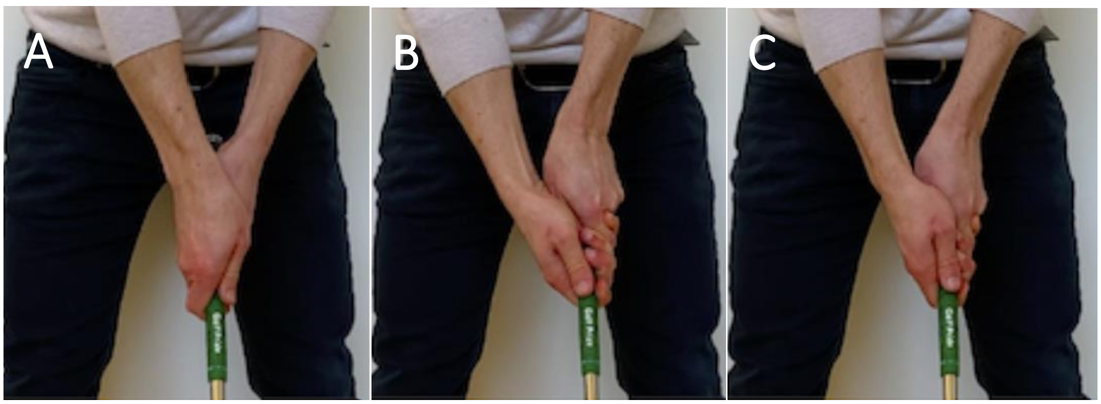

Figure 3: Demonstration of golf grip types. (A) neutral (B) strong (C) weak ("Strong, Weak & Neutral Golf Grips – Which is Best for You? – Golf Insider," n.d.).

In tennis the main grip types include the continental grip (forehand), eastern grip (forehand and backhand), western grip (forehand), and semi-western grip (forehand and backhand). Each grip type is defined by what bevel (side of the octagonal shaped racquet handle) the palm side bottom knuckle of the index finger is on (Figure 4). For both right-handed and left-handed players, the palms side of the bottom knuckle of the index finger would be placed on the second bevel for the continental forehand, third bevel for the eastern forehand, first bevel for eastern backhand, fifth bevel for western forehand, fourth bevel for semi-western forehand, and the eight bevel for the semi-western backhand.

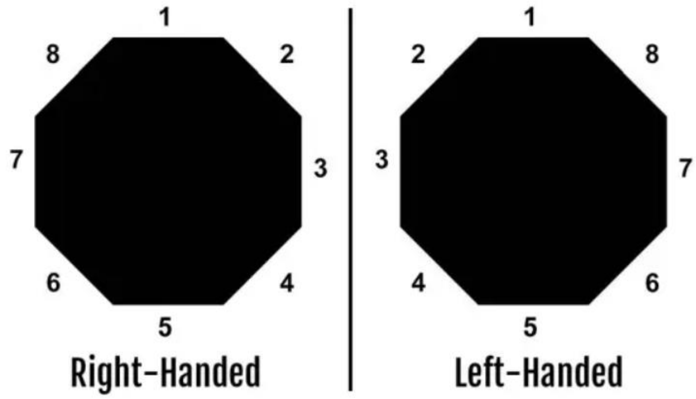

Figure 4: Diagram of tennis racquet handle. Corresponding bevel numbers for both right-handed and left-handed tennis players (tenthingstennis, 2021).

Effect of Grip on Performance

General Knowledge: Effect of Grip

In baseball the way that you grip a bat is an important factor when it comes to swinging a baseball bat as it is believed to impact multiple variables throughout the swing. The general knowledge is that grip can affect things such as bat speed, bat control, and bat position at contact ("Baseball Bat Grip and Angle," 2020; "How to hold a baseball bat the right way," n.d.; baseballbysanom, 2023). It also can affect a hitter's overall power, efficiency of contact, and adjustment to pitches (Academy, 2020). Not only is grip believed to affect variables related to the swing but it can also have an effect on what happens after contact has been made, such as direction and speed of the ball ("Gripping A Bat," 2023).

In golf the way that you grip the golf club can have an immense impact on both the swing and outcome. The general known effects that grip can have on the golf swing include clubhead speed, club path, club face angle, and contact. Also, the outcome or post impact effects associated with grip include ball speed, direction, trajectory, and distance (golfdds, 2018; “Strong vs. Weak Grip,” n.d.).

Tennis is another sport where the effect of grip is known. Tennis involves players moving all around the court at different angles depending on where the ball has been hit. The location of the player on the court along with their body position and shot selection can dictate the type of grip used. Therefore, the way you grip the racket can have a major impact on your shot such as racket control, topspin, direction, and power (“Understanding tennis grip types,” 2024).

Research: Grip and Performance

Current literature has shown that different baseball grip types could influence bat speed. Bat speed can be measured in two different ways. The first is to measure the speed of the distal end of the bat at ball contact. The other and more practical way is to measure the speed of the sweet spot (six inches below the distal end of the bat) of the bat at ball contact (“Blast Connect | What is Bat Speed?,” n.d.). Despite different methods of measuring bat speed there were similarities across studies showing that conventional and palmar hamate grips produced higher bat speeds compared to other grips (Escamilla et al., 2009; “Hand Positions and Hitting,” 2020). Escamilla et al. 2009 found that the normal or conventional grip produced a significantly greater bat velocity of 31 ± 4 m/s compared to the choked-up grip (28 ± 5 m/s). Another study performed by Driveline, a well-known and respected organization in the baseball biomechanics community, similarly found a significant increase in bat speed when using the conventional grip (72.3 ± 4.3 mph) compared to the choked-up grip (70.6 ± 4.4 mph). In addition to the conventional and choked-up grips, the Driveline study also analyzed the effect of the palmar hamate grip on bat speed. Like the conventional grip, the palmar hamate grip also produced a significantly greater bat speed of 72.0 ± 4.1 mph compared to the choked-up grip. However, there was no significant difference in bat speed found between the conventional and palmar hamate grip.

Although there has been little research, in addition to bat speed the way you grip a bat could also affect bat path or attack angle. As mentioned before, attack angle is the measurement of the angle of the bat path at ball contact in relation to the ground ("Blast Connect | Metrics," n.d.; "Hand Positions and Hitting," 2020). A positive attack angle indicates that a hitter is swinging up, and a negative attack angle indicates that a hitter is swinging down, where zero is parallel to the ground ("Blast Connect | Metrics," n.d.; "Hand Positions and Hitting," 2020). In the same study performed by Driveline that was mentioned earlier attack angle was found to be significantly higher for conventional, palmar hamate, and choked-up grip compared to an uncommon grip called the split grip (space between top and bottom hand) ("Hand Positions and Hitting," 2020). When looking at the more common grip types, the palmar hamate grip had the highest attack angle of 14.9 ± 6.0° compared to the conventional grip (14.4 ± 7.0°) and choked-up grip (13.5 ± 6.2°), but there was no significant difference found.

Based on the findings from above the effect that the palmar hamate grip specifically could have on performance is still unknown. Of the two studies mentioned, Escamilla et al. 2009 was the only published article and they did not even investigate the palmar hamate grip. The study performed by Driveline, a well-known and respected organization in the baseball biomechanics community, is the only research that has investigated the palmar hamate grip and its effect on performance. However, this study is not a peer reviewed or published, rather a study posted on a web page. Also, there were limitations in the design of the study, as they did not consider the grip preference or grip of choice of the hitter. Not considering grip preference limits the ability to draw accurate conclusions about differences in grip type, because there is no way to tell if the differences found were due to the grip type regardless of preference or if grip preference played a major role. With the only information on the palmar hamate grip and its effect on performance being imperfect, the quest to find the effects of the palmar hamate grip on performance is still needed.

Across other sports, different grip types have been shown to effect performance. In golf, different grip types have been found to significantly affect variables related to accuracy (Carson et al., 2019; D‘Arcy et al., 2021) and distance (D‘Arcy et al., 2021). A study performed by Carson et al. 2019 found a significant difference in clubface angle between the weak grip (-6.36 ± 6.9°) and both the strong (-1.51 ± 4.7°) and neutral grip (-2.57 ± 4.5°), representing a more open face to the intended hitting direction. Similarly, D’Arcy et al. 2021 found a significant difference in clubface angle between a weak grip and both strong and neutral grips. In addition to clubface angle, D’Arcy et al. 2021 also found that there were significant differences in other accuracy related variables (sideways deviation, accuracy absolute, club path angle, face to path angle, launch direction) when using the weak grip compared to the other grips. When looking at variables such as clubhead speed and total distance, again D’Arcy et al. 2021 found that the weak grip produced a significantly lower clubhead speed (130.71 ± 11.70 km/h) and total distance (150.77 ± 21.99 m) compared to the strong (137.03 ± 13.45 km/h; 177.13 ± 20.89 m) and neutral grips (137.25 ± 14.11 km/h; 178.09 ± 24.95 m).

The effect of grip type on performance has also been shown in tennis. Different grip types have been shown to effect where the ball was impacted (Elliott and Christmass, 1995), racket head linear velocity (Busuttil et al., 2022; Elliott et al., 1997), and post-impact ball speed (Busuttil et al., 2022). Elliot and Christmass 1995 found that using a non-preferred grip (hand behind the handle) compared to a preferred grip (eastern backhand or continental: hand on top of the handle), the ball was impacted further out in front of the body. Elliot et al. 1997 found that a western forehand grip produced higher y direction racket head velocity compared to an eastern forehand. Another study by Busuttil et al. 2022, also found a significant difference in linear racket head velocity when comparing two different tennis grips. They found that an eastern grip produced a significantly higher horizontal racket head linear velocity compared to a continental grip at different shot depths. They also found that the eastern grip produced a significantly greater ball speed compared to the continental grip.

The effect of grip types on body kinematics has also been shown in golf and tennis. A study done by Carson et al. 2019 found significant differences across different golf grip types for tri-planar motion (flexion/extension, internal/external rotation, and ulnar/radial deviation) of both wrists at different timepoints throughout the golf swing. Many of the significant interactions between grips were found in wrist flexion/extension and internal/external rotation, with less significant interactions found in wrist ulnar/radial deviation across grips. In tennis, different grips have been shown to effect upper limb kinematics such as peak racket-shoulder speed (Elliott and Christmass, 1995) and peak shoulder angular velocity (Busuttil et al., 2022). Elliot and Christmass 1995 found a significantly higher peak-racket shoulder speed when using the preferred grip (eastern backhand or continental: hand on top of the handle) compared to the non-preferred grip (hand behind the handle). Similarly, Busuttil et al. 2022 found significant differences in dominant shoulder kinematics between different two-handed backhand tennis grips, with the eastern grip producing greater dominant limb peak shoulder abduction and adduction angular velocity compared to the continental grip. When looking at non-dominant limb kinematics, Busuttil et al. 2022 found that the eastern grip produced significantly greater shoulder, elbow, and wrist angular velocities compared to the continental grip. These findings show that grip type can affect body kinematics which could be a potential explanation for change in performance.

Baseball Grips and Injury

Hamate fractures are a common hand injury for baseball players (Camp et al., 2018; Rhee et al., 2021; Sheridan et al., 2021). A study performed from 2011-2016 by Camp et al. 2018 found that hamate fractures were one of the 10 most frequent wrist injuries in major league baseball players. In addition, a more recent study done by Rhee et al. 2021 found that hamate fractures were the third most common hand/wrist injury in professional baseball players. The hamate bone is a carpal bone located towards the medial side of the wrist directly below the fourth and fifth metacarpals (Figure 5). This wedged shaped bone has a hook like process that faces the palmar side of the hand. The hamate bone can become fractured due to either a direct blow with great enough pressure or repetitive blows over time.

Figure 5: Diagram of hamate bone. The palm side of a left hand is displayed with the hamate bone shown in red (“Hamate bone,” 2024).

Hamate fractures are not a severe season ending injury but they can cause players to miss a significant amount of time away from the game. A study performed by Rhee et al. 2021, looking at hand and wrist injuries in professional baseball players from 2011-2016 found that players who were diagnosed with a hook of hamate fracture missed on average 51.5 days and surgery was required in 72.4% of the cases. They also found that during this time the hook of hamate excision was the most common surgery performed for hand and wrist injuries representing 32.8 % of all hand and wrist surgeries (Rhee et al., 2021). The good news is that following surgery of the hook of hamate, most players return to sport with only a slight decrease in performance. A study by Erickson et al. 2020 found that of the professional baseball players that underwent surgery of the hook of hamate between 2010-2017, 84% were able to return to sport, with 81% returning to the same or higher level of play (minor or major league level). They also found a decrease in batting average (pre surgery: 0.26 ± 0.04; post-surgery: 0.25 ± 0.04), on-base percentage (pre surgery: 0.34 ± 0.04; post-surgery: 0.32 ± 0.04), and on-base plus slugging percentage (pre surgery: 0.73 ± 0.12; post-surgery: 0.70 ± 0.11), but the changes were very minimal (Erickson et al., 2020). The slight decrease in performance should not be of concern as it is common in athletes coming back from injury. Based on these findings, hook of hamate fractures can cause players to miss some time but it is not a season or career ending injury, with most players returning without a significant deterioration in performance.

The palmar hamate grip is believed to increase the risk of hamate fractures. This is due to the placement of the knob of the bat which sits right over the hamate bone. Studies by Flynn et al. 2021 and Alexeev et al. 2021 investigated different baseball grips and their effects on pressure over the hamate bone. Both studies found that the palmar hamate grip produced higher peak pressures over the hamate bone compared to other grips. Alexeev et al. 2021 found a 366%

increase in pressure exerted over the hook of hamate when using the palmar hamate grip compared to the conventional grip. Flynn et al. 2021 also found an increase in mean pressure over the area of the hamate using the palmar hamate grip (1.68 ± 1.17 kg/cm^2) compared to both conventional (1.36 ± 0.73 kg/cm^2) and choked-up grips (1.18 ± 0.96 kg/cm^2). These findings suggest that palmar hamate grip can increase the likelihood of hamate fractures due to the increased pressure it puts over the hamate area.

Summary of Literature Review

In summary, hitting is an important aspect of baseball associated with success. The perspective on hitting success has changed from statistics such as batting average to performance metrics such as bat speed. Grip type has been shown across multiple sports to influence performance. However, in baseball the effect of grip type on performance is still significantly understudied, specifically with relation to palmar hamate grip. Most of the research regarding the palmar hamate grip is focused on its association with injury. However, many players still use this grip as there is belief that it can improve performance. Are the improvements in performance real and if so, do they outweigh the risk of injury? Also, grip type has been shown to affect body kinematics in golf and tennis, therefore it would be interesting to see if this is shown in baseball as well. The wrist being near the bat and its effect on the orientation on the bat could be important to investigate in regards to grip type. If a difference in performance is seen between baseball grip types, the change in kinematics of the wrist could be a possible explanation of this finding. Finally, prior studies have not considered grip preference when analyzing effects of grip type, therefore it is inconclusive on whether results found were due to grip type or if grip preference was a factor. Further research needs to be done on the palmar hamate grip and its effect on performance as well as wrist kinematics, considering grip preference.

CHAPTER 3: METHODS

Participants

The sample consisted of 21 baseball players (ages 16-22) recruited from local high schools and colleges around the Greenville, NC area. All participants batted right-handed, played on a high school varsity level or higher, and had no significant injuries within the past 12 months. Participants were separated into two groups based on grip preference; conventional (n = 14), palmar (n = 7). All participants provided a written form of consent before proceeding with the study (see appendix B). Participants completed a brief survey, reporting their age, year in school, years of experience, highest level of competition, handedness, grip preference, how long they had been using preferred grip, and injury history within the last 12 months (see appendix B). Participants height and weight were measured using a standard medical-grade scale. Characteristics of the participants for each group based on grip preference are summarized in Table 1.

Table 1: Participant Characteristics

	Conventional (N=14)	Palmar Hamate (N=7)
Age (years)	17.21 (0.80)	18.43 (2.51)
Height (m)	1.85 (0.06)	1.86 (0.04)
Weight (kg)	84.51 (9.88)	80.56 (9.11)
Lifetime Experience (years)	11.50 (1.22)	13.00 (3.27)
College-level Experience (years)	0.00 (0.00)	0.86 (1.21)
Grip Usage (years)	11.50 (1.22)	4.79 (4.33)

Data are presented as mean (SD)

Measures (Equipment/Instrumentation)

In this study the measuring equipment or instrumentation used consisted of a Qualisys 3D motion capture system, Blast Motion sensor, and Stalker Sport 2 radar gun. The Qualisys system consisted of 12 cameras (12 Oqus 3+ cameras (operating ~ 500 fps, sampling at 300 Hz). This 3D motion capture system was used to measure wrist kinematics of the swing. Blast Motion sensor was used to measure bat speed and attack angle. This sensor calculates bat speed and attack angle based off of ball impact, where bat speed is the total speed of the barrel at impact and attack angle is the angle the barrel approaches the ball at impact. Blast Motion is known to be the most accurate sensor in baseball and is trusted by many college and professional level teams. A validation study performed by the Center for Human Performance in 2016 tested multiple sensors against 3D motion capture when measuring bat speed and found that Blast Motion had the least margin of error (6 ± 2%) compared to Zepp (11 ± 6%) and Diamond Kinetics (8 ± 3%) sensors, with the error values expressed as a percentage of the respective criterion measured from motion capture (average error ± SD). Also Blast Motion estimated bat speed with up to 94% accuracy on average ("Baseball Bat Swing Sensor Validation | PDF | Post Hoc Analysis | Statistical Significance," n.d.). Although 3D motion capture is a more accurate method for measuring bat speed, the short setup time and quick analysis that Blast Motion offers is what makes it favorable. The Stalker Sport radar gun which has been the choice of many baseball professionals for decades was used to measure exit speed of the ball.

Procedures

Setup/Location

The study took place in the biomechanics lab at East Carolina University (Ward Sports Medicine Building, room 332). A stand-up hitting net was set up against the back wall with another net hung from the ceiling behind it to help stop a hit baseball. Once cameras were setup the system was calibrated. A tee was then placed in front of the net with a ball on top. A radar gun on a tripod was placed behind the tee and at a height in line with the ball. A diagram of this setup (Figure 6) along with the actual setup (Figure 7) are shown below.

