Pressures Exerted on the Hook of the Hamate in Collegiate Baseball Players

A Comparison of Grips, With Emphasis on Fracture Prevention

Mikhail Alexeev,*[†] MD, Steven M. Kane,[†] MD, and Gary M. Lourie,[‡] MD
Investigation performed at Wellstar Atlanta Medical Center, Atlanta, Georgia, USA

Background: Variations in batting technique may put baseball players at increased risk of hook of the hamate fractures. A better comprehension of the mechanism of such fractures is needed.

Purpose/Hypothesis: The purpose of the study was to compare 2 different grip types to quantify the pressures exerted on the hook of the hamate during batting. It was hypothesized that when compared with the conventional batting style, players holding the knob of the bat in the palm of the hand (termed the "palmar hamate grip") would have higher pressures exerted on the hook of the hamate.

Study Design: Controlled laboratory study.

Methods: Athletes were recruited for participation on a volunteer basis from the rosters of 2 National Collegiate Athletic Association Division I baseball teams and were divided into 2 groups based on their usual grip type. A force sensor system was applied to the nondominant hand of each participating player, with the central portion of the sensing mechanism placed on the batting glove directly over the hook of the hamate. All players used the same batting glove, which transmitted data from the sensor to a laptop computer. Measurements were collected on consecutive hits at a standardized distance using a ball machine at 70 mph.

Results: Nine collegiate baseball players underwent testing (5 players exclusively used the conventional grip, 3 players exclusively used the palmar hamate grip, and 1 player naturally alternated between the 2 grip types). The palmar hamate grip demonstrated a 366% increase in pressure exerted on the sensor overlying the hook of the hamate when compared with the conventional batting grip (536.42 kPa [95% confidence interval, 419.39-653.44 kPa] vs 115.84 kPa [95% confidence interval, 96.97-135.10 kPa]). The player who used both grips demonstrated significantly higher maximum pressure when using the palmar hamate versus conventional grip (482.90 vs 142.40 kPa; $t = 6.95$; $P < .0001$).

Conclusion: Use of the palmar hamate grip may increase the risk of hook of the hamate fracture in National Collegiate Athletic Association Division I baseball players.

Clinical Relevance: Educating players on the risks associated with the palmar hamate grip may prevent injury and minimize time out of competition.

Keywords: wrist; hand; injury prevention; baseball/softball; athletic training

Fractures involving the hook of the hamate represent a mere 2% incidence of carpal fractures, after the scaphoid, triquetrum, and trapezium, in order of frequency.[2,7] However, a delay in diagnosis and ultimate treatment can lead to significant morbidity, which is common in the sport of baseball. There is a higher incidence of hook of the hamate fractures in baseball compared with other sports, and its deleterious effect on return to play can pose serious consequences, as evidenced in 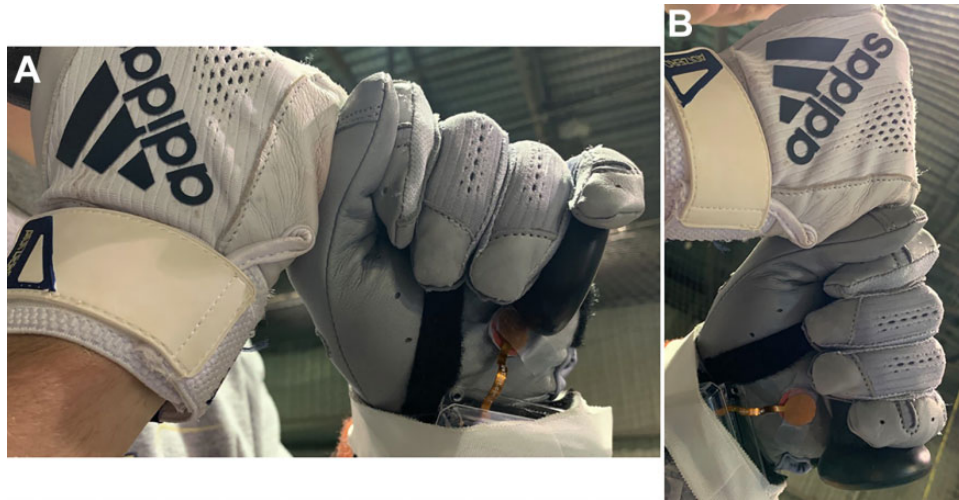recent studies. In a report on the top 50 injuries seen in professional baseball, presented at the 2018 Major League Baseball Winter Meetings, Camp et al[4] found that fractures of the hook of the hamate were present in the 10 most frequent wrist and hand injuries, with affected players averaging nearly 53 days on the injured list. Rhee et al[11] similarly found that among hand and wrist injuries in professional baseball, hook fractures were the third most common wrist injury overall, resulting in an average of 51.5 days on the injured list. In a study of all Major League Baseball athletes sustaining fractures of the hook of the hamate between 2010 and 2017, 81% of athletes were able to return at the same level of play.[9] Clearly, educational programs emphasizing specific

