# Biomechanical Study of the New Axe Handle Baseball Bats and Comparison with Standard Round Knob Bats

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## Abstract

A biomechanical study was performed to understand the kinematics of the handle of a bat within the grip of a hitter during a baseball swing. The focus of the study was to compare and contrast the performance of traditional round handle bats with those equipped with the newly designed axe handle. The bats were evaluated with respect to injury potential, comfort, consistency of swing, and transfer of power to the ball. To assist in the study, the bat grip area of several Division 1 Varsity players were filmed at 1000 frames per second using a high speed camera (Olympus i-SPEED 2, Waltham, Ma). Subsequent slow motion analysis was performed using the i-SPEED software to understand the subtle yet important differences in the micro-movements between the bat handle and the grip of the players for the two handle designs.

## Overall Conclusions

Axe is a new bat design incorporating an angled knob with a flush backside profile. The biomechanical study on these features, when compared to traditional round bat handles, confirms that the Axe handle: 1.) Is more comfortable. 2.) Improves performance based on bat handle kinematics and enhanced grip stability 3). Delivers more efficient power from the hands to the bat, through reduced tension. 4.) Creates additional bat rotational speed by adding force over a greater swing angle, 5.) Improves bat control and reduces pain by controlling the velocity of oscillations which hammer the knob between the fingers and hypothenar area of the palm, and 6). Reduces hamate bone and ulnar nerve injuries, and incidents of thrown bats, by removing localized pressures from the hypothenar region. These findings are discussed in detail below. For the purposes of this paper, Performance is defined broadly as relating to swing kinematics and handle effects, such as swing efficiency, ability to meet pitches effectively, and added swing force due to comfort. This does not include barrel effects such as BBCOR, which must be maintained below game-legal limits.

## Background of Grip Types

### Round Handle Bats

There are two primary grips that players employ when using a round handle bat.  The first is to wrap the bottom hand around the handle of the bat, with the bottom finger and palm in line with the knob.  The knob protrudes from the handle at a perpendicular angle.  This is illustrated in figures 1 and 2.  For the purpose of this study, we will call this flush grip because the bottom finger and palm are flush with the top surface of the knob.

The second grip type is used most by high level players.  In this grip position, the fingers are wrapped around the handle of the bat, with the lower finger resting on the top edge of the knob, the same as with the flush grip.  However, the palm of the bottom hand is positioned lower.  Instead of resting on the top edge of the knob, it is now down beside the knob, with the edge of the knob pressing into the palm, as seen in figures 3 and 4.  Players use this grip in order to achieve a more neutral wrist angle on the onset of the swing.  For the purpose of this study, we will refer to this grip as an angled grip.

*Figure 1*

*Figure 3*

*Figure 2*

*Figure 4*

There are variations to the angled grip, where players 'hang on' or 'hang off'. With these grips, the player will drop the entire hand down so that the bottom finger of the bottom hand either wraps around the edge of the knob, or sits entirely below the knob (figure 5 and 6). These grip variations are all adopted to achieve the same results of putting the player's wrist in a neutral position with the forearm and avoid impingement from the knob on the bottom of the palm. They all also result in the edge of the knob pressing into the palm of the bottom hand.

*Figure 5*

*Figure 6*

**Axe Handle Bat**

The bottom of the axe handle bat uses an ergonomically designed shape. This shape extends up the entire portion of the handle that the bottom hand grasps. The axe handle blends into a traditional handle shape, a round cylinder, between the top and bottom hand so that the top hand is gripping a completely cylindrical shape. By keeping the top hand on a cylindrical handle, players are able to maintain the desired swing mechanics taught in baseball and softball.

To grip an axe handle bat, the batter simply grabs the bat as though they were employing a flush grip. The ergonomic shape of the axe handle naturally aligns to the shape of the hand (figure 7).

*Figure 7*

*Figure 8*

Alternate grips are possible with the axe handle bat. Players are able to 'hang on' or 'hang off' similar to a round handle bat (Figure 8 shows 'hanging on'). However, the intention of the axe handle design is to eliminate the need to use these alternate grips by removing the obstructive features of the round handle bat. For this reason, we will not address these grips in this study.