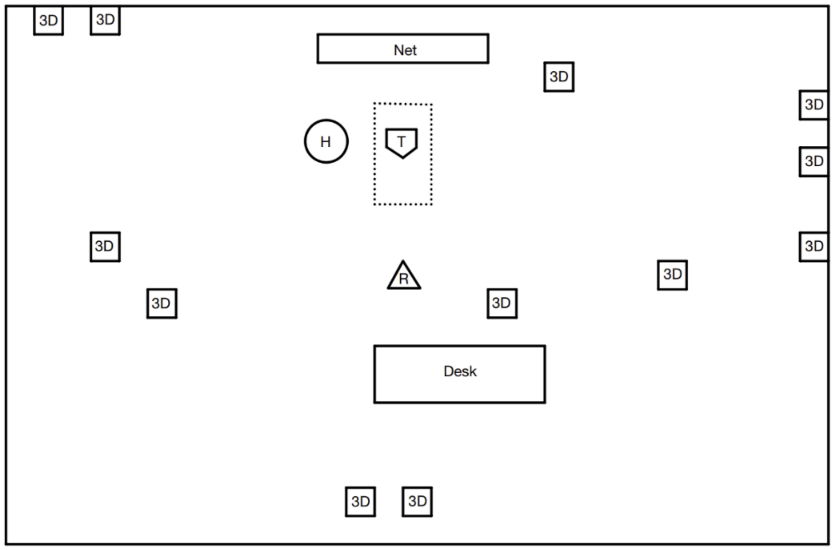

Figure 6: Diagram of experimental setup. Location in Ward Sports Medicine Building, room 332. H = hitter; T = tee; R = radar gun; 3D = 3D Qualisys camera.

Figure 7: Image of experimental setup.

Participant Preparation

Upon arrival participants were provided with informed consent and filled out a brief survey. Height and weight were then recorded for each participant. Then each participant had 14 reflective markers placed on their body. The location of the markers consisted of the right and left lateral and medial epicondyles of the elbow, right and left forearm, right and left ulnar and radial styloid processes, and right and left base of 2^{nd} and 5^{th} metacarpals (Figure 8). This marker setup for the forearm and hand segments came from C-Motion's marker set guidelines and is a standard marker setup in literature ("Marker Set Guidelines - Visual3D Wiki Documentation," n.d.; Trasolini et al., 2022). An additional marker was placed on the ball to see when contact was made. Participants were then instructed get in their hitting stance and the tee was adjusted to the desired height and location of hitter to resemble a pitch that is down the middle of the plate. Once the hitter was comfortable with the adjustments, the location of the tee and height of tee along with the front foot of the hitter was marked on the floor with tape (Figure 9). This was done to make sure that the hitter started from the same spot and that the height and location of the tee was the same for every swing. Each participant then performed a static trial using a t-pose (Figure 10). The blast motion sensor was then inserted into the knob of a Rawlings Quatro Pro BBCOR bat (Figure 11) and connected to the Blast Baseball App on an iOS device.

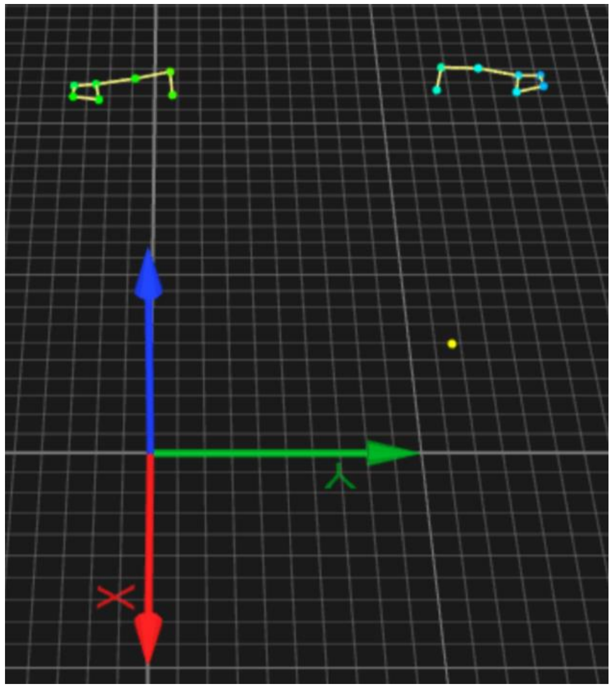

Figure 8: Image of body marker setup. Image taken from Qualisys Track Manager.

Figure 9: Image of tee and front foot location. Tee height and location along with front foot location marked with tape.

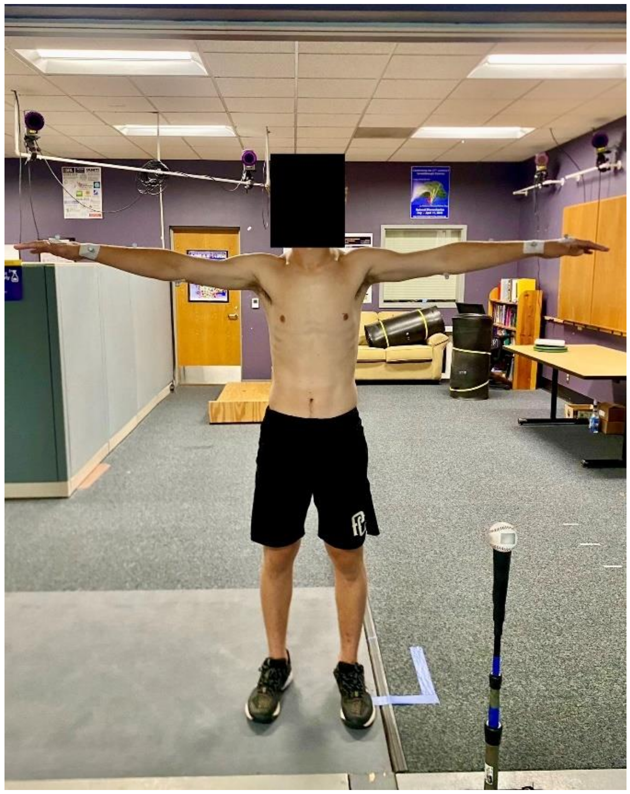

Figure 10: Image of static trial pose.

Figure 11: Blast Motion sensor bat integration. Blast sensor inserted into knob of Rawlings Quatro Pro BBCOR bat.

Experimental Design

Each participant was given as many warm up swings as needed off the tee with their preferred grip. Once ready they transitioned into the first condition, consisting of 5 swings with their preferred grip. Each participant was then introduced to the non-preferred grip type and was given as many warm up swings as needed. Once ready they began the second condition, consisting of 5 swings with the non-preferred grip. Before each condition the participants were instructed to perform a maximal effort swing, and focus on hitting hard line drives up the middle. Participants were able to see their bat speed and attack angle after each swing to keep performance consistent across all trials. After the five swings in each condition participants were given an opportunity to beat the highest bat speed from the five swings. If achieved, participants would continue swinging until they could no longer increase bat speed. This was done to make sure maximal effort was given by each participant. The five highest bat speeds for each condition were chosen for further analysis. Swings were excluded due to either poor contact or measurement error.

Data Analysis

The data analyzed was organized into two different data groups (performance and kinematics). The performance data included bat speed, exit speed, attack angle, and smash factor. Smash factor is a metric that is calculated by dividing exit speed by bat speed and is a measurement of collision efficiency or how well contact has been made. The kinematic data included wrist angle at contact, wrist range of motion (max wrist angle – min wrist angle), wrist angular velocity at contact, and maximum wrist angular velocity for the three types of wrist movements (x-flexion/extension, y-ulnar/radial deviation, z-pronation/supination). Both performance and kinematic dependent variables are defined in Table 2.

Table 2: Dependent Variable Definitions

Variables	Definitions
Bat Speed	Measurement of how fast the "sweet spot" (6 inches below the distal end) of the bat is moving at ball contact.
Exit Speed	Measurement of how fast the ball comes off the bat immediately after contact has been made.
Attack Angle	Measurement of the angle of the bat path at ball contact in relation to the ground. Zero-degree angle = parallel to the ground; Positive angle = swinging up; Negative angle = swinging down.
Smash Factor	Measurement of collision efficiency or how much energy is transferred from the bat to the ball. Smash factor = exit speed / bat speed.
Wrist Angle at Contact	The position of the hand in relation to the forearm measured at ball contact.
Wrist Range of Motion	Maximum wrist angle minus minimum wrist angle, calculated between start of swing and ball contact events.
Wrist Angular Velocity at Contact	The angular rate of change of the wrist angle at ball contact.
Maximum Wrist Angular Velocity	Maximum angular rate of change of the wrist angle, calculated between the start of swing and ball contact.

Performance

Bat speed and attack angle from Blast Motion and exit speed from the Stalker Sport 2 radar gun were recorded for each swing. Data was imported into MATLAB as a .xlsx file, where smash factor was calculated and then means for each participant were calculated and combined into a table. The table was exported as a .csv file to be used in RStudio for statistical analysis.

Kinematics

The swings trials captured via Qualisys 3D motion capture system were processed using Qualisys Track Manager (QTM). In QTM, events were first defined at the start of swing (first frame when full front foot contact was made) and at ball contact (first frame before ball marker disappears or starts to move). Data was cropped to 10 frames before start of swing and 3 frames after ball contact. Markers were then labeled appropriately and tracked throughout the entirety of the swing and gaps filled appropriately when needed. Data was then smoothed using a Butterworth filter with a 10 Hz cutoff frequency. Trials were then exported as a .c3d file to be used in Visual3D (V3D) software. In V3D, models were built using static calibration trials for each participant (Figure 12). A pipeline was built to calculate wrist angle and wrist angular velocity in all three axes (x-flexion/extension, y-ulnar/radial deviation, z-pronation/supination) using the Euler angle method. V3D data was exported as a .txt files to be used in MATLAB. In MATLAB, mean wrist kinematic metrics were calculated for each participant and combined into two tables. The first table included the individual means for wrist angle metrics (wrist angle at contact, wrist range of motion). The second table included the individual means for wrist angular velocity metrics (wrist angular velocity at contact, maximum wrist angular velocity). Tables were exported as .csv files to be used in RStudio for statistical analysis.

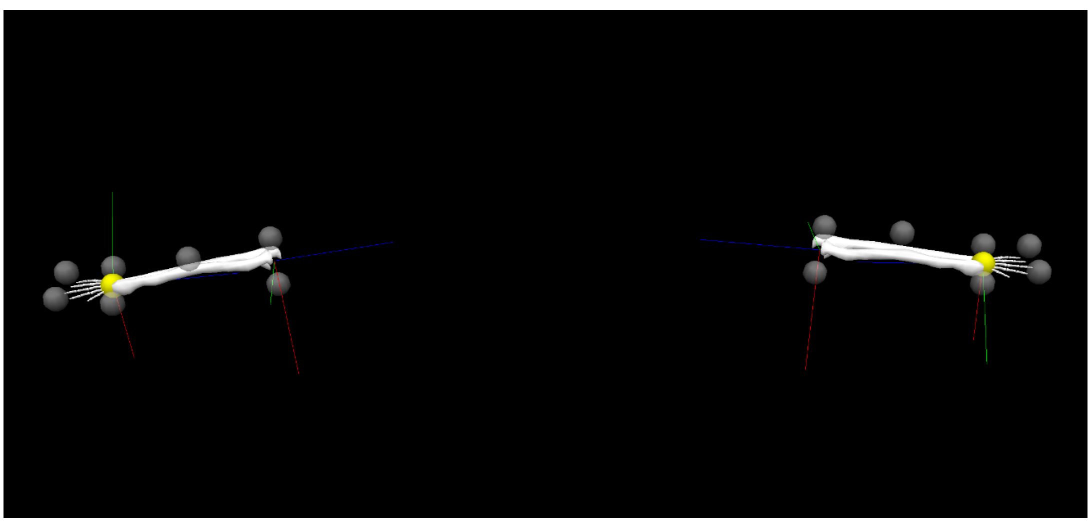

Figure 12: Image of body segment model. Image taken from Visual 3D.

Statistical Analysis

All statistical analyses for both performance and kinematic data were performed in RStudio. For all performance variables a mixed model ANOVA was performed based on grip preference (conventional vs. palmar) and condition (preferred grip vs. non-preferred grip). For all wrist kinematic variables, a mixed model ANOVA was performed based on grip preference (conventional vs. palmar) and grip type (conventional vs. palmar hamate). Post hoc analyses using unpaired and paired t-tests with an alpha level of 0.05 and a priori of 0.1 were performed (Curran-Everett and Benos, 2004).

CHAPTER 4: RESULTS

The main purpose of this study was to analyze the effect of the palmar hamate grip on baseball hitting performance in comparison to the conventional grip, accounting for grip preference. The secondary purpose of this study was to analyze the effect of the palmar hamate grip on wrist kinematics in comparison to the conventional grip, also accounting for grip preference. In this chapter, the results of the analyses will be presented in the order of the main and secondary purposes of this study. Specifically, analyses of performance variables based on grip preference and condition followed by analyses of wrist kinematic variables based on grip preference and grip type will be reported.

Performance

Table 3 includes the means and SD of each performance variable by grip preference (conventional preferred vs. palmar preferred) and condition (preferred grip vs. non-preferred grip).

Table3: Perfromance variables by grip preference and condition.

	C		P	
	Preferred (N=14)	**Non-Preferred (N=14)**	**Preferred (N=7)**	**Non-Preferred (N=7)**
Bat Speed (mph)	69.63 (3.59)	69.14 (3.59)	68.23 (3.80)	66.99 (2.98)
Attack Angle (°)	4.37 (4.13)	3.89 (3.77)	8.57 (4.29)	7.14 (5.00)
Exit Speed (mph)	80.83 (3.59)	81.40 (3.64)	79.51 (4.82)	79.29 (5.19)
Smash Factor	1.16 (0.03)	1.18 (0.03)	1.17 (0.03)	1.18 (0.04)

Data are presented as mean (SD)
C, Convenitonal Preferred; P, Palmar Preferred

Bat Speed

There were no significant main effects of preference ($p = 0.275$), condition ($p = 0.053$), or preference-condition interaction ($p = 0.385$) found for bat speed. The mean bat speed for the conventional preferred group slightly decreased from the preferred grip condition to the non-preferred grip condition (69.63 ± 3.59 vs. 69.14 ± 3.59 mph). The mean bat speed for the palmar preferred group also decreased from the preferred grip condition to the non-preferred grip condition (68.23 ± 3.80 vs. 66.99 ± 2.98 mph). The mean bat speed for the palmar preferred group was slightly less than the conventional preferred group regardless of condition.

Attack Angle

Figure 13 shows the mean attack angle of both grip preference groups (conventional vs. palmar) for each condition (preferred grip vs. non-preferred grip). A significant main effect of condition was found ($p = 0.001$), while there was no significant main effect of preference ($p = 0.068$), or preference-condition interaction ($p = 0.077$) observed. Post hoc analysis revealed that in the preferred grip condition, the palmar preferred group had a significantly greater attack angle compared to the conventional preferred group (8.57 ± 4.29° vs. 4.37 ± 4.13°, $p < 0.05$). The effect size, as measured by Cohen's d, was $d = 1.00$, indicating a large effect. In the non-preferred grip condition, the palmar preferred group again had a greater attack angle compared to the conventional preferred group (7.14 ± 5.00° vs. 3.89 ± 3.77°), however no significant difference was found ($p = 0.110$). For the palmar preferred group, a significant decrease in attack angle was found between the preferred and non-preferred grip conditions (8.57 ± 4.29° vs. 7.14 ± 5.00°, $p < 0.05$). The effect size, as measured by Cohen's d, was $d = 1.24$, indicating a large effect. For the conventional preferred group, there was a slight decrease in attack angle between the preferred and non-preferred grip conditions (4.37 ± 4.13° vs. 3.89 ± 3.77°), but no significant difference was found ($p = 0.110$).

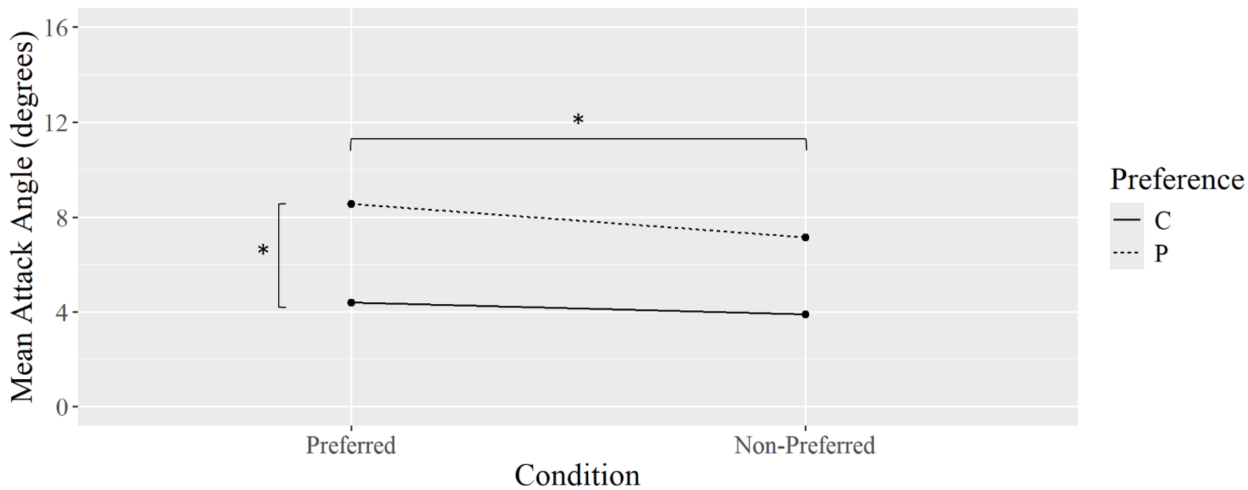

Figure 13: Attack Angle. Mean attack angle of both grip preference groups (C = conventional; P = palmar) for each condition (preferred grip, non-preferred grip). Significant differences: *p < 0.05.

Exit Speed

There were no significant main effects of preference (p = 0.367), condition (p = 0.682), or preference-condition interaction (p = 0.344) found for exit speed. The mean exit speed for the conventional preferred group slightly increased from the preferred grip condition to the non-preferred grip condition (80.83 ± 3.59 vs. 81.40 ± 3.64 mph). The mean exit speed for the palmar preferred group slightly decreased from the preferred grip condition to the non-preferred grip condition (79.51 ± 4.82 vs. 79.29 ± 2.98 mph). The mean exit speed for the palmar preferred group was slightly less than the conventional preferred group regardless of condition.