Figure 1. Player demonstrating (A) palmar hamate grip and (B) conventional grip. The force sensor was positioned over the hook of the hamate.

mechanisms of injury, earlier diagnosis, more expedient treatment, and optimum rehabilitation may decrease the overall morbidity of this injury. Most important, and often not discussed, are improved approaches to prevent this injury before it occurs, to minimize its morbidity.

The accepted mechanism of injury in the hook fracture is that of the knob of the bat being driven into the hypothenar aspect of the palm, delivering a direct traumatic blow resulting in fracture of the hook of the hamate. This involves the nondominant or bottom hand in 2-handed sports and, in baseball, is often due to a checked swing on a high inside pitch. It is the senior author's (G.M.L.) experience that highly skilled Latino players experience a higher incidence of hook fractures in the Atlanta Braves organization. On closer inspection, we have recorded that many of these players are taught to hold the knob of the bat in the palm of their hand (Figure 1A) rather than conventional positioning of the knob outside the palm on the ulnar border of the hand (Figure 1B), as some believe that this technique can maximize power and control while batting. We have termed this the "palmar hamate grip," and it is our hypothesis that this position of the knob places it perilously close to the hook, potentially increasing the chance of direct trauma and fracture.

The purpose of our study was to compare pressures exerted to the hook using the conventional versus the palmar hamate grip to gain insight into the differing rates of injury seen. Furthermore, we aimed to provide recommendations to modify, lessen, or even prevent its occurrence.

We hypothesized that players using the palmar hamate grip will have higher pressures exerted on the hamate when compared with players batting with the conventional batting style.

METHODS

Institutional review board approval was obtained for this study. Nine athletes were recruited for participation, on a volunteer basis, from the rosters of 2 National Collegiate Athletic Association (NCAA) Division I baseball teams. After providing informed consent, the 9 participating players were divided into 2 groups based on their usual grip type. Players were not asked to deviate from their usual grip type to minimize the risk of injury. All players were active members of NCAA Division I baseball teams, were 18 to 22 years of age, and hit right-handed.

A 15 mm–diameter, 450-N, SingleTact calibrated miniature force sensor (Pressure Profile Systems Inc) was used for force measurement. The sensor was an industry-leading, calibrated, single-element capacitive force sensor with accuracy within 3% and excellent repeatability with an error rate of <1% reported by the manufacturer. The force sensor system was applied to the bottom hand of each participating player, with the central portion of the sensing mechanism placed on the batting glove directly over the hook of the hamate by the testing physician (M.A.) after palpation of the hook approximately 1.5 to 3 cm distal to

*Address correspondence to Mikhail Alexeev, MD, Wellstar Atlanta Medical Center, 303 Parkway Drive NE, Atlanta, GA 30312, USA (email: alexeevm2@gmail.com).
†Department of Orthopedic Surgery, Wellstar Atlanta Medical Center, Atlanta, Georgia, USA.
‡Hand and Upper Extremity Center of Georgia, Atlanta, Georgia, USA.

TABLE 1
Friedman Test Results to Evaluate the Effects of Player, Grip, and Trial on Pressure (With Player 9).[a]

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Value	P Value
Grip	1	297.02	297.02	28.03	**<.0001**
Trial	16	329.76	20.61	1.95	**.0335**
Player	8	1008.64	126.08	11.90	**<.0001**
Grip × trial	14	305.07	21.79	2.06	**.0282**

[a]Bolded P values denote statistical significance ($P < .05$).