The material differences between the shape of the axe handle and a traditional round handle are as follows: The axe handle has an oval cross section that increases in size along its long axis as it extends down to the end of the handle. The oval shape is not concentric to the handle of the bat, meaning that as it increases in size, it only extends in the direction of the fingers. The back side of the handle is almost completely flush with the rest of the handle. The bottom of the axe handle is cut at an angle which matches the natural angle of the bottom of the hand (figure 9).

**Improved Comfort**

Compared with a round handle bat, the axe handle is found to be more comfortable.

The shape features of the axe handle align much more closely with the natural shape of the hand as it grips. By matching the contours and angles of the hand, the axe handle increases the surface area of the grip, more evenly distributing grip pressure over a larger portion of the palm and fingers. This results in far fewer pressure points between the hand and handle.

A round handle bat in both common grip positions results in less surface area and more concentrated pressure distributions. The angle grip places pressure at a single point over the ulnar nerve and hamate bone in the bottom of the palm. It also pushes the hand away from the handle resulting in two localized points on the palm that are responsible for absorbing all the grip pressure created by the fingers.

Because the round knob protrudes at 90 degrees from the handle, it does not match the natural angle of the bottom of the palm. Thus a flush grip forces the hand to compensate for these misaligned angles. This creates areas of increased pressure at multiple points on the hand.

For these reasons, the axe handle bat was found to be more comfortable to grip than a round handle bat in both flush and angled grip positions.

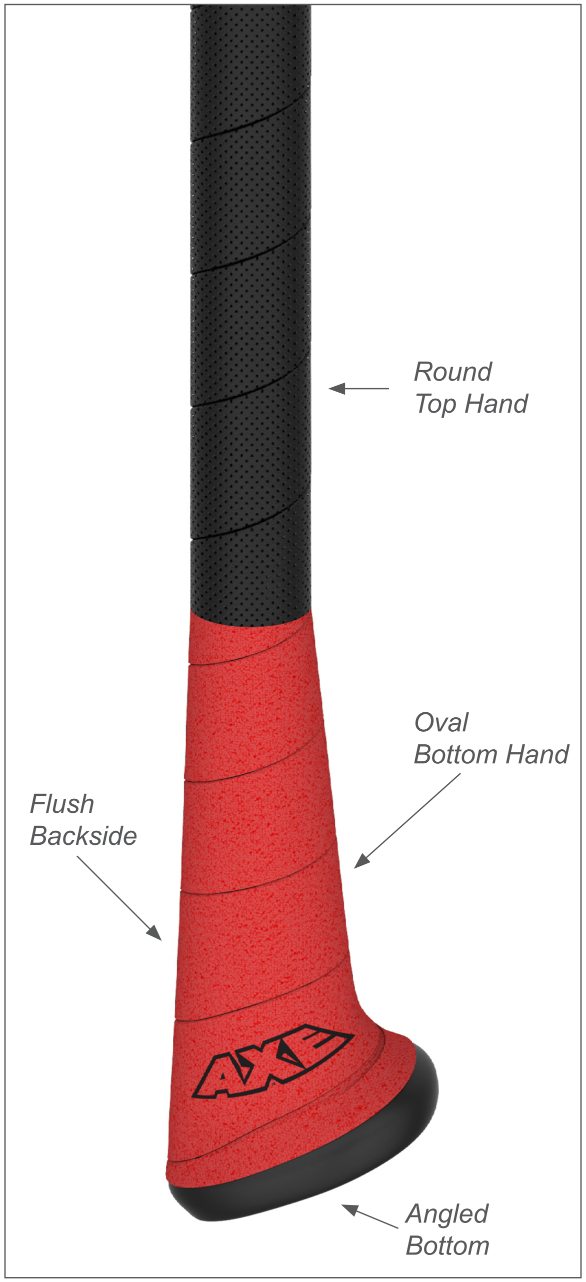


*Figure 9*

## Improved Performance Based on Bat Handle Kinematics and Enhanced Grip Stability

When a batter grips a round handle bat using a flush grip, as shown in figure 1, the protruding round knob rests against the edge of the player's palm, ready to push into its surface at the onset of the swing. An angled grip, shown in figure 3, moves the player's palm onto the edge of the protruding knob from the onset. With both grips, the palm is pressed onto the protruding edge of the round knob.