Smash Factor

Figure 14 shows the mean smash factor of both grip preference groups (conventional vs. palmar) for each condition (preferred grip vs. non-preferred grip). A significant main effect of condition was found (p = 0.028), while there was no significant main effect of preference (p =

0.750), or preference-condition interaction ($p = 0.954$) observed. Post hoc analysis revealed that in the preferred grip condition, there was no significant difference in smash factor between the conventional preferred and palmar preferred groups (1.16 ± 0.03 vs. 1.17 ± 0.03, $p = 0.779$). In the non-preferred grip condition, again there was no significant difference in smash factor between the conventional preferred and palmar preferred groups (1.18 ± 0.03 vs. 1.18 ± 0.04, $p = 0.777$). For the conventional preferred group, a significant increase in smash factor was found between the preferred and non-preferred conditions (1.16 ± 0.03 vs. 1.18 ± 0.03, $p < 0.05$). The effect size, as measured by Cohen's d, was $d = 0.46$, indicating a small effect. For the palmar preferred group, there was a slight increase in smash factor between the preferred and non-preferred grip conditions (1.17 ± 0.03 vs. 1.18 ± 0.04), however no significant difference was found ($p = 0.272$).

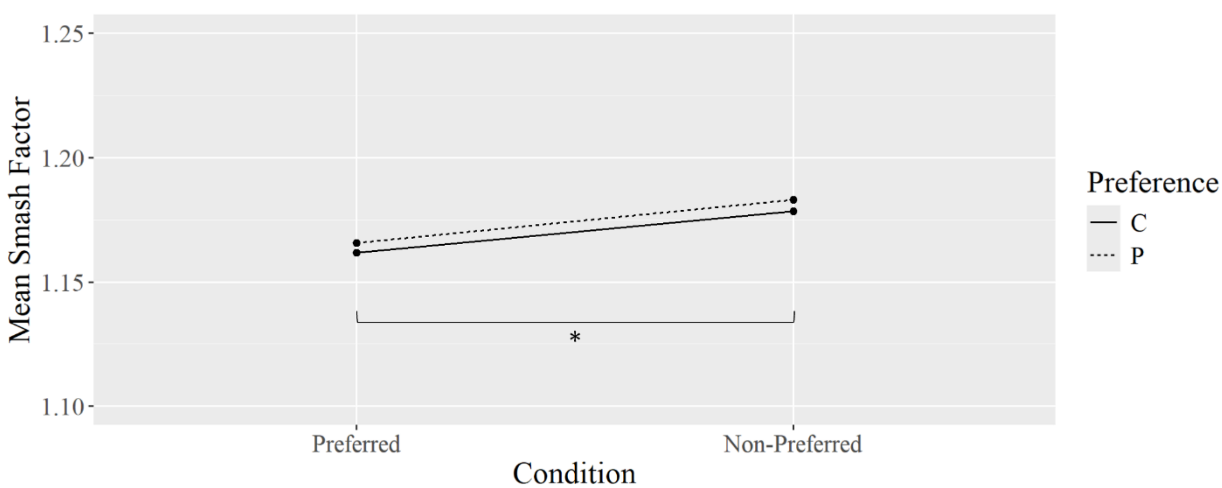

Figure 14: Smash Factor. Mean smash factor of both grip preference groups (C = conventional; P = palmar) for each condition (preferred grip, non-preferred grip). Smash factor = exit speed / bat speed. Significant differences: *$p < 0.05$.

Wrist Kinematics

Wrist Angle Contact

Table 4 includes the means and SD of each wrist angle variable at contact by grip preference (conventional preferred vs. palmar preferred) and grip type (conventional vs. palmar hamate).

Table 4: Wrist angle variables at contact by grip preference and grip type.

	C		P	
	Conventional (N=14)	**Palmar Hamate (N=14)**	**Conventional (N=7)**	**Palmar Hamate (N=7)**
Left Wrist Flexion/Extension (°)	-17.77 (7.52)	-14.36 (7.76)	-19.09 (5.31)	-18.68 (4.84)
Left Wrist Ulnar/Radial Deviation (°)	4.17 (6.83)	5.15 (6.97)	6.15 (4.51)	5.46 (4.95)
Left Wrist Pronation/Supination (°)	37.28 (11.44)	40.30 (11.93)	39.02 (15.48)	39.20 (16.29)
Right Wrist Flexion/Extension (°)	4.58 (12.49)	5.50 (11.56)	5.33 (10.01)	6.54 (9.87)
Right Wrist Ulnar/Radial Deviation (°)	29.31 (10.53)	30.18 (12.04)	35.17 (11.88)	36.57 (12.01)
Right Wrist Pronation/Supination (°)	9.23 (15.96)	9.50 (16.83)	14.07 (15.39)	15.11 (13.86)

Data are presented as mean (SD)
C, Convenitonal Preferred; P, Palmar Preferred

Figure 15 shows the mean left wrist flexion/extension angle at contact of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant main effect of grip ($p = 0.002$) and preference-grip interaction ($p = 0.009$) was found. Post hoc analysis revealed that for the conventional grip, there was no significant difference in left wrist flexion/extension angle at contact between the conventional preferred and palmar preferred groups (-17.77 ± 7.52° vs. -19.09 ± 5.31°, $p = 0.686$). For the palmar hamate grip, again there was no significant difference in left wrist flexion/extension angle at contact between the conventional preferred and palmar preferred groups (-14.36 ± 7.76° vs. -18.68 ± 4.84°, $p = 0.196$). For the conventional preferred group, a significant difference in left wrist flexion/extension angle at contact was found between grip with the palmar hamate grip creating less flexion at contact compared to the conventional grip (-14.36 ± 7.76° vs. -17.77 ± 7.52°, p <

0.001). The effect size, as measured by Cohen's d, was d = 1.40, indicating a large effect. For the palmar preferred group, no significant difference in left wrist flexion/extension angle at contact was found between the conventional and palmar hamate grip (-19.09 ± 5.31° vs. -18.68 ± 4.84°, p = 0.563).

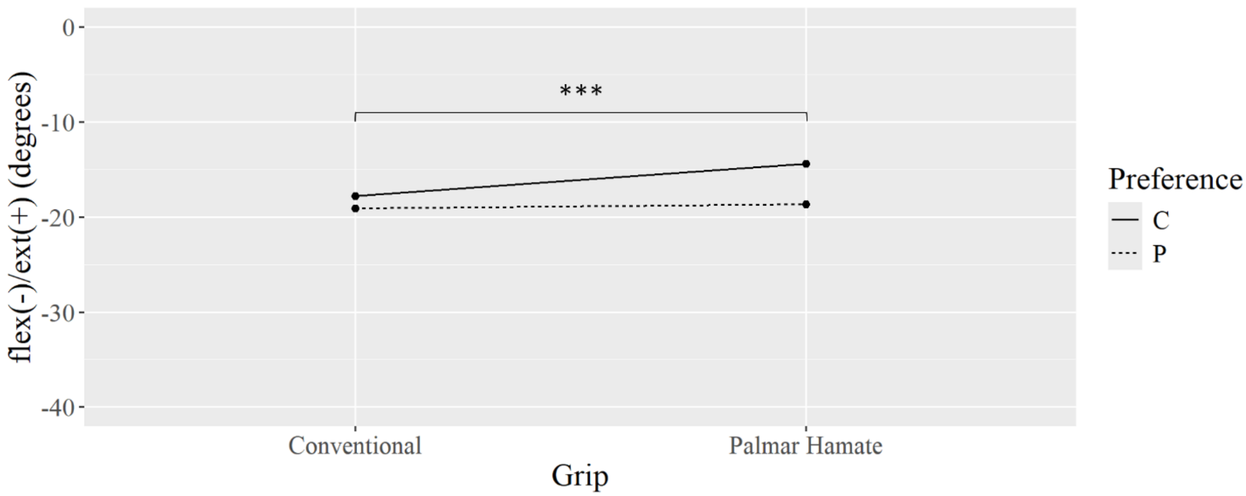

Figure 15: Left wrist flexion/extension angle at contact. Mean left wrist flexion/extension angle at contact of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: ***p < 0.001.

Figure 16 shows the mean left wrist pronation/supination angle at contact of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant main effect of grip and preference-grip interaction was found. Post hoc analysis revealed that for the conventional grip, there was no significant difference in left wrist pronation/supination angle at contact between the conventional preferred and palmar preferred groups (37.28 ± 11.44° vs. 39.02 ± 15.48°, p = 0.773). For the palmar hamate grip, there was also no significant difference in left wrist pronation/supination angle at contact between the conventional preferred and palmar preferred groups (40.30 ± 11.93° vs. 39.20 ± 16.29°, p =

0.863). For the conventional preferred group, a significant difference in left wrist pronation/supination angle at contact was found between grips with the palmar hamate grip creating more pronation at contact compared to the conventional grip (40.30 ± 11.93° vs 37.28 ± 11.44°, $p < 0.0001$). The effect size, as measured by Cohen's d, was d = 2.47, indicating a large effect. For the palmar preferred group, no significant difference in left wrist pronation/supination angle at contact was found between the conventional and palmar hamate grip (39.02 ± 15.48° vs. 39.20 ± 16.29°, $p = 0.767$).

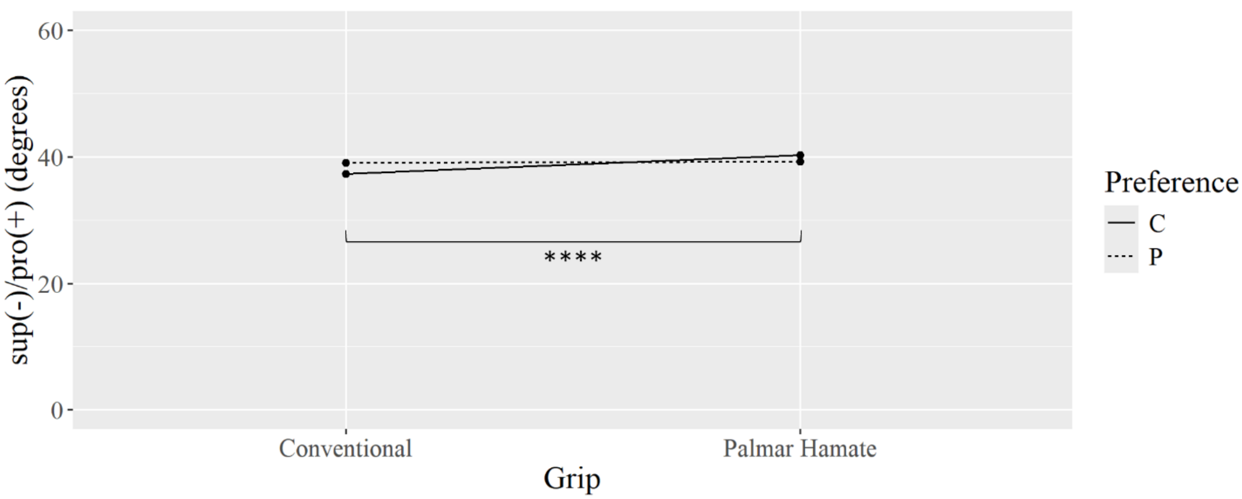

Figure 16: Left wrist pronation/supination angle at contact. Mean left wrist pronation/supination angle at contact of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: ****$p < 0.0001$.

Wrist Range of Motion

Table 5 includes the means and SD of each wrist range of motion variable by grip preference (conventional preferred vs. palmar preferred) and grip type (conventional vs. palmar hamate).

Table 5: Wrist range of motion variables by grip preference and grip type.

	C		P	
	Conventional (N=14)	**Palmar Hamate (N=14)**	**Conventional (N=7)**	**Palmar Hamate (N=7)**
Left Wrist Flexion/Extension ROM (°)	51.36 (13.39)	48.21 (13.05)	39.24 (9.75)	36.99 (9.51)
Left Wrist Ulnar/Radial ROM (°)	15.83 (7.57)	15.48 (7.47)	22.77 (7.00)	22.60 (5.95)
Left Wrist Pronation/Supination ROM (°)	18.53 (5.31)	18.10 (6.40)	16.12 (6.86)	17.44 (7.84)
Right Wrist Flexion/Extension ROM (°)	49.84 (13.80)	49.17 (13.32)	47.98 (9.23)	48.17 (10.39)
Right Wrist Ulnar/Radial Deviation ROM (°)	25.60 (6.46)	26.73 (6.74)	24.89 (10.47)	25.44 (9.09)
Right Wrist Pronation/Supination ROM (°)	47.64 (11.75)	47.59 (12.25)	46.24 (10.75)	45.34 (10.64)

Data are presented as mean (SD)
C, Convenitonal Preferred; P, Palmar Preferred

Figure 17 shows the mean left wrist flexion/extension ROM of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant main effect of grip was found ($p = 0.002$), while no significant main effect of preference (0.051), or preference-grip interaction (0.549) were observed. Post hoc analysis revealed that for the conventional grip, there was a significant difference in left wrist flexion/extension ROM between groups, with the conventional preferred group having more ROM compared to the palmar preferred group (51.36 ± 13.39° vs. 39.24 ± 9.75°, $p < 0.05$). The effect size, as measured by Cohen's d, was $d = 1.04$, indicating a large effect. For the palmar hamate grip, there was no significant difference in left wrist flexion/extension ROM between groups, however the conventional preferred group again had more ROM compared to the palmar preferred group (48.21 ± 13.05° vs. 36.99 ± 9.51°, $p = 0.059$). For the conventional preferred group, a significant difference in left wrist flexion/extension ROM was found between grips with the conventional grip creating a little more ROM compared to the palmar hamate grip (51.36 ± 13.39° vs. 48.21 ± 13.05°, $p < 0.01$). The effect size, as measured by Cohen's d, was d = 1.00, indicating a large effect. For the palmar preferred group, no significant difference in left wrist flexion/extension ROM was found between the conventional and palmar hamate grip (39.24 ± 9.75° vs. 36.99 ± 9.51°, p = 0.125).

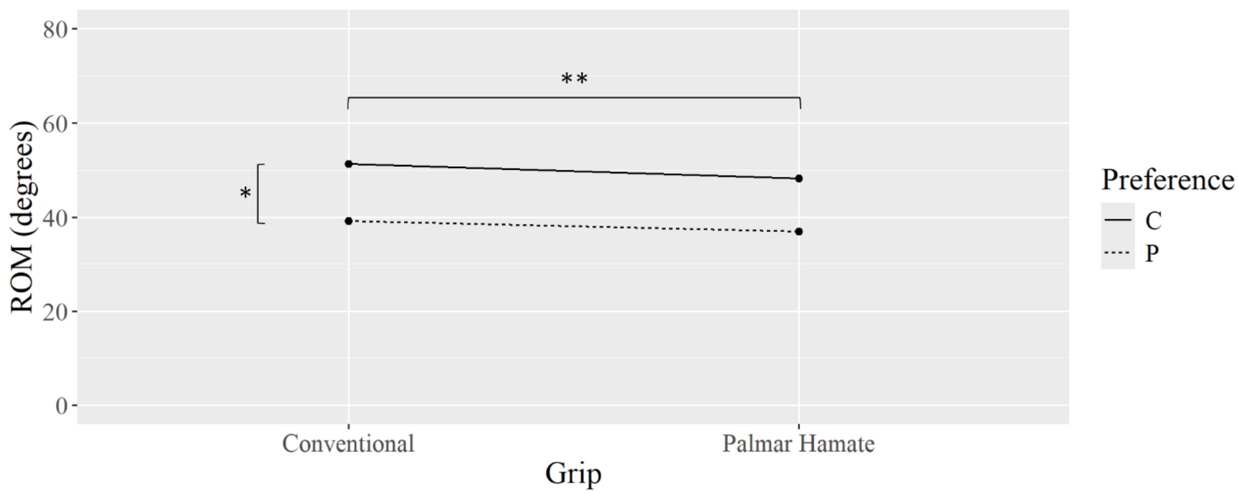

Figure 17: Left wrist flexion/extension ROM. Mean left wrist flexion/extension ROM of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: *$p < 0.05$; **$p < 0.01$.

Figure 18 shows the mean left wrist ulnar/radial ROM of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant main effect of preference was found (p = 0.046), while no significant main effect of grip (p = 0.618), or preference-grip interaction (p = 0.867) were observed. Post hoc analysis revealed that for the conventional grip, there was no significant difference in left wrist ulnar/radial ROM between groups, however the palmar preferred group had more ROM compared to the conventional preferred group (22.77 ± 7.00° vs. 15.83 ± 7.57°, p = 0.057). For the palmar hamate grip, a significant difference in left wrist ulnar/radial ROM was found between groups, with the palmar preferred group having more ROM compared to the conventional preferred group (22.60 ± 5.95° vs. 15.48 ± 7.47°, $p < 0.05$). The effect size, as measured by Cohen's d, was $d = 1.05$, indicating a large effect. For the conventional preferred group, no significant difference in left wrist ulnar/radial ROM was found between the conventional and palmar hamate grip (15.83 ± 7.57° vs. 15.48 ± 7.47°, $p = 0.382$). Similarly for the palmar preferred group, no significant difference in left wrist ulnar/radial ROM was found between the conventional and palmar hamate grip (22.77 ± 7.00° vs. 22.60 ± 5.95°, $p = 0.895$).

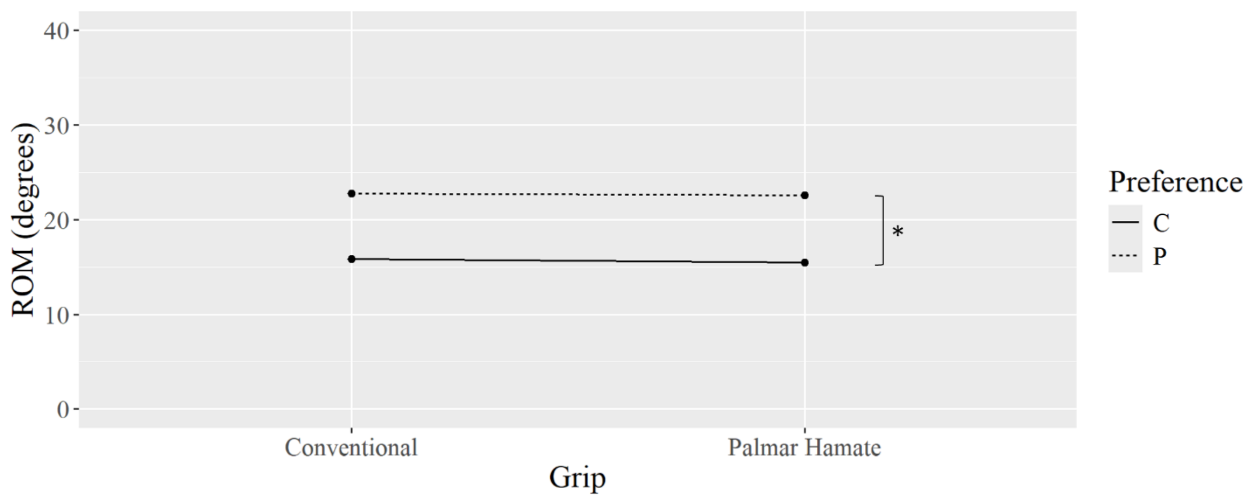

Figure 18: Left wrist ulnar/radial ROM. Mean left wrist ulnar/radial ROM of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: *p < 0.05.