TABLE 2
Repeated-Measures ANOVA to Evaluate the Effects of Player, Grip, and Trial on Pressure (Without Player 9).[a]

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Value	P Value
Grip	1	657.19	657.19	61.47	**<.0001**
Trial	16	288.49	18.03	1.69	.0809
Player	7	1008.56	144.08	13.48	**<.0001**
Grip × trial	9	135.10	15.01	1.40	.2118

[a]Player 9 was excluded from the analysis. Bolded P values denote statistical significance ($P < .05$). ANOVA, analysis of variance.

the pisiform along a line from the pisiform to the index finger metacarpal head.[5]

To allow for a uniform distribution of contact area between the sensor and the palm and to prevent sensor deformation during trials, a 15 mm–diameter and 1-mm-thick plastic disk equivalent to the diameter of the sensor was secured to the underside of the sensor, which was secured to the batting glove. A single batting glove was used for all players, which was fashioned with a strap on the most proximal portion of the glove to secure a USB cable required to transmit data from the sensor to a laptop computer running the SingleTact data collection program (Pressure Profile Systems Inc) (Figure 1). Measurements were collected on consecutive hits at a standardized distance using a ball machine pitching "fastballs" at 70 mph. No breaking balls were included during testing. Before data collection began, players were allowed to warm up according to personal preference; no standardized warm-up protocol was used. Once data collection was started, the position of the sensor was confirmed by the testing physician after each hit. A single aluminum bat, meeting NCAA bat-ball coefficient of restitution performance standards, was used for testing.

Force measurements collected by the sensor were converted to pressure measurements by dividing the force (in newtons) by the surface area of the force sensor. A nonparametric Friedman test, which provides for nonparametric repeated-measures comparisons, was used to compare the pressure measurements between the 2 groups of batters. SAS Studio (Statistical Analysis System version 9.4; SAS Institute) was used for statistical analysis.

RESULTS

Of the 9 study participants, 5 players preferred to bat exclusively with the conventional grip, while 3 players preferred to bat exclusively with the palmar hamate grip. A single player naturally alternated between the 2 grip types; as a result, pressure measurements were collected for both of the player's preferred grip variations, allowing this player to serve as his own control. Data on a total of 99 hits (labeled as "trials") were collected. There were 54 hits recorded for the conventional grip and 45 hits recorded for the palmar hamate grip. A comparison of average pressure for each successive at bat, up to a maximum of 17 hits,

demonstrated that there was no degradation of pressure as the number of trials for each player increased.

The palmar hamate grip demonstrated an average pressure of 536.42 kPa exerted on the sensor overlying the hook of the hamate (95% confidence interval [CI], 419.39-653.44 kPa), whereas the conventional grip demonstrated an average of 115.84 kPa (95% CI, 96.97-135.10 kPa). The palmar hamate grip demonstrated a 366% increase in pressure exerted on the sensor overlying the hook of the hamate when compared with the conventional batting grip. The single player who alternated between the 2 grip types demonstrated a 239% increase in pressure exerted on the hamate when using the palmar hamate grip (mean, 482.90 kPa; 95% CI, 377.89-587.88 kPa) compared with the conventional grip (mean, 142.44 kPa; 95% CI, 92.55-192.33).

A nonparametric Friedman test, which provides for nonparametric repeated-measures comparisons, was used to evaluate the effects of player, grip, and trial (ie, hit number) on pressure recorded. The F value was recorded at 4.97 ($R^2 = 0.766$, $P < .0001$), explaining approximately 77% of the difference in pressure. Analysis demonstrated that player, grip, trial, and grip × trial interaction significantly affected pressure (Table 1).

Player 9 was an outlier, with significantly higher pressure measurements (mean, 832.21 kPa; 95% CI, 588.66-1125.76 kPa), potentially inflating the palmar hamate grip results. The Friedman test was run a second time, with player 9 excluded. In this repeat analysis, results were consistent; the conventional grip demonstrated a mean of 115.84 kPa, whereas the palmar hamate grip demonstrated a mean of 388.52 kPa. The test results without player 9 demonstrated values of $F = 5.27$, $P < .0001$, and $R^2 = 0.78$. With player 9 removed from the analysis, we found trial and grip × trial interaction to have no significant effect on pressure. While the effect of player was still significant, grip was found to have the greatest effect on pressure (Table 2).