The back of the axe handle bat is flush down its entire length. When gripped, there is no protruding knob edge resting against the lower edge of the palm at the onset of the swing (Fig 10).

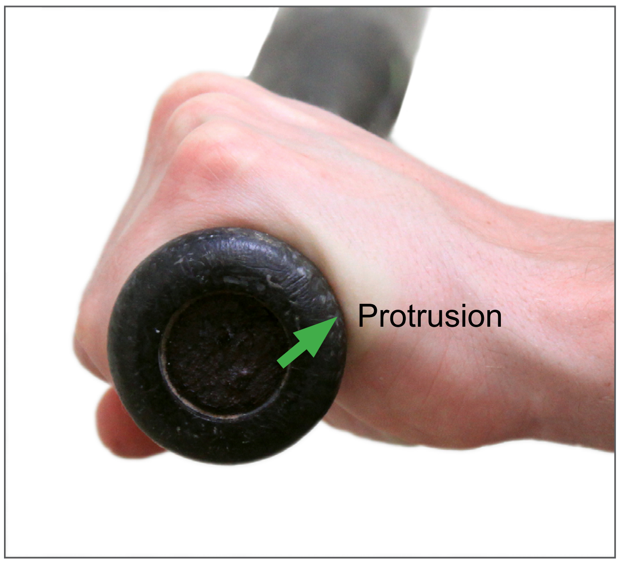


*Figure 1*

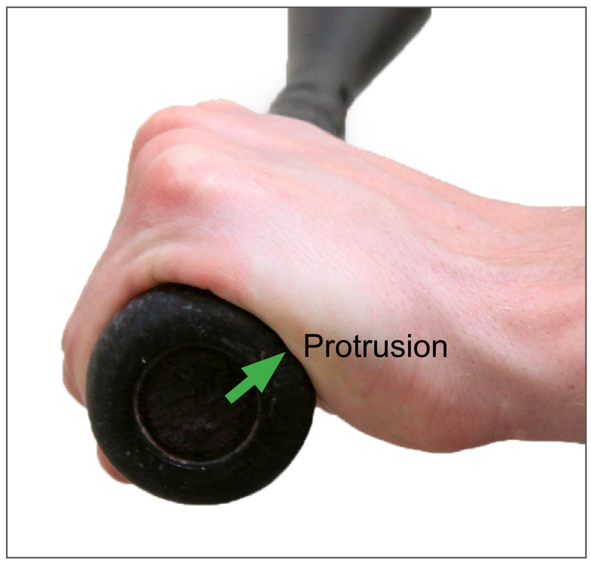


*Figure 3*

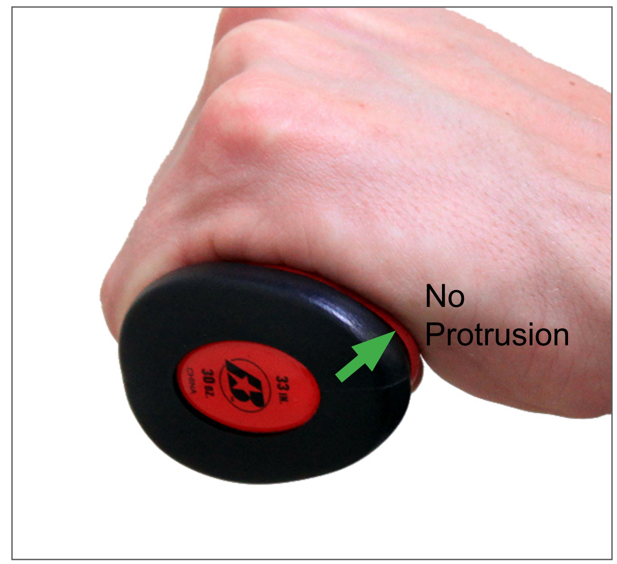


*Figure 10*

Consider the mechanics of a bat handle during the swing prior to ball contact. As the hitter swings the bat from a position above his shoulders, bringing the bat forward and around, a large centrifugal force is generated along the axis of the bat just prior to contact with the ball (shown by blue arrow in Figs. 11-13). This force tends to pull the bat away from the batter with the edge of the round knob tending to slide into his palm. This force is directed along the long axis of the bat and shown by blue arrow A in a focused view of the grip in Fig. 13.