Wrist Angular Velocity Contact

Table 6 includes the means and SD of each wrist angular velocity variable at contact by grip preference (conventional preferred vs. palmar preferred) and grip type (conventional vs. palmar hamate).

Table 6: Wrist angular velocity varaibles at contact by grip preference and grip type.

	C		P	
	Conventional (N=14)	**Palmar Hamate (N=14)**	**Conventional (N=7)**	**Palmar Hamate (N=7)**
Left Wrist Flexion/Extension Angular Velocity (°/s)	-518.40 (227.22)	-553.34 (200.23)	-506.50 (290.39)	-433.08 (248.84)
Left Wrist Ulnar/Radial Angular Velocity (°/s)	178.32 (204.91)	207.52 (171.42)	262.37 (294.97)	265.77 (258.42)
Left Wrist Pronation/Supination Angular Velocity (°/s)	-476.42 (130.86)	-443.07 (103.49)	-600.48 (230.74)	-588.61 (202.45)
Right Wrist Flexion/Extension Angular Velocity (°/s)	-926.38 (241.51)	-928.52 (265.07)	-833.18 (247.93)	-882.43 (200.27)
Right Wrist Ulnar/Radial Angular Velocity (°/s)	-924.01 (328.70)	-910.57 (345.67)	-824.66 (311.96)	-868.83 (351.94)
Right Wrist Pronation/Supination Angular Velocity (°/s)	-544.26 (188.59)	-504.03 (220.33)	-459.34 (178.59)	-405.91 (136.64)

Data are presented as mean (SD)
C, Convenitonal Preferred; P, Palmar Preferred

Figure 19 shows the mean left wrist flexion/extension angular velocity at contact of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant preference-grip interaction was found (p = 0.002), while no significant main effect was observed for preference (p = 0.544) or grip (p = 0.211). Post hoc analysis revealed that for the conventional grip, there was no significant difference in left wrist flexion/extension angular velocity at contact between the conventional preferred and palmar preferred groups (-518.40 ± 227.22°/s vs. -506.50 ± 290.39°/s, p = 0.919). For the palmar hamate grip, there was also no significant difference in left wrist flexion/extension angular velocity at contact between groups, however the palmar preferred group has less flexion angular velocity compared to the conventional preferred group (-433.08 ± 248.84°/s vs. -553.34 ± 200.23°/s, p = 0.245). For the conventional preferred group, no significant difference in left wrist flexion/extension angular velocity was found between the conventional and palmar hamate grip (-518.40 ± 227.22°/s vs. -553.34 ± 200.23°/s, p = 0.066). For the palmar preferred group, a significant difference in left wrist flexion/extension angular velocity was found between grips, with the palmar hamate creating less flexion angular velocity compared to the conventional grip (-433.08 ± 248.84°/s vs. -506.50 ± 290.39°/s, $p < 0.05$). The effect size, as measured by Cohen's d, was d = 1.18, indicating a large effect.

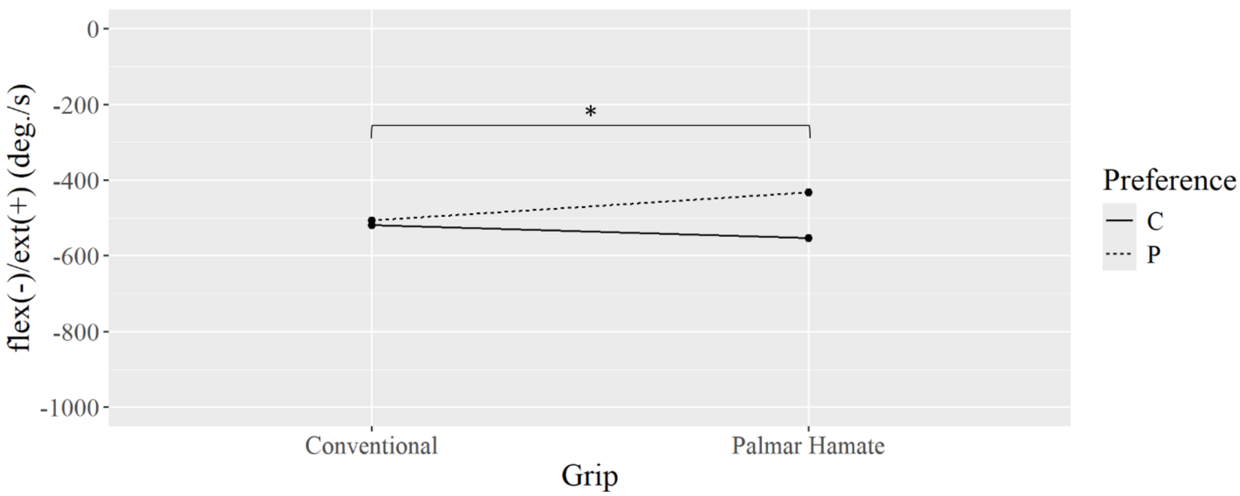

Figure 19: Left wrist flexion/extension angular velocity at contact. Mean left wrist flexion/extension angular velocity at contact of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: *$p < 0.05$.

Maximum Wrist Angular Velocity

Table 7 includes the means and SD of each maximum wrist angular velocity variable by grip preference (conventional preferred vs. palmar preferred) and grip type (conventional vs. palmar hamate).

Table 7: Maximum wrist angular velocity variables by grip preference and grip type.

	C		P	
	Conventional (N=14)	Palmar Hamate (N=14)	Conventional (N=7)	Palmar Hamate (N=7)
Left Wrist Flexion/Extension Max Angular Velocity (°/s)	-840.77 (169.38)	-789.60 (167.76)	-741.27 (226.97)	-680.22 (226.87)
Left Wrist Ulnar/Radial Angular Max Velocity (°/s)	-42.78 (299.98)	-52.50 (277.58)	66.04 (438.77)	102.33 (376.02)
Left Wrist Pronation/Supination Max Angular Velocity (°/s)	-494.24 (153.64)	-442.40 (164.78)	-620.96 (217.46)	-613.58 (187.71)
Right Wrist Flexion/Extension Max Angular Velocity (°/s)	-986.91 (338.85)	-940.39 (451.07)	-812.98 (518.72)	-926.56 (348.09)
Right Wrist Ulnar/Radial Max Angular Velocity (°/s)	-941.64 (329.28)	-888.27 (401.23)	-833.73 (373.22)	-842.35 (429.48)
Right Wrist Pronation/Supination Max Angular Velocity (°/s)	-761.70 (173.64)	-791.85 (203.21)	-849.86 (319.13)	-777.14 (278.57)

Data are presented as mean (SD)
C, Convenitonal Preferred; P, Palmar Preferred

Figure 20 shows the mean left wrist flexion/extension maximum angular velocity of both grip preference groups (conventional vs. palmar) for each grip type (conventional vs. palmar hamate). A significant main effect of grip was found ($p < 0.05$), while no significant main effects of preference ($p = 0.243$), or preference-grip interaction ($p = 0.683$) were observed. Post hoc analysis revealed that for the conventional grip, there was no significant difference in left wrist flexion/extension maximum angular velocity between the conventional preferred and palmar preferred groups (-840.77 ± 169.38°/s vs. -741.27 ± 226.97°/s, $p = 0.271$). For the palmar hamate grip, again no significant difference in left wrist flexion/extension maximum angular velocity was found between the conventional preferred and palmar preferred groups (-789.60 ± 167.76°/s vs. -680.22 ± 226.87°/s, $p = 0.225$). For the conventional preferred group, a significant difference in left wrist flexion/extension maximum angular velocity was found between grips, with the conventional grip creating more maximum flexion angular velocity compared to the palmar hamate grip (-840.77 ± 169.38°/s vs. -789.60 ± 167.76°/s, $p < 0.01$). The effect size, as measured by Cohen's d, was $d = 1.02$, indicating a large effect. Similarly for the palmar preferred group, a significant difference in left wrist flexion/extension maximum angular velocity was found between grips, with the conventional grip creating more maximum flexion angular velocity compared to the palmar hamate grip (-741.27 ± 226.97°/s vs. -680.22 ± 226.87°/s, $p < 0.05$). The effect size, as measured by Cohen's d, was d = 1.13, indicating a large effect.

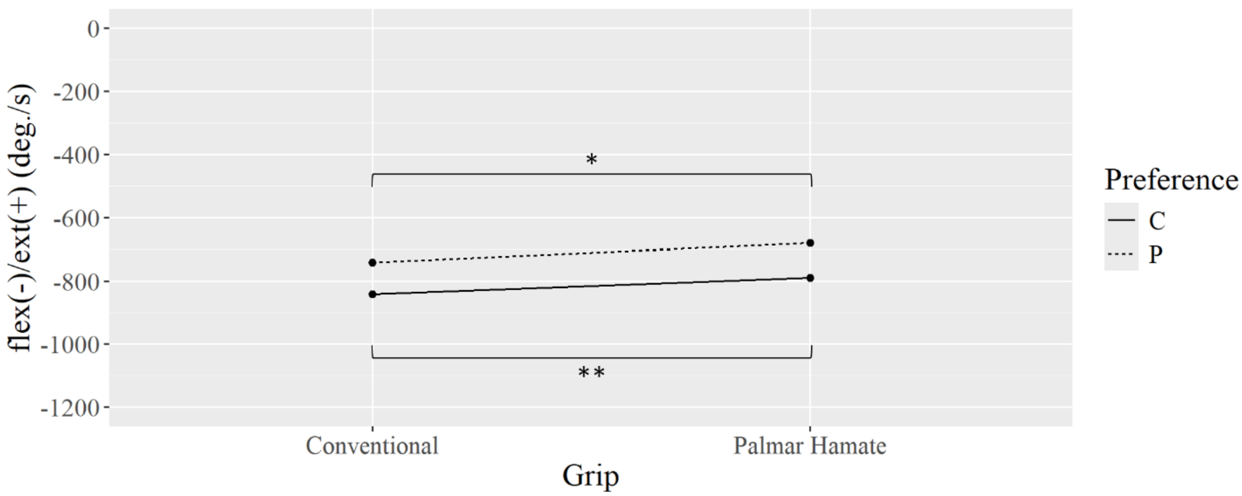

Figure 20: Left wrist flexion/extension maximum angular velocity. Mean left wrist flexion/extension maximum angular velocity of both grip preference groups (C = conventional; P = palmar) for each grip type. Significant differences: *$p < 0.05$; **$p < 0.01$.

CHAPTER 5: DISCUSSION

Performance

Table 8: Summary of Performance Findings

Variables	Findings
Bat Speed	No significant effect of grip based on grip preference or condition.
Attack Angle	Preferred grip condition: palmar preferred group > conventional preferred group (8.57 ± 4.29° vs. 4.37 ± 4.13°, $p < 0.05$, $d = 1.00$).
	Palmar preferred group: preferred > non-preferred condition (8.57 ± 4.29° vs. 7.14 ± 5.00°, $p < 0.05$, $d = 1.24$).
Exit Speed	No significant effect of grip based on grip preference or condition.
Smash Factor	Conventional preferred group: preferred > non-preferred condition (1.16 ± 0.03 vs. 1.18 ± 0.03, $p < 0.05$, $d = 0.46$).

The main purpose of this study was to analyze the effect of the palmar hamate grip on baseball hitting performance in comparison to the conventional grip, accounting for grip preference. The findings indicate that the palmar hamate grip impacted attack angle but had no effect on the other performance metrics, with grip preference being a contributing factor (Table 8). Regardless of condition, the palmar preferred group had a higher attack angle compared to the conventional preferred group, with a significantly higher attack angle of around 4 degrees in the preferred grip condition. Also, looking within each group, the conventional preferred group had little to no change in attack angle between conditions, but the palmar preferred group did have a significant decrease in attack angle of about 1 degree between the preferred and non-preferred grip conditions. Given that the changes in attack angle acutely were modest, the findings suggest that long term use of the palmar hamate grip could potentially increase attack angle.

There are findings from previous research that both support and contradict the findings of this study. Although prior research did not account for grip preference the acute findings can still be compared. Escamilla et al 2009 found that the conventional grip, which creates a longer lever than the choked-up grip produced a significantly greater bat speed. The notion of a longer lever grip creating more bat speed did not hold up in the current study, with the palmar hamate grip not showing a significant difference in bat speed compared to the conventional grip. Similarly, a Driveline study found no significant difference in bat speed between the conventional and palmar hamate grip. The same Driveline study also found that the palmar hamate grip produced slightly more attack angle compared to the conventional grip but no significance was found as the difference was less than a degree. This finding was partially supported in the current study, with no meaningful significance in attack angle between conditions regardless of grip preference. However, in contradiction the conventional preferred group had a slightly lower attack angle when using the palmar hamate grip compared to the conventional grip. With that being said, the comparison of this study to previous studies is difficult due to the current study accounting for grip preference.

The significantly more positive attack angle produced by the palmar preferred group compared to the conventional preferred group in the preferred grip condition is meaningful ($d = 1.00$). Again, attack angle is the measurement of the bat path at ball contact in relation to the ground, with a positive attack angle indicating a hitter is swinging up and a negative attack angle indicating that a hitter is swinging down (“Blast Connect | Metrics,” n.d.; “Hand Positions and Hitting,” 2020). Having a more positive attack angle is beneficial for making solid contact, creating an optimal launch angle, and maximizing ball distance (“Blast Connect | Why is Attack Angle important?,” n.d.). Being able to match the path of the bat with the path of the incoming pitch increases the chances of making good contact. With the pitcher throwing the ball from an elevated surface, the path of the incoming pitch is typically a downward angle. Therefore, a positive attack angle gives you a better chance of matching the bat path with the path of the pitch, optimizing contact. Also, attack angle has been shown to be correlated with launch angle ("Hitting Biomechanics," 2022), or the angle at which the ball leaves the bat after contact. Therefore, a positive attack angle can create an optimal launch angle and help you get the ball in the air maximizing ball flight distance. In addition, the optimal attack angle is said to be within the range of 5-15 degrees ("Blast Connect | What should Attack Angle be?," n.d.; RPP, 2018). This is partly due to the fact that the average fastball crosses the plate at -6 degrees and the average curveball crosses the plate at -10 degrees ("Blast Connect | What should Attack Angle be?," n.d.; "Optimizing the Swing," 2015). Also, a study performed by Rockland Peak Performance in 2018, a respected organization in the baseball biomechanics community, found that the highest percentage of Well Hit Balls (balls hit with at least 90% of peak exit velo and a launch angle between 6 and 24 degrees) was between 5 and 15 degrees of attack angle. Therefore, an attack angle that is within the optimal range will give the hitter the best chance to match the bat path to the pitch path of various pitches, optimizing contact. This suggests that the palmar preferred group produced a more optimal attack angle of 8.57 degrees, falling within the optimal range compared to the conventional preferred group attack angle of 4.37 degrees.

Other than the effect of grip, possible alternative explanations for the higher attack angle seen in the palmar preferred group compared to the conventional preferred group regardless of condition could be due to the palmar preferred group being more experienced or more skilled. Although the palmar preferred group does have slightly more experience, the findings from the other performance metrics does not suggest that this group is more skilled than the conventional group, with the palmar preferred group having less bat speed and exit speed compared to the conventional group regardless of condition. Also, the significant decrease in attack angle when the palmar preferred group transitioned from their preferred to non-preferred grip was found to be meaningful (d = 1.24). This further supports the notion that the differences seen in attack angle between groups were more likely due to grip rather than experience or skill.

Wrist Kinematics

Table 9: Summary of Wrist Kinematic Findings

Variables	Definitions
Left Wrist Flex/Ext Angle at Contact	Conventional preferred group: palmar hamate grip created less flexion at contact compared to the conventional grip (-14.36 ± 7.76° vs. -17.77 ± 7.52°, $p < 0.001$, d = 1.40).
Left Wrist Pro/Sup Angle at Contact	Conventional preferred group: palmar hamate grip created more pronation at contact compared to the conventional grip (40.30 ± 11.93° vs 37.28 ± 11.44°, $p < 0.0001$, d = 2.47).
Left Wrist Flex/Ext ROM	Conventional grip: conventional preferred group > palmar preferred group (51.36 ± 13.39° vs. 39.24 ± 9.75°, $p < 0.05$, d = 1.04).
	Conventional preferred group: conventional grip > palmar hamate grip (51.36 ± 13.39° vs. 48.21 ± 13.05°, $p < 0.01$, d = 1.00).
Left Wrist Uln/Rad ROM	Palmar hamate grip: palmar preferred group > conventional preferred group (22.60 ± 5.95° vs. 15.48 ± 7.47°, $p < 0.05$, d = 1.05)
Left Wrist Flex/Ext Angular Velocity at Contact	Palmar preferred group: palmar hamate created less flexion angular velocity compared to the conventional grip (-433.08 ± 248.84°/s vs. -506.50 ± 290.39°/s, $p < 0.05$, d = 1.18).
Left Wrist Flex/Ext Max Angular Velocity	Conventional preferred group: conventional grip created more maximum flexion angular velocity compared to the palmar hamate grip (-840.77 ± 169.38°/s vs. -789.60 ± 167.76°/s, $p < 0.01$, d = 1.02).
	Palmar preferred group: conventional grip created more maximum flexion angular velocity compared to the palmar hamate grip (-741.27 ± 226.97°/s vs. -680.22 ± 226.87°/s, $p < 0.05$, d = 1.13).

The secondary purpose of this study was to analyze the effect of the palmar hamate grip on wrist kinematics in comparison to the conventional grip, accounting for grip preference. The findings indicate that the palmar hamate grip does not have a meaningful effect on wrist kinematics (Table 9).

Left wrist flexion/extension at contact was not affected by grip preference or grip type. The significance found showed that the conventional preferred group had less left wrist flexion at contact using the palmar hamate grip compared to using the conventional grip, resulting in a large effect size (d = 1.40). Although there was a large effect, the difference in wrist angle seen was only about 3 degrees, which is not a meaningful physiological difference. Similarly, left wrist pronation/supination at contact was not affected by grip preference or grip type. The only significance found was between grip types in the conventional preferred group, with the palmar hamate grip producing less supination than the conventional grip, resulting in a large effect size (d = 2.47). However, the difference was not meaningful in terms of physiology, with the change in wrist angle being about 3 degrees.