In addition to higher average pressures, the palmar hamate grip demonstrated greater maximum peak pressures exerted on the hamate, with 3 out of 4 players using the palmar hamate grip, recording pressures >700 kPa with a maximum recorded pressure of 2312.712 kPa, whereas the maximum pressure recorded by any player using the conventional grip was 274.08 kPa. The only

player who used both grips, player 5, demonstrated significantly higher maximum pressure when using the palmar hamate grip (482.90 vs 142.40 kPa; $t = 6.95$; $P < .0001$).

DISCUSSION

Hook of the hamate fractures represent a cause of significant morbidity in baseball. The diagnosis is often delayed, resulting in a prolonged course of treatment, which can be especially detrimental for competitive and professional athletes, as well as for their respective professional organizations. The delay in diagnosis is variable depending on the injury presentation, as well as on the experience of the team medical staff, and often occurs because of difficulty in visualization of the fracture on standard radiographic views. Tenderness to palpation over the hook of the hamate, as well as the hook of the hamate pull test, may point to the diagnosis of fracture.[14] Effective diagnosis is aided by radiographic views such as the carpal tunnel view and supinated lateral view.[13] Advanced imaging such as magnetic resonance imaging and computed tomography in the axial plane of the hamate can serve as important diagnostic tools in the case of a minimally displaced fracture not visible on radiographic images.[8,10] Although nonoperative treatment for nondisplaced fractures has been described, excision of the fracture fragment has shown superior results, allowing the athlete a more reliable and expeditious return to play, usually within 5 to 8 weeks postoperatively.[1,3,5,6,12]

Most studies of the hook have discussed mechanism of injury along with surgical treatment. To our knowledge, no study has examined grip technique, its effect on pressures exerted on the hamate, or the effect of grip and possible grip modifications on the incidence of the injury. Our results have demonstrated that the palmar hamate grip results in significantly higher average pressures exerted on the hook of the hamate. Furthermore, and perhaps even more interesting, peak pressure measurements demonstrated that in addition to consistently higher pressures on the hamate, the maximum pressure that the hamate may encounter with the palmar hamate grip is extreme and can be upward of 2300 kPa—>8 times greater than the maximum pressure exerted by any player using the conventional grip. It is possible that pressures in these high outliers may be even greater with the occasional high checked swing or mishit ball, although these factors were not examined in this study. Our findings support the proposed mechanism of increased rates of hook of the hamate fractures in players using the palmar hamate grip. As stated previously, this relationship between batting technique and injury rate has not been previously described, and our findings can serve as an educational tool for players and professional organizations seeking to minimize their risk of injury and time out of competition. Athlete education regarding the risks of using the palmar hamate grip, as well as consideration of the use of modified bats such as the Axe Bat, may play a role in decreasing pressures on the hamate, although future research directed at this topic is necessary.

Our study definitively demonstrated that grip type is a statistically significant factor in pressure exerted on the hook of the hamate. Although the Friedman test, excluding player 9, demonstrated some effect of player on pressure, the grip type was by far the most statistically significant effect. A limitation of this study is that although grip types can generally be divided into conventional and palmar hamate grips, batting technique varies from athlete to athlete, and there remains a slight amount of variation between each player's unique grip type and palmar anatomy, which could influence pressures exerted on the hamate.

To minimize the risk of injury, we did not ask players to deviate from their usual grip type; thus, a true control group did not exist. However, the single player who naturally preferred to alternate between the grip types and served as his own control demonstrated a 239% increase in pressure when using the palmar hamate grip. In addition, the relative infrequency of the use of the palmar hamate grip in collegiate baseball players has made it difficult to obtain a large sample size of players using the palmar hamate grip. While we have definitively shown that grip type is a significant factor contributing to pressure exerted on the hook of the hamate, because of the small overall sample size, it is possible that further research on additional athletes using the palmar hamate grip could alter the average pressure values reported.