Left wrist flexion/extension ROM seemed to be affected more by grip preference than grip type. Regardless of grip, the conventional preferred group produced more left wrist flexion/extension ROM compared to the palmar preferred group. The significance difference found between preference groups for the conventional grip had a large effect size (d = 1.04), but with a wrist ROM difference of only 10 degrees, the effect on performance is unclear. Also, regardless of preference, the palmar hamate grip produced less flexion/extension ROM than the conventional grip, with a significant difference found within the conventional preferred group and a large effect size (d = 1.00). However, the difference in wrist ROM of about 3 degrees is not a meaningful physiological change. Left wrist ulnar/radial ROM was also affected more by grip preference than grip type. Regardless of grip, the palmar preferred group produced more left wrist ulnar/radial ROM compared to the conventional preferred group. The significance difference found between preference groups for the palmar hamate grip had a large effect size (d = 1.05), but with a wrist ROM difference of 7 degrees, it is unclear the effect it would have on performance. Although the differences are small, it is interesting to note that regardless of condition, the conventional preferred group produced more left wrist flexion/extension ROM and the palmar preferred group produced more left wrist ulnar/radial ROM. This suggest that the wrist movement that drives the swing could come from different axes depending on preferred grip.

Left wrist flexion/extension angular velocity at contact was not largely affected by either grip preference or grip type. The significance found showed that the palmar preferred group using the palmar hamate grip produced less flexion velocity at contact compared to using the conventional grip, with a large effect size (d = 1.18). Although a large effect was seen, a physiological change of 70 degrees per second, it is unclear how this would affect performance. Left wrist flexion/extension maximum angular velocity seemed to be more affected by grip type than grip preference. Regardless of grip preference, the palmar hamate grip produced less left wrist flexion maximum angular velocity compared to the conventional grip, with the significance differences found having a large effect size of d = 1.02 for the conventional preferred group and d = 1.13 for the palmar preferred group. However, the differences between grip being about 50 degrees per second for the conventional preferred group and about 60 degrees per second for the palmar preferred group, the effect that these differences would have on performance is unclear.

Given that no clear effect of grip on wrist kinematics were found, suggests that other body kinematics could be a possible explanation for the effects seen in attack angle.

Limitations

There were a few limitations in this study that should be noted. First, participants were hitting off a tee, which limited the findings to a controlled setting and may not apply to an in-game environment. Second, the participants level of play was limited to high school and college, therefore the results of this study may not apply to the professional level. However, the participants were competent hitters with on average 12 years of experience and 69 mph bat speed, falling into the higher end of bat speed ranges for high school varsity and collegiate level hitters ("Blast Connect | What should Bat Speed be?," n.d.). Third, there was a limited number of participants who preferred the palmar hamate grip, potentially resulting in some comparisons being underpowered. Finally, the grip order of each participant was the same, swinging with the preferred grip first then the non-preferred grip. The most ideal study design would be a randomized design, however swinging with the non-preferred grip first could affect the way a participant swings with their preferred grip which is a limitation within itself.

Future Studies

Future studies should focus on improving the limitations mentioned such as including higher level/more skilled participants, having more participants that prefer the palmar hamate grip, and implementing a more game-like environment. Because the palmar hamate grip is considered a more advanced grip, it was difficult to find participants within the skill level of this study, being mostly high-school level players with a few college level players. Future studies should include higher level participants (D1 College/Professional) which would make it easier to find participants who prefer the palmar hamate grip and would also create more homogeneity across preference groups. Also due to the findings of this study indicating that grip effected attack angle, and the fact that attack angle is affected by height of the pitch and the downward angle of the ball crossing the plate, future studies should implement a more game-like environment (pitching machine, live pitching, etc.) to account for these factors. Additionally, given the results of the palmar hamate grip effecting attack angle, it would be logical to examine the potential effects on other bat orientation metrics such as horizontal attack angle, vertical bat angle, and horizontal bat angle. Also, given that the significant changes in attack angle suggested a more long-term effect rather than acute, future research should perform a longitudinal study that changes grip from conventional to palmar hamate tracking the effect of grip over time. This could be important from a training perspective, potentially answering the question of how long or how much practice is needed with the palmar hamate grip to see an effect. However, a longitudinal study practically would be difficult to accomplish. Also, with no meaningful effect of grip on wrist kinematics found in this study, future research should focus on examining other joint kinematics such as the elbow or shoulder, which also play a crucial role in the swing. Lastly, with practically all the research related to attack angle and performance coming from non-published sources, there needs to be more research on understanding the effect of attack angle on performance.

Conclusion

In conclusion, the findings of this study indicate that the palmar hamate grip influences attack angle, but not bat speed, exit speed, or smash factor. Also, the palmar hamate grip had no clear effect on wrist kinematics, suggesting the change in attack angle seen could potentially be due to other body kinematics. Given that the changes in attack angle acutely were modest, the findings suggest that long term use of the palmar hamate grip could potentially increase attack angle. Therefore, a hitter would have to train with the palmar hamate grip for a long period of time to potentially see an effect.

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APPENDIX A: IRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
Willis Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: Robert Langston
CC: Zachary Domire
Steven Philpott
Date: 6/28/2024
Re: UMCIRB 24-001009
The Effects of Bat Grip Type on Baseball Hitting Performance

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 6/28/2024. The research study is eligible for review under expedited category # 4,6,7. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

The approval includes the following items:

Name	Description
Assent Form Version 1.docx	Consent Forms
Informed-Consent-Document-No-More-Than-Minimal-Risk-Version-1.doc	Consent Forms
Parental-Permission-Consent-Form-Version-1.docx	Consent Forms
Text Script.docx	Recruitment Documents/Scripts
Thesis Proposal	Study Protocol or Grant Application
Thesis Survey.docx	Surveys and Questionnaires

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

APPENDIX B: CONSENT FORMS & SURVEY

***Title of Study**: The Effects of Bat Grip Type on Baseball Hitting Performance*

ECU

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: The Effects of Bat Grip Type on Baseball Hitting Performance

Principal Investigator: Robert Langston (Person in Charge of this Study)
Institution, Department or Division: East Carolina University, Department of Kinesiology
Address: 238 Rivers West Greenville, NC
Telephone #: (252) 328-4237
Study Coordinator: Steven Philpott

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?

The purpose of this research is to analyze the effects of grip type on hitting performance. You are being invited to take part in this research because you are a healthy high school or college baseball player. The decision to take part in this research is yours to make. By doing this research, we hope to learn if different ways to grip a bat can affect performance?

If you volunteer to take part in this research, you will be one of about 30 people to do so.

Are there reasons I should not take part in this research?

I understand I should not volunteer for this study if I am, under 18 years of age, or if I have had a significant prior wrist or hand injury.

What other choices do I have if I do not take part in this research?

You can choose not to participate.

Where is the research going to take place and how long will it last?

The research will be conducted at Ward Sports Medicine Building located on the athletic campus at East Carolina University. You will need to come to Ward Sports Medicine Building, room 332 one time during the study. The total amount of time you will be asked to volunteer for this study is 1 hour for 1 day.

What will I be asked to do?

You will be asked to do the following:

- You will fill out a survey used for obtaining participant characteristics.
- Your height and weight will be measured. This is to create an accurate model of your body needed for analysis.

- Reflective markers will be placed on both elbows, forearms, wrists, and hands. This is needed for the Qualisys 3D motion capture system to measure kinematics (joint angle, joint velocity, joint acceleration) of the wrist.
- You will take as many warm up swings needed off a tee with your natural or preferred grip. These swings will not be considered for the analysis.
- You will take 5 maximal effort swings off a tee with the natural or preferred grip that will be collected for analysis.
- You will be asked to switch to the nonpreferred grip and will be allowed to take as many warm up swings needed off a tee. These swings will not be considered for the analysis.
- You will take 5 maximal effort swings off a tee with the nonpreferred grip that will be collected for analysis.
- Photographs may be taken but only with your consent. Photographs may be used for a presentation or research paper. The photographs will not be identifiable, face will be either cropped or blurred out. We as the researchers will have access to these photos along with select ECU faculty members. The photographs will be kept for the duration of the study and then will be deleted from the device they are kept on.

  Participant agrees to be photographed ___Yes ___ No

What might I experience if I take part in the research?
We don't know of any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. We don't know if you will benefit from taking part in this study. There may not be any personal benefit to you but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
We will not be able to pay you for the time you volunteer while being in this study.

Will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

How will you keep the information you collect about me secure? How long will you keep it?
Data will be coded in encrypted spreadsheets, housed on a password-protected, secure computer in Ward Sports Medicine Building Biomechanics Lab room 332. Your name will not be published, revealed in papers, abstracts, or any other form. Should there be any paper copies with your data on it, they will be stored in a locked file cabinet in Ward Sports Medicine Building Biomechanics Lab until at least three years after the study has concluded. The papers will then be destroyed.

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-367-2573 (days, between 10 am – 4 pm).

If you have questions about your rights as someone taking part in research, you may call the ECU University and Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914.

Is there anything else I should know?

The following research results will be provided to you:

- Bat speed
- Attack angle
- Exit speed

These results will be shared with you after completion of the research study upon your request.

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

Parental Permission to Allow Your Child to Take Part in Research
Information to consider before allowing your child to take part in research that has no more than minimal risk.

Title of Research Study: The Effects of Bat Grip Type on Baseball Hitting Performance

Principal Investigator: Robert Langston (Person in Charge of this Study)
Institution, Department or Division: East Carolina University, Department of Kinesiology
Address: 238 Rivers West Greenville, NC
Telephone #: (252) 328-4237
Study Coordinator: Steven Philpott

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why is my child being invited to take part in this research?
The purpose of this research is to analyze the effects of grip type on hitting performance. Your child is being invited to take part in this research because they are a healthy high school baseball player. The decision for your child to take part in this research will also depend upon whether your child wants to participate. By doing this research, we hope to learn if different ways to grip a bat can affect performance?

If you and your child agree for him/her to volunteer for this research, your child will be one of about 30 people to do so.

Are there reasons my child should not take part in this research?
You should not agree for your child to take part in this study if he/she is unable or uncomfortable, or he/she had a significant prior wrist or hand injury.

What other choices do I have if my child does not take part in this research?
Your child can choose not to participate.

Where is the research going to take place and how long will it last?
The research will be conducted at Ward Sports Medicine Building located on the athletic campus at East Carolina University. You will need to come to Ward Sports Medicine Building, room 332 one time during the study. The total amount of time your child will be asked to volunteer for this study is 1 hour for 1 day. There will be space available for you to wait for your child during the research.

What will my child be asked to do?
Your child will be asked to do the following:

- Your child will fill out a survey used for obtaining participant characteristics.
- Your child's height and weight will be measured. This is to create an accurate model of your child's body needed for analysis.

- Reflective markers will be placed on your child's elbows, forearms, wrists, and hands. This is needed for the Qualisys 3D motion capture system to measure kinematics (joint angle, joint velocity, joint acceleration) of the wrist.
- Your child will take as many warm up swings needed off a tee with their natural or preferred grip. These swings will not be considered for the analysis.
- Your child will take 5 maximal effort swings off a tee with the natural or preferred grip that will be collected for analysis.
- Your child will be asked to switch to the nonpreferred grip and will be allowed to take as many warm up swings needed off a tee. These swings will not be considered for the analysis.
- Your child will take 5 maximal effort swings off a tee with the nonpreferred grip that will be collected for analysis.
- Photographs of your child may be taken but only with the consent of you and your child. Photographs may be used for a presentation or research paper. The photographs will not be identifiable, face will be either cropped or blurred out. We as the researchers will have access to these photos along with select ECU faculty members. The photographs will be kept for the duration of the study and then will be deleted from the device they are kept on.

  Parent agrees for child to be photographed ___Yes ___ No

What might my child experience if they take part in the research?
We don't know of any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. We don't know if your child will benefit from taking part in this study. There may not be any personal benefit to your child but the information gained by doing this research may help others in the future.

Will my child be paid for taking part in this research?
We will not be able to pay you or your child for the time you volunteer while being in this study.

Will it cost me anything for my child to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that your child took part in this research and may see information about your child that is normally kept private. With your permission, these people may use your child's private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your child's welfare during this research and may need to see research records that identify your child.

How will you keep the information you collect about my child secure? How long will you keep it?
Data will be coded in encrypted spreadsheets, housed on a password-protected, secure computer in Ward Sports Medicine Building Biomechanics Lab room 332. Your child's name will not be published, revealed in papers, abstracts, or any other form. Should there be any paper copies with your child's data on it, they will be stored in a locked file cabinet in Ward Sports Medicine Building Biomechanics Lab until at least three years after the study has concluded. The papers will then be destroyed.

What if my child decides he/she doesn't want to continue in this research?
Your child can stop at any time after it has already started. There will be no consequences if he/she stops and he/she will not be criticized. Your child will not lose any benefits that he/she would normally receive.

Who should I contact if I or my child have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-367-2573 (days, between 10 am – 4 pm).

If you have questions about your rights as someone taking part in research, you may call the ECU University and Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914.

Is there anything else I or my child should know?

The following research results of your child will be provided to you:

- Bat speed
- Attack angle
- Exit speed

These results will be shared with you after completion of the research study upon your request.

I have decided my child can take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that my child can stop taking part in this study at any time.
- By signing this informed consent form, my child is not giving up any of his/her rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Parent/Guardian's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

Assent Form
Things You Should Know Before You Agree to Take Part in this Research

UMCIRB Study # 24-001009

Title of Study: The Effects of Bat Grip Type on Baseball Hitting Performance

Person in charge of study: Robert Langston
Where they work: Graduate Student at East Carolina University

Study contact phone number: (252) 367-2573
Study contact E-mail Address: langstonr18@students.ecu.edu

People at ECU study ways to make people's lives better. These studies are called research. This research is trying to find out if different ways to grip a bat can affect hitting performance?

Your parent(s) needs to give permission for you to be in this research. You do not have to be in this research if you don't want to, even if your parent(s) has already given permission.

You may stop being in the study at any time. If you decide to stop, no one will be angry or upset with you

Why are we doing this research study?
The reason for doing this research is to analyze the effects of grip type on hitting performance.

Why are you being asked to be in this research study?
We are asking you to take part in this research because you are a healthy high school baseball player.

How many people will take part in this study?
If you decide to be in this research, you will be one of about 30 people taking part in it.

What will happen during this study?
You will be asked to do the following:

- You will fill out a survey used to obtain participant characteristics.
- Your height and weight will be measured. This is to create an accurate model of your body needed for analysis.
- Reflective markers will be placed on both elbows, forearms, wrists, and hands. This is needed for the Qualisys 3D motion capture system to measure kinematics (joint angle, joint velocity, joint acceleration) of the wrist.
- You will take as many warm up swings needed off a tee with your natural or preferred grip. These swings will not be considered for the analysis.
- You will take 5 maximal effort swings off a tee with the natural or preferred grip that will be collected for analysis.
- You will be asked to switch to the nonpreferred grip and will be allowed to take as many warm up swings needed off a tee. These swings will not be considered for the analysis.

- You will take 5 maximal effort swings off a tee with the nonpreferred grip that will be collected for analysis.
- Photographs may be taken but only with your consent. Photographs may be used for a presentation or research paper. The photographs will not be identifiable, face will be either cropped or blurred out. We as the researchers will have access to these photos along with select ECU faculty members. The photographs will be kept for the duration of the study and then will be deleted from the device they are kept on.

  Participant agrees to be photographed ___Yes ___No

This study will take place at Ward Sports Medicine Building room 332 located on the athletic campus at East Carolina University and will last 1 hour.

Who will be told the things we learn about you in this study?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

What are the good things that might happen?
Sometimes good things happen to people who take part in research. These are called "benefits." There is little chance you will benefit from being in this research. The benefits to you of being in this study may be an increase in hitting performance.

What are the bad things that might happen?
Sometimes things we may not like happen to people in research studies. These things may even make them feel bad. These are called "risks." You may or may not have these things happen to you. Things may also happen that the researchers do not know about right now. You should report any problems to your parents and to the researcher. This research study has no known risks.

Will you get any money or gifts for being in this research study?
You will not receive any money or gifts for being in this research study.

Who should you ask if you have any questions?
If you have questions about the research, you should ask the people listed on the first page of this form. If you have other questions about your rights while you are in this research study you may call the Institutional Review Board at 252-744-2914.

If you decide to take part in this research, you should sign your name below. It means that you agree to take part in this research study.

____ ______________

Sign your name here if you want to be in the study Date

____
Print your name here if you want to be in the study

____ ________________
Signature of Person Obtaining Assent Date

____
Printed Name of Person Obtaining Assent

Thesis Survey

Age (years)

____

Year in School (Ex: Freshman)

____

Years of Experience

____

Highest level of competition (Ex: junior varsity, varsity, junior college, DI, etc.)

____

What side do you bat?

- ○ Right-handed
- ○ Left-handed

What is your preferred grip?

- ○ Conventional (normal)
- ○ Palmar Hamate (pinky off)

How long have you been using this grip?

____

Have you ever experienced an injury that caused you to miss play in the past 12 months? (Please specify what & when)

____

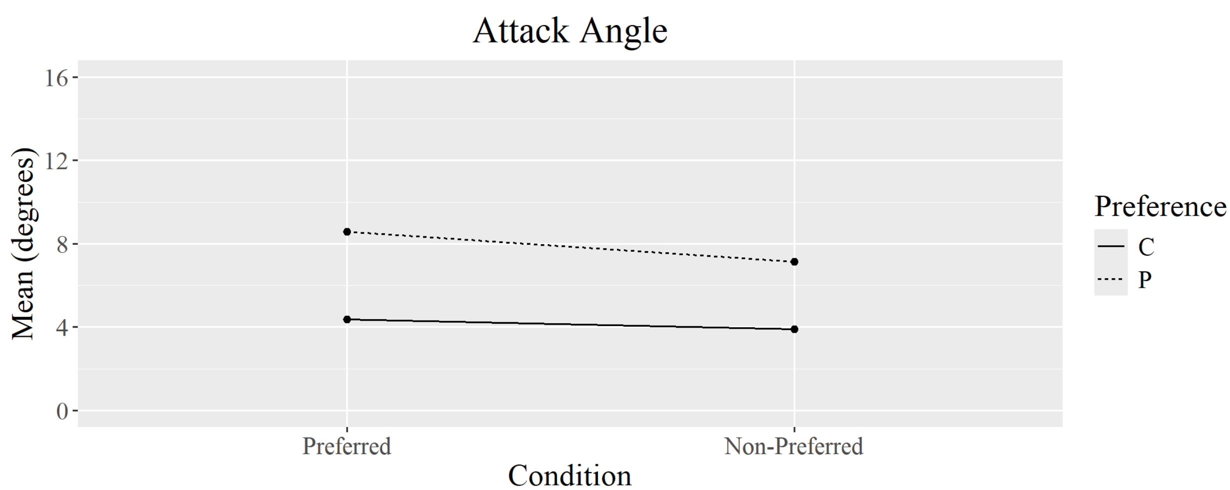
Have you experienced an injury that required surgery in the past 12 months? (Please specify what & when)

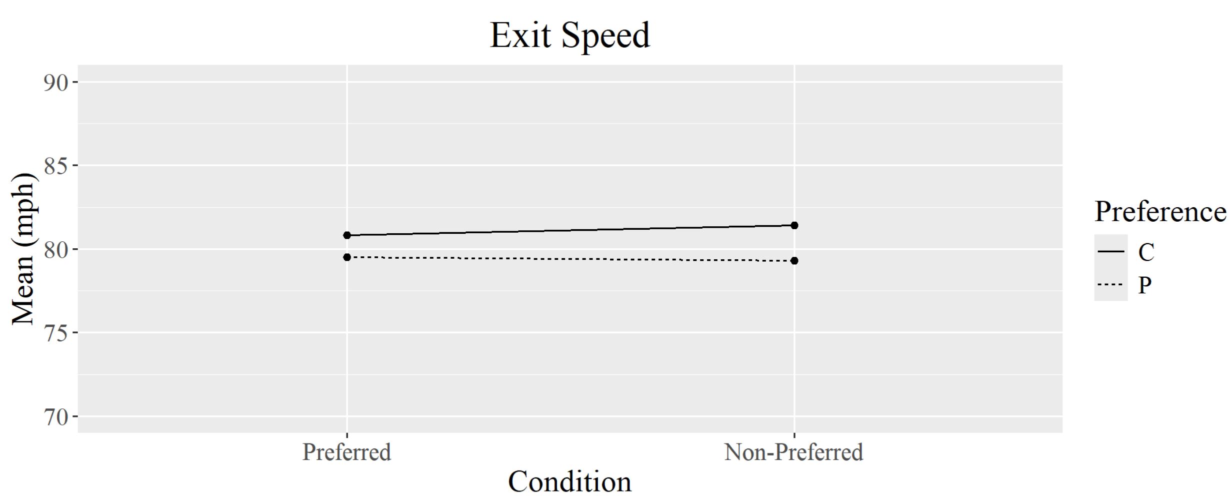
____

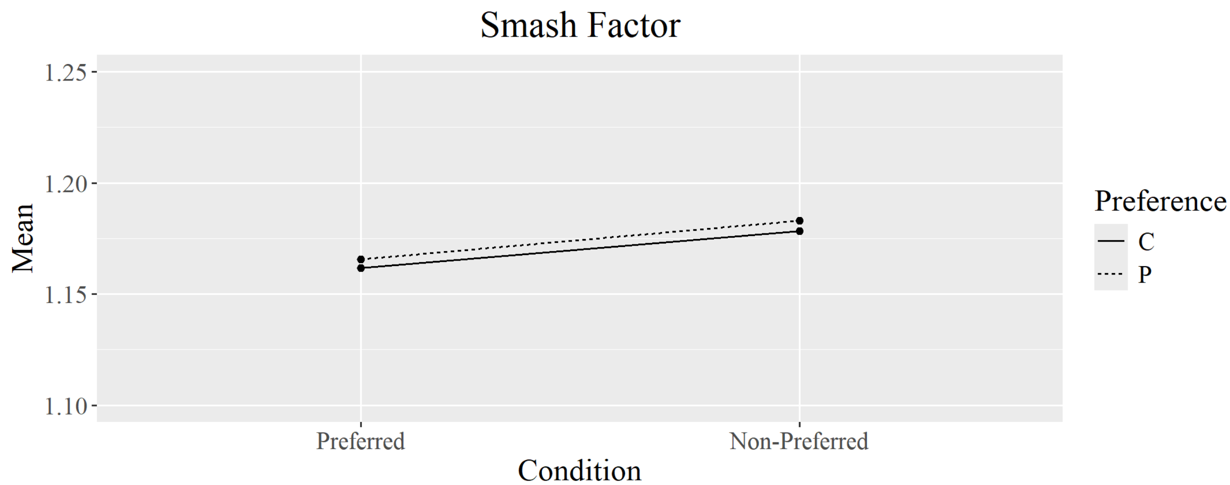
Emergency Contact Information (name & phone)

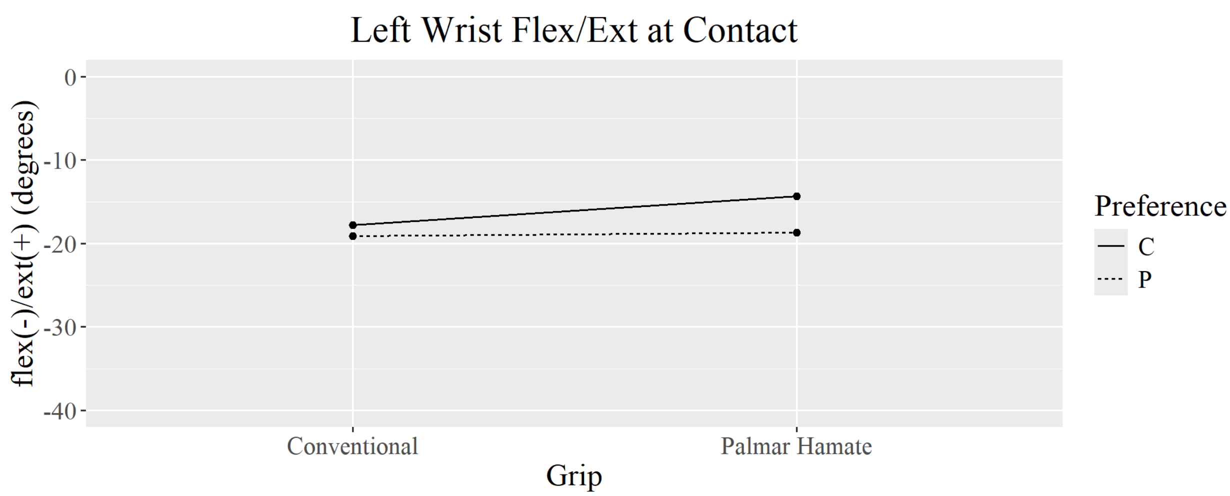
____

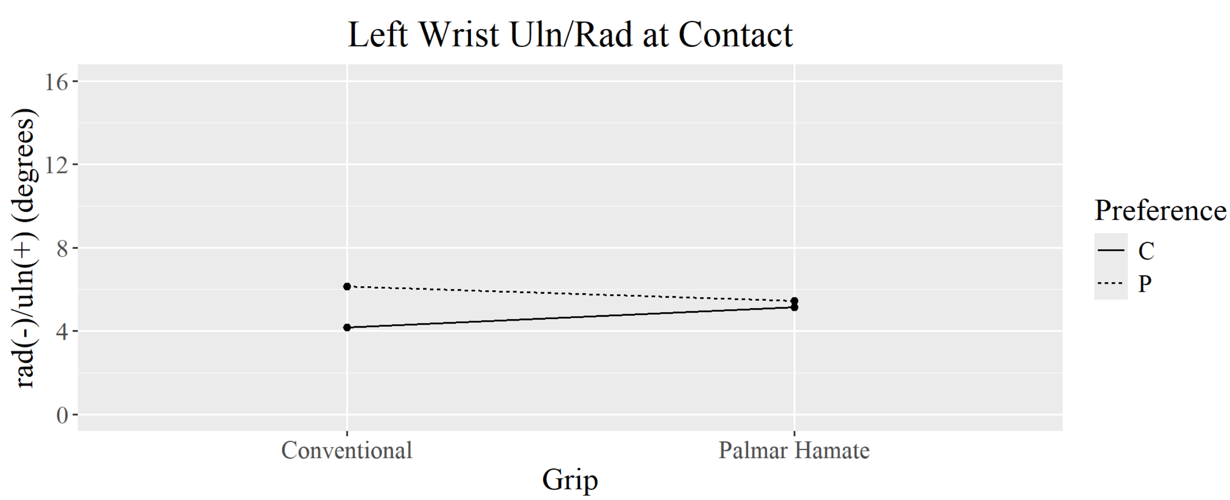
APPENDIX C: GRAPHS OF DEPENDENT VARIABLES

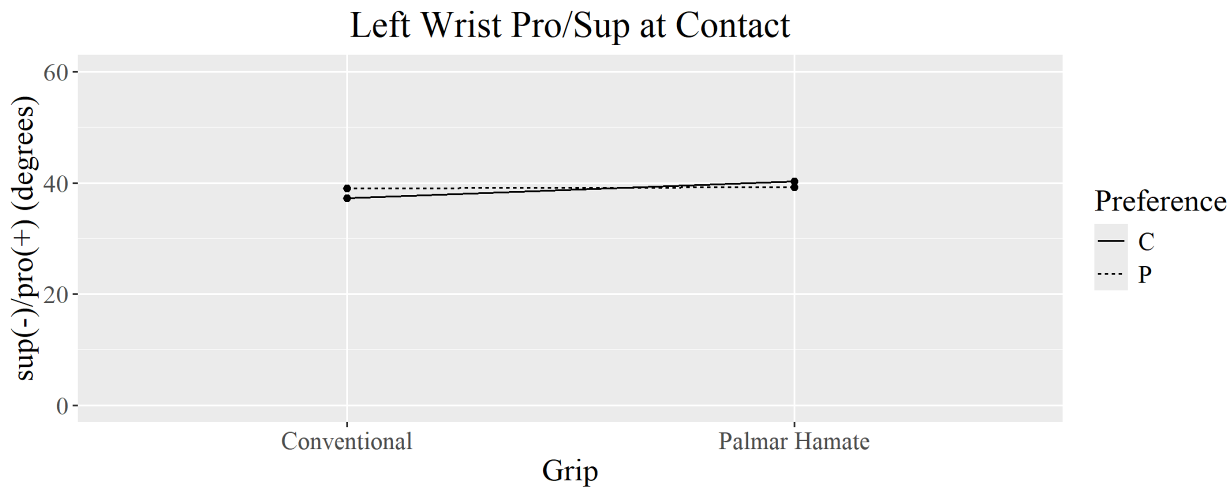


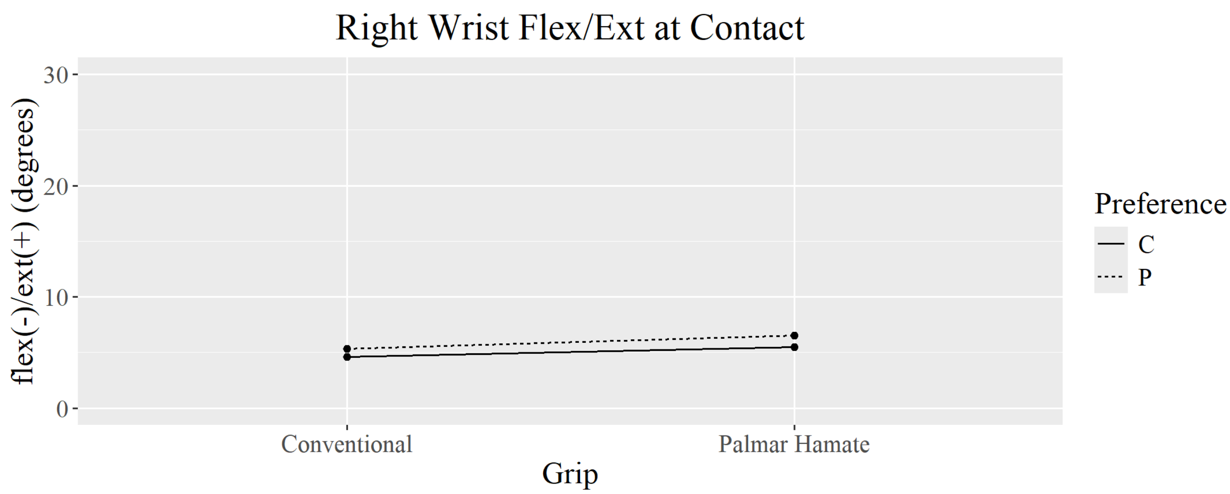


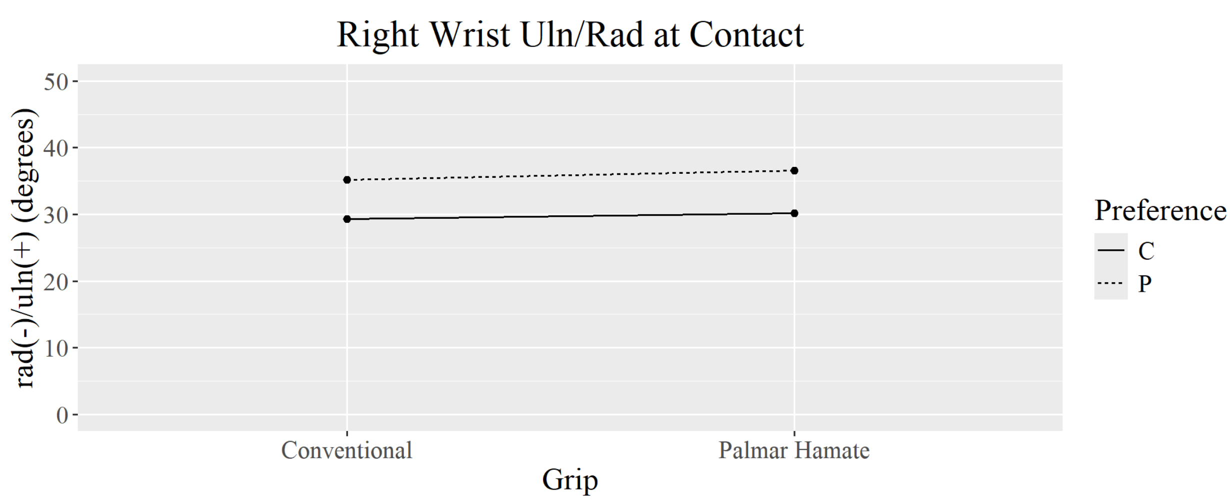

Smash Factor
Mean
1.25
1.20
1.15
1.10
Preferred
Non-Preferred
Condition
Preference
C
P

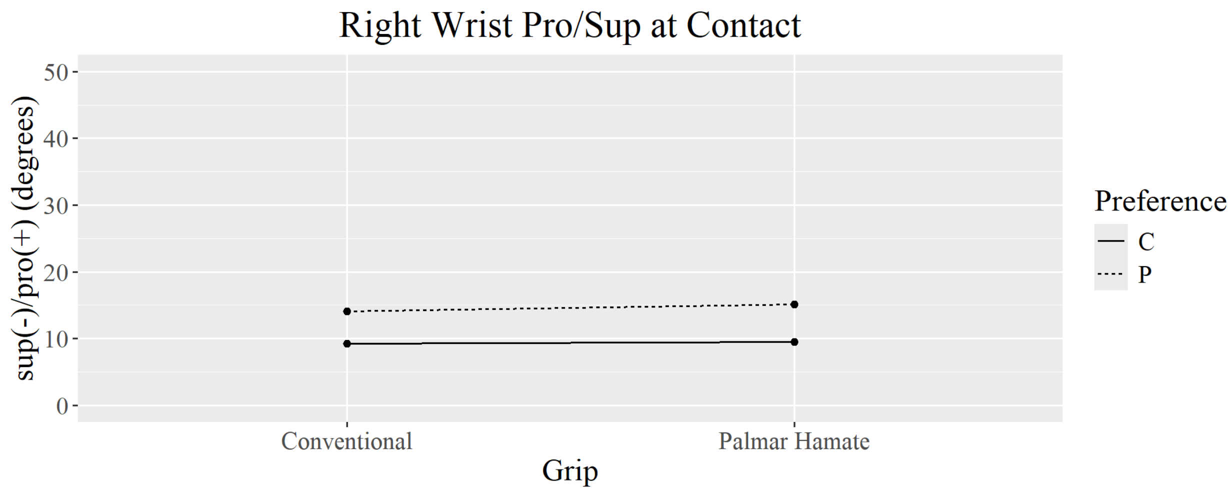

Left Wrist Flex/Ext at Contact
flex(-)/ext(+) (degrees)
0
-10
-20
-30
-40
Conventional
Palmar Hamate
Grip
Preference
C
P

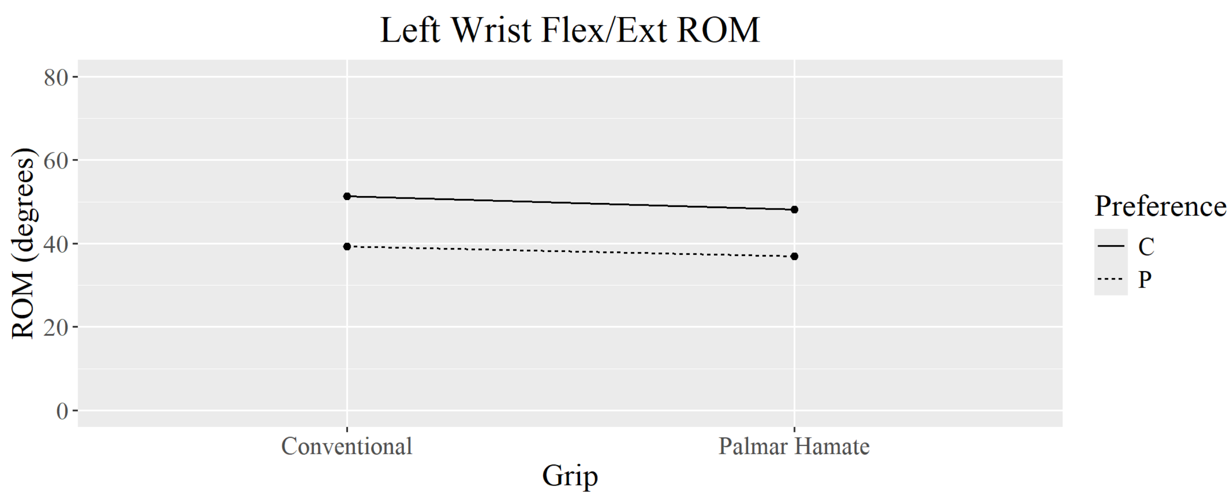

Left Wrist Uln/Rad at Contact
rad(-)/uln(+) (degrees)
16
12
8
4
0
Conventional
Palmar Hamate
Grip
Preference
C
P