With regard to the biomechanical methodology of the study, the ideal pressure measurement would be taken directly on the cortical surface of the hook of the hamate. As this in not possible in an in vivo study, our study design must accept the limitation of soft tissues overlying the hook of the hamate potentially dissipating some of the forces that the bone itself may encounter during play. In addition, the sensor was secured to the surface of the batting glove, allowing for accurate placement of the sensor directly over the hook of the hamate by the testing physician without risk of sensor migration with glove application, as well as for confirmation of accurate sensor position after each hit. This was critical to the validity of the study, but it did not allow our sensor measurement to account for the minimal amount of force dissipated by the glove during play. A thin layer of plastic was placed between the sensor and the batting glove to prevent deformation of the sensor, which could also potentially minimally contribute to this effect.

In addition, the resolution of the pressure sensor is a potential limitation, as the 15 mm–diameter sensor only allows for the calculation of pressure over a 15 mm–diameter area centered directly over the hook of the hamate. While advanced pressure sensing arrays consisting of multiple sensing elements with the potential for advanced pressure mapping calculations exist, these systems are prohibitively expensive, and we believe that a single-element, 15 mm–diameter sensor is a reasonable tool to measure pressures that may put the hamate at risk. Finally, it is the experience of the senior author that many fractures of the hamate occur during an awkwardly hit ball or high checked swing. We did not ask the players to intentionally mishit the ball or check their swings to minimize risk of injury during testing.

CONCLUSION

The palmar hamate grip demonstrated a 366% increase in the average pressure exerted on the hook of the hamate when compared with the conventional grip, suggesting that use of the palmar hamate grip may increase the risk of hook of the hamate fracture in NCAA Division I baseball players. Educating players on the risks associated with the palmar hamate grip may prevent injury and minimize time out of competition, benefiting players and their respective athletic organizations.

REFERENCES

1. Bansal A, Carlan D, Moley J, Goodson H, Goldfarb CA. Return to play and complications after hook of the hamate fracture surgery. *J Hand Surg Am*. 2017;42(10):803-809.
2. Bishop AT, Beckenbaugh RD. Fracture of the hamate hook. *J Hand Surg Am*. 1988;13(1):135-139.
3. Burleson A, Shin S. Return to play after hook of hamate excision in baseball players. *Orthop J Sports Med*. 2018;6(10):2325967118803090.
4. Camp CL, Dines JS, van der List JP, et al. Summative report on time out of play for Major and Minor League Baseball: an analysis of 49,955 injuries from 2011 through 2016. *Am J Sports Med*. 2018;46(7):1727-1732.
5. Carter PR, Eaton RG, Littler JW. Ununited fracture of the hook of the hamate. *J Bone Joint Surg Am*. 1977;59(5):583-588.
6. Devers BN, Douglas KC, Naik RD, Lee DH, Watson JT, Weikert DR. Outcomes of hook of hamate fracture excision in high-level amateur athletes. *J Hand Surg Am*. 2013;38(1):72-76.
7. Dunn AW. Fractures and dislocations of the carpus. *Surg Clin North Am*. 1972;52(6):1513-1538.
8. Egawa M, Asai T. Fracture of the hook of the hamate: report of six cases and the suitability of computerized tomography. *J Hand Surg Am*. 1983;8(4):393-398.
9. Erickson BJ, Mcelheny K, Chalmers PN, et al. Performance and return to sport after excision of the fractured hook of the hamate in professional baseball players. *Am J Sports Med*. 2020;48(12):3066-3071.
10. Polivy KD, Millender LH, Newberg A, Phillips CA. Fractures of the hook of the hamate—a failure of clinical diagnosis. *J Hand Surg Am*. 1985;10(1):101-104.
11. Rhee PC, Camp CL, D'Angelo J, et al. Epidemiology and impact of hand and wrist injuries in Major and Minor League Baseball. *Hand*. 2019:1558944719864450.
12. Stark HH, Chao EK, Zemel NP, Rickard TA, Ashworth CR. Fracture of the hook of the hamate. *J Bone Joint Surg Am*. 1989;71(8):1202-1207.
13. Stark HH, Jobe FW, Boyes JH, Ashworth CR. Fracture of the hook of the hamate in athletes. *J Bone Joint Surg Am*. 1977;59(5):575-582.
14. Wright TW, Moser MW, Sahajpal DT. Hook of hamate pull test. *J Hand Surg Am*. 2010;35(11):1887-1889.