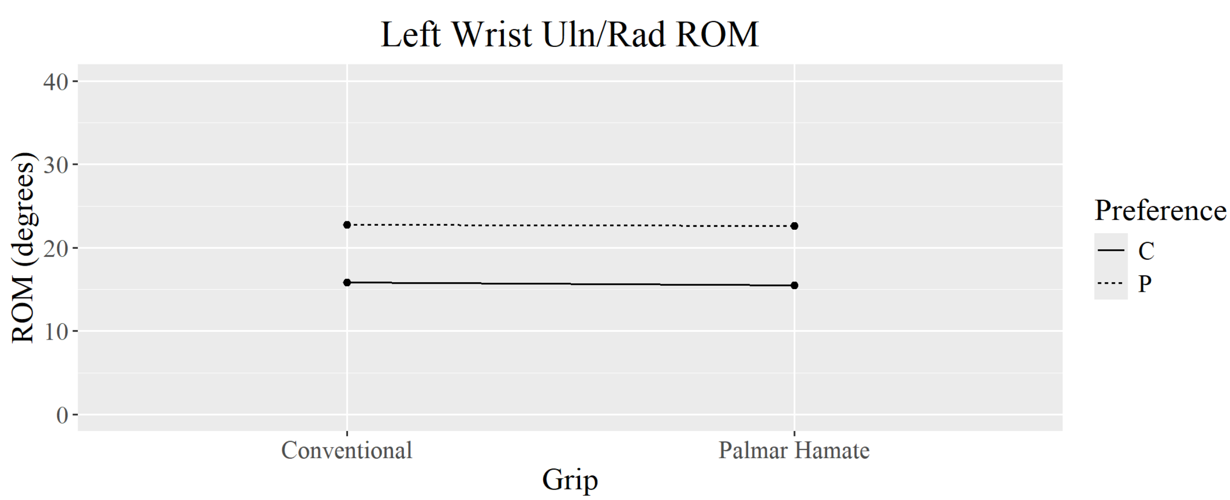

Left Wrist Pro/Sup at Contact
sup(-)/pro(+) (degrees)
60
40
20
0
Conventional
Palmar Hamate
Grip
Preference
C
P

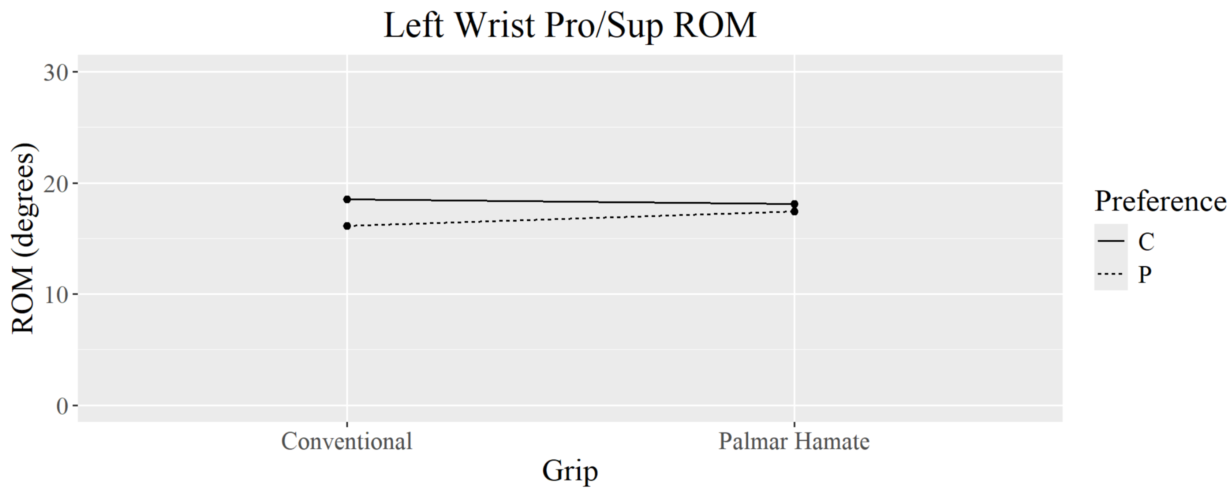

Right Wrist Flex/Ext at Contact
flex(-)/ext(+) (degrees)
30
20
10
0
Conventional
Palmar Hamate
Grip
Preference
C
P

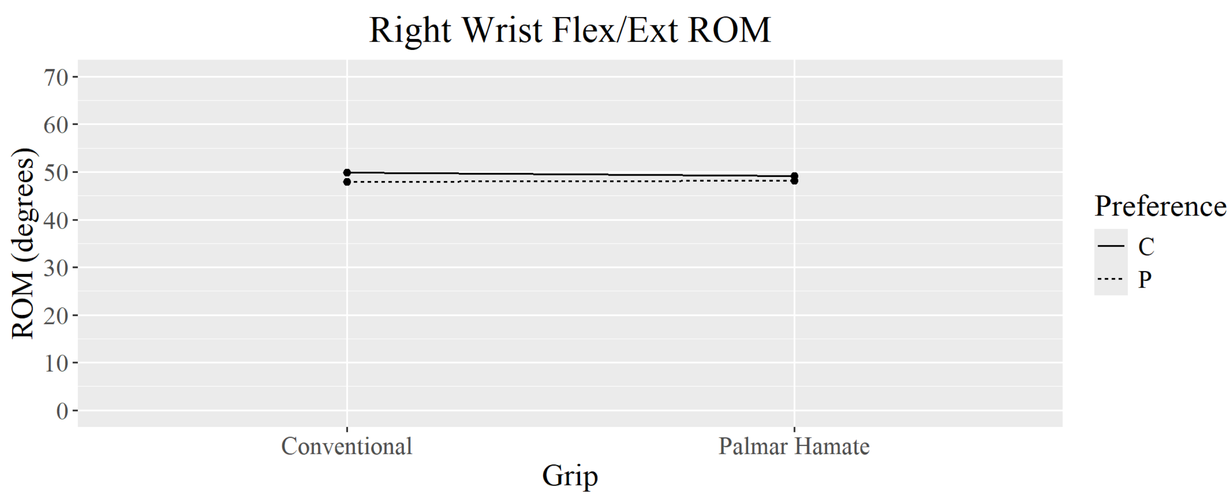

Right Wrist Uln/Rad at Contact
rad(-)/uln(+) (degrees)
50
40
30
20
10
0
Conventional
Palmar Hamate
Grip
Preference
C
P

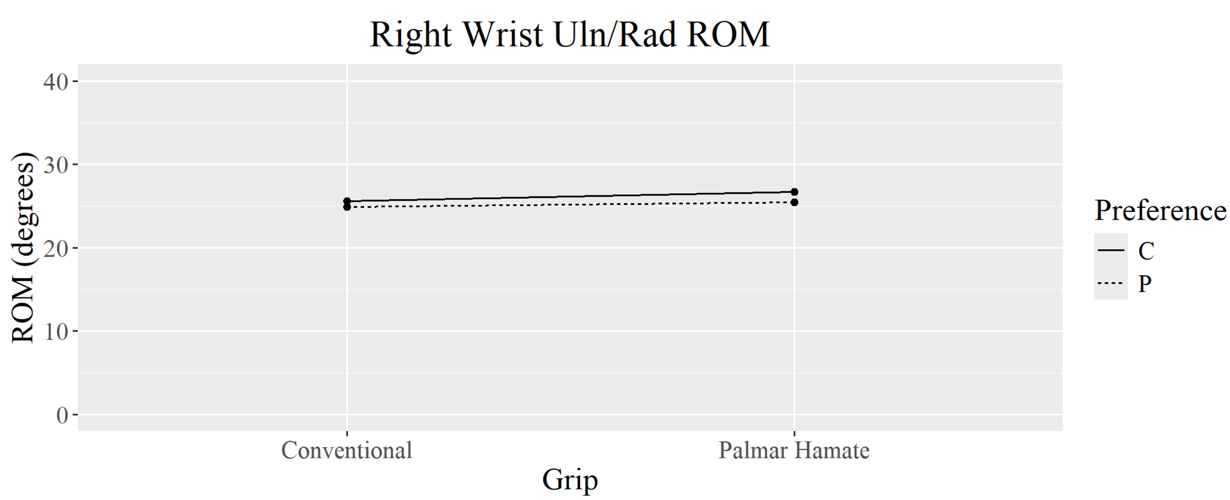

Right Wrist Pro/Sup at Contact
sup(-)/pro(+) (degrees)
50
40
30
20
10
0
Conventional
Palmar Hamate
Grip
Preference
C
P

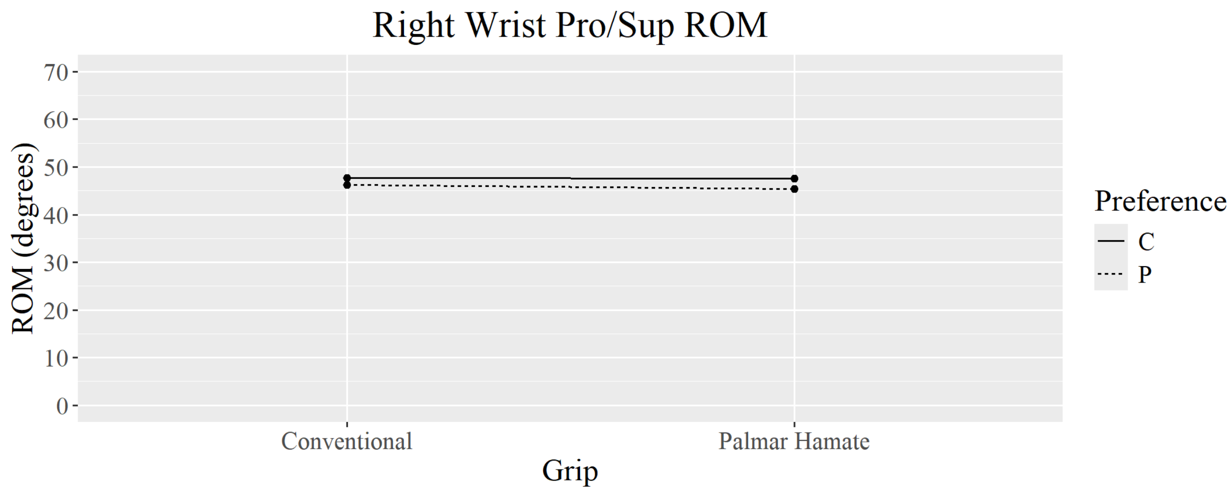

Left Wrist Flex/Ext ROM
ROM (degrees)
80
60
40
20
0
Conventional
Palmar Hamate
Grip
Preference
C
P

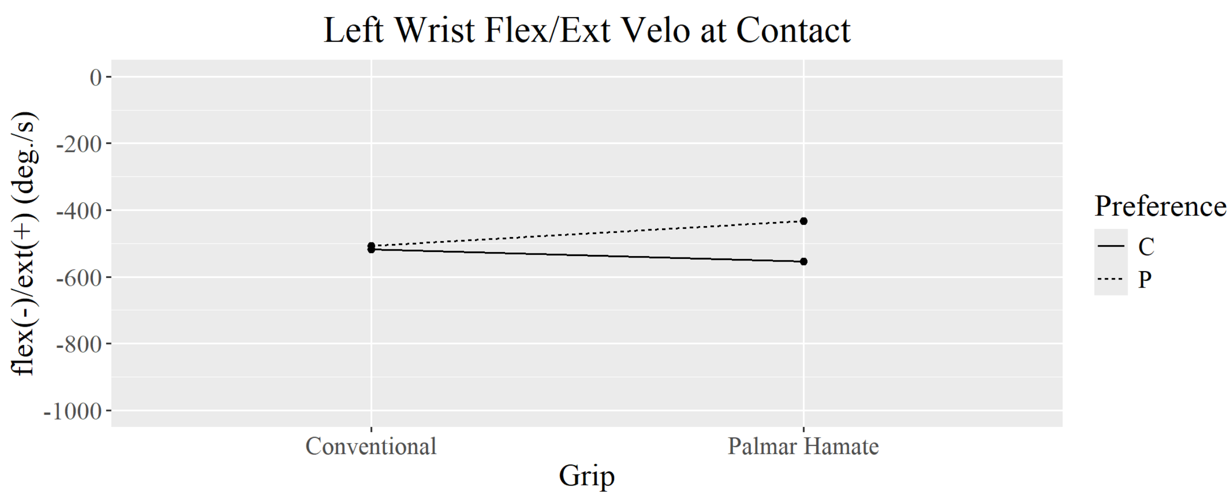

Left Wrist Uln/Rad ROM
ROM (degrees)
40
30
20
10
0
Conventional
Palmar Hamate
Grip
Preference
C
P

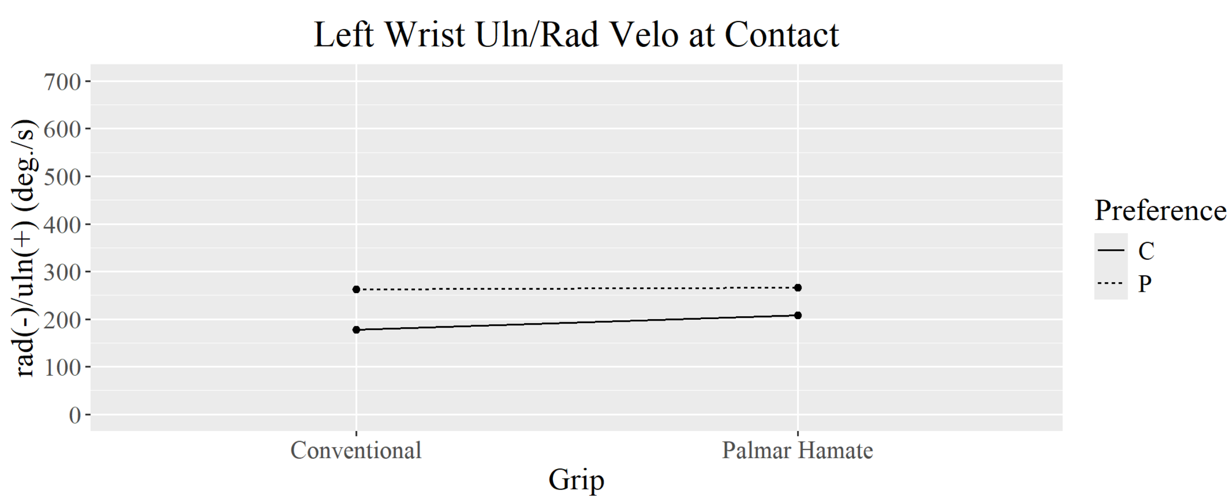

Left Wrist Pro/Sup ROM
ROM (degrees)
0
10
20
30
Conventional
Palmar Hamate
Grip
Preference
C
P

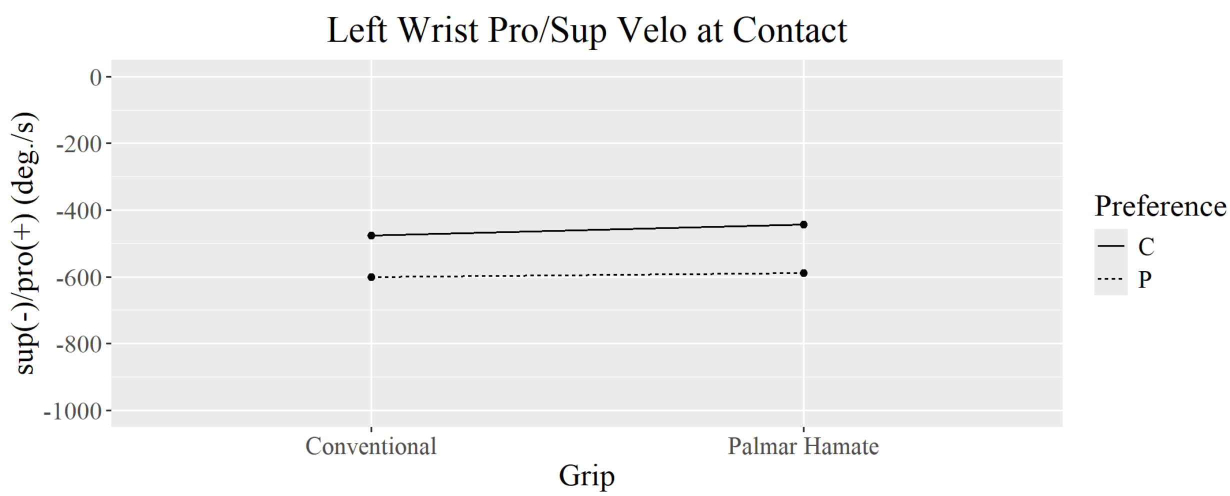

Right Wrist Flex/Ext ROM
ROM (degrees)
0
10
20
30
40
50
60
70
Conventional
Palmar Hamate
Grip
Preference
C
P

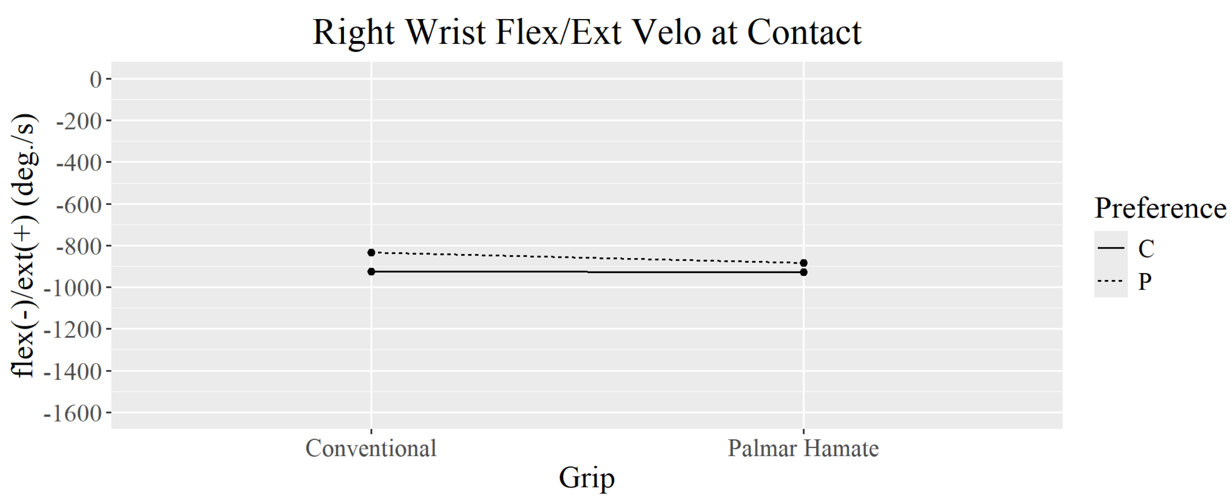

Right Wrist Uln/Rad ROM
ROM (degrees)
0
10
20
30
40
Conventional
Palmar Hamate
Grip
Preference
C
P

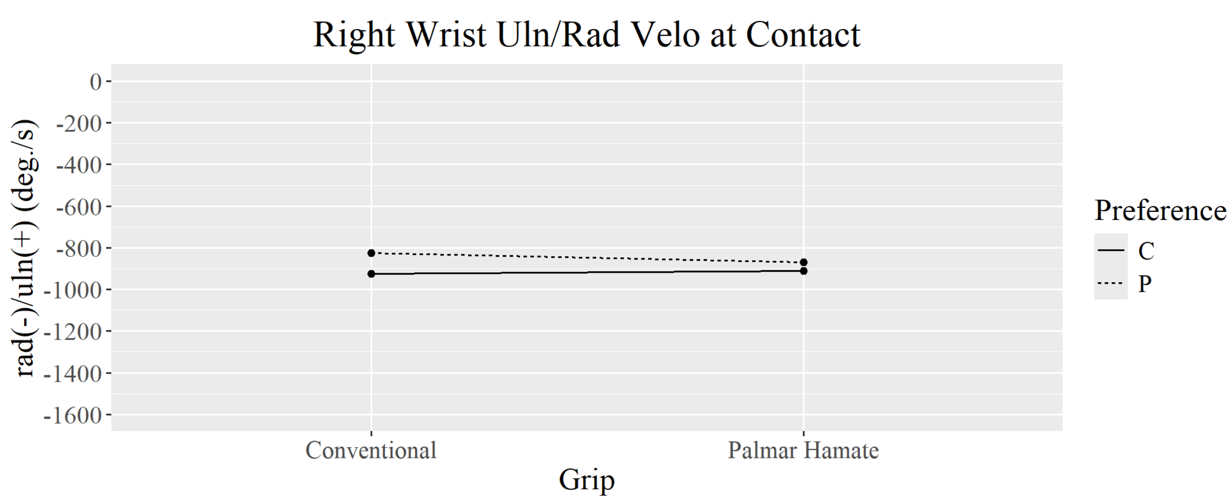

Right Wrist Pro/Sup ROM
ROM (degrees)
70
60
50
40
30
20
10
0
Conventional
Palmar Hamate
Grip
Preference
C
P

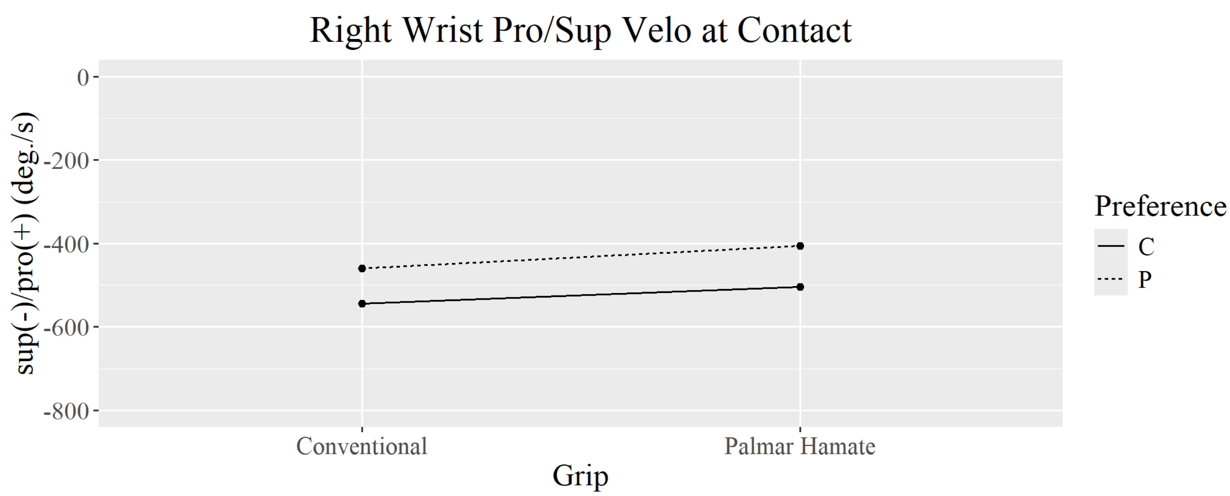

Left Wrist Flex/Ext Velo at Contact
flex(-)/ext(+) (deg./s)
0
-200
-400
-600
-800
-1000
Conventional
Palmar Hamate
Grip
Preference
C
P

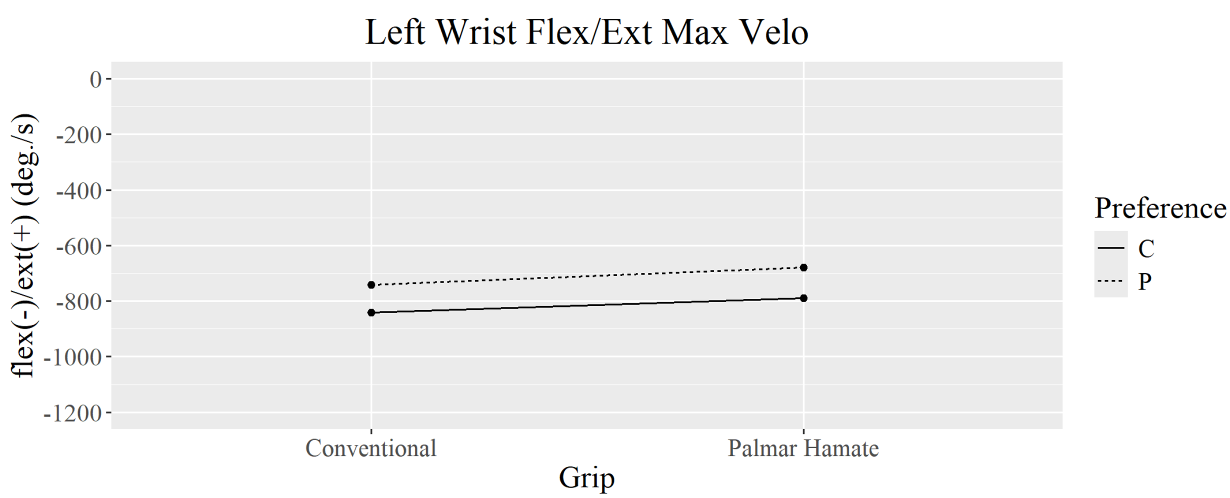

Left Wrist Uln/Rad Velo at Contact
rad(-)/uln(+) (deg./s)
700
600
500
400
300
200
100
0
Conventional
Palmar Hamate
Grip
Preference
C
P

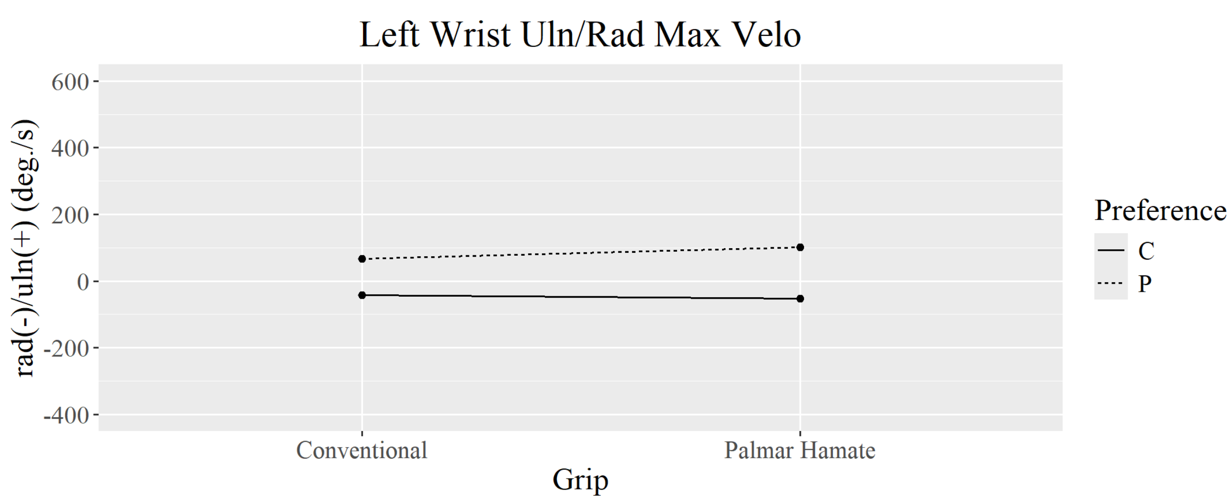

Left Wrist Pro/Sup Velo at Contact
sup(-)/pro(+) (deg./s)
0
-200
-400
-600
-800
-1000
Conventional
Palmar Hamate
Grip
Preference
C
P

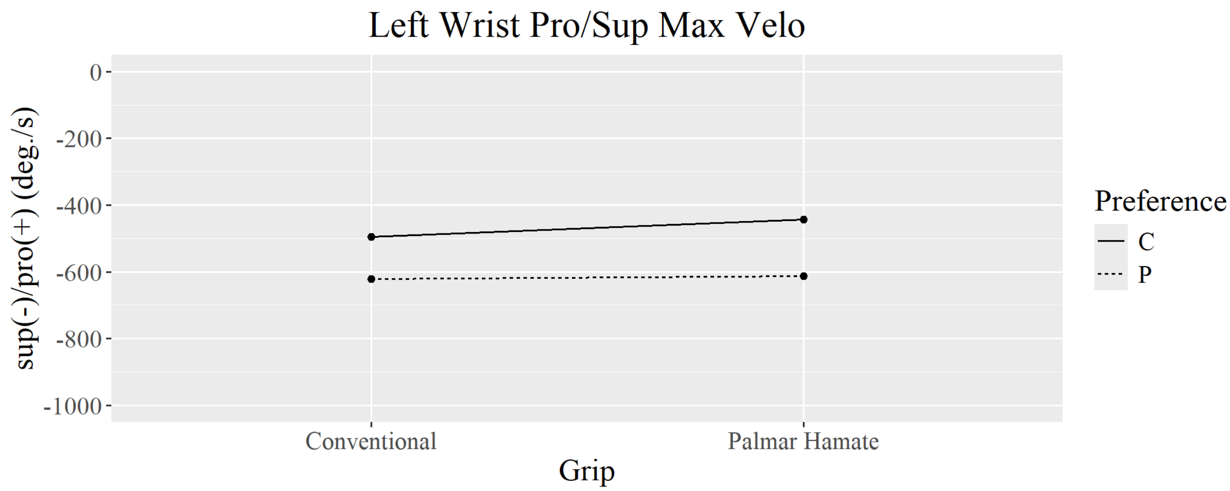

Right Wrist Flex/Ext Velo at Contact
flex(-)/ext(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Conventional
Palmar Hamate
Grip
Preference
C
P

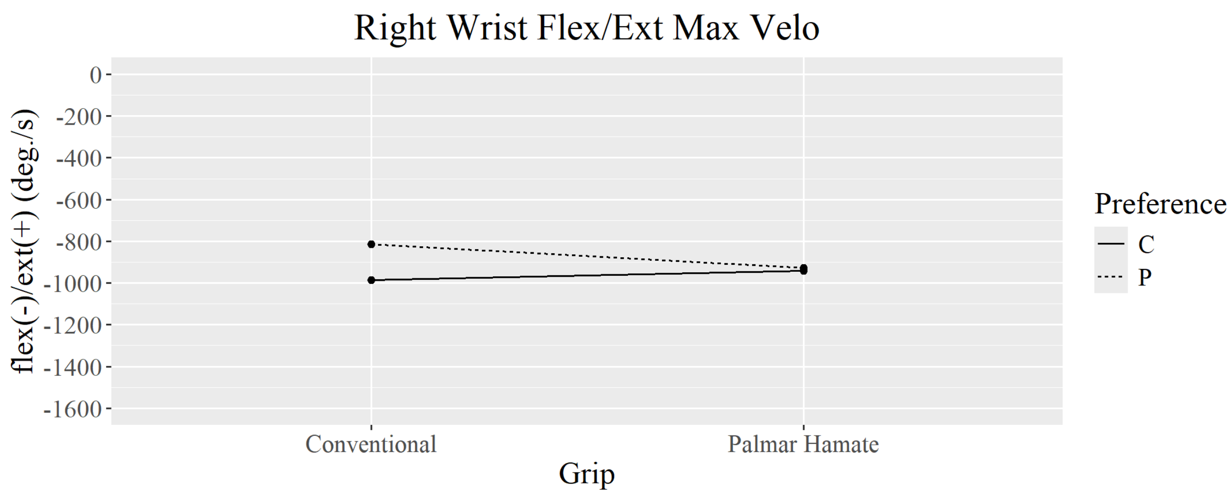

Right Wrist Uln/Rad Velo at Contact
rad(-)/uln(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Conventional
Palmar Hamate
Grip
Preference
C
P

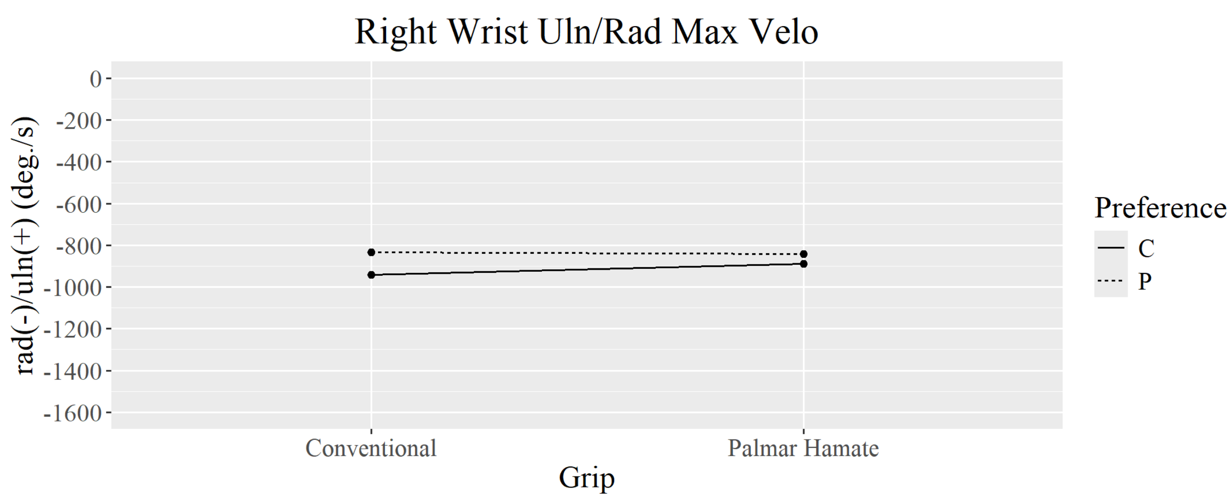

Right Wrist Pro/Sup Velo at Contact
sup(-)/pro(+) (deg./s)
0
-200
-400
-600
-800
Conventional
Palmar Hamate
Grip
Preference
C
P

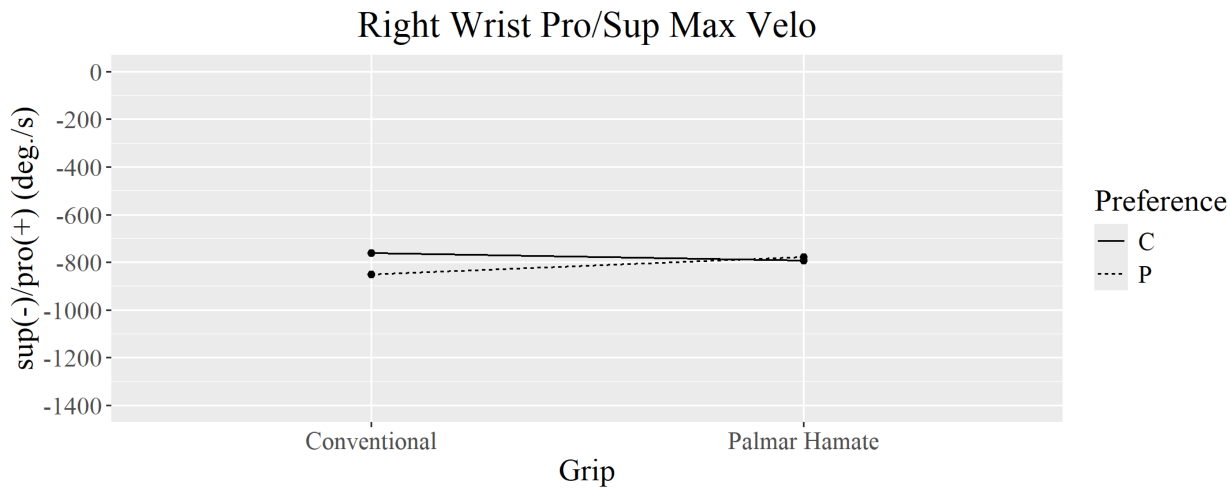

Left Wrist Flex/Ext Max Velo
flex(-)/ext(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
Conventional
Palmar Hamate
Grip
Preference
C
P


Left Wrist Uln/Rad Max Velo
rad(-)/uln(+) (deg./s)
600
400
200
0
-200
-400
Conventional
Palmar Hamate
Grip
Preference
C
P


Left Wrist Pro/Sup Max Velo
sup(-)/pro(+) (deg./s)
0
-200
-400
-600
-800
-1000
Conventional
Palmar Hamate
Grip
Preference
C
P


Right Wrist Flex/Ext Max Velo
flex(-)/ext(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Conventional
Palmar Hamate
Grip
Preference
C
P


Right Wrist Uln/Rad Max Velo
rad(-)/uln(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Conventional
Palmar Hamate
Grip
Preference
C
P


Right Wrist Pro/Sup Max Velo
sup(-)/pro(+) (deg./s)
0
-200
-400
-600
-800
-1000
-1200
-1400
Conventional
Palmar Hamate
Grip
Preference
C
P