In addition to this inward sliding force A, the edge of the round knob also compresses into the surface of the palm with a force B, shown by the red arrow in Fig. 13

This occurs because the axis of bat rotation is somewhere within the player's grip which causes the knob of the bat to move into the palm as the barrel rotates towards the on-coming ball.

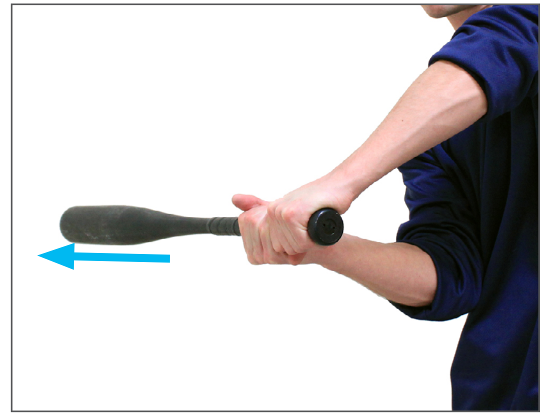

*Figure 11*

*Figure 12*

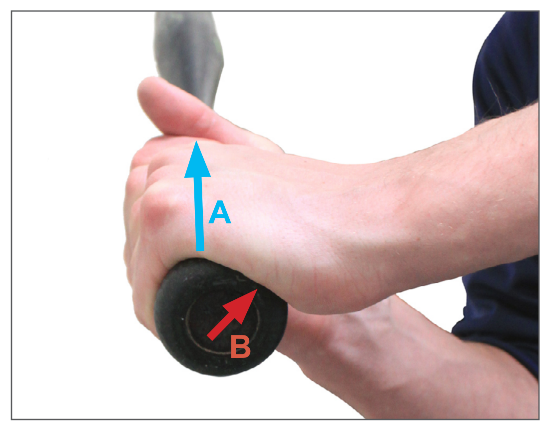


*Figure 13*

Because of the round edge of the knob, the contact with the palm is limited to a very small area.

Figure 14 shows this with a focused view of the area where the knob impinges into the palm. As the knob pushes into the edge of the palm under the combined effects of the aforesaid forces (centrifugal and rotational), the knob tends to wedge-open the grip by pushing the lower area of the bat away from the palm surface. This results in a gap within the lower grip which can be seen in Figs. 15 and 16.

*Figure 14*

All this occurs prior to impact with the ball. Thus, in round knob bats, the bat is pivoted on a raised knob edge over a small area of the palm with most of the lower grip area having no pressure at the bat/palm interface. This makes the grip prone to instability at ball contact and can result in rolling. Additionally, because the bat is insufficiently supported over a very small area of the palm, the player is unable to transfer full power to the ball. Players can overcome this by over-tensioning the grip but that is well known to result in poor performance.

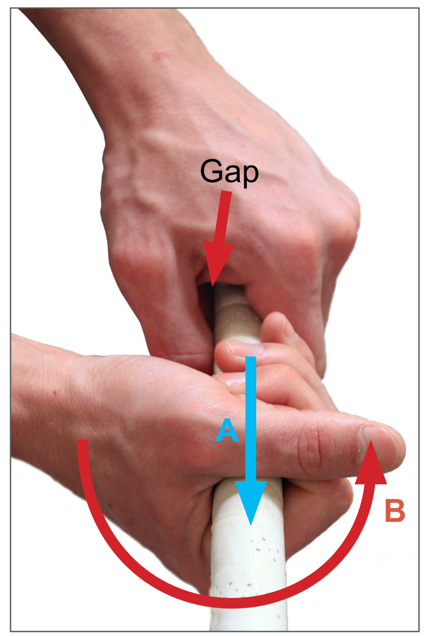


*Figure 15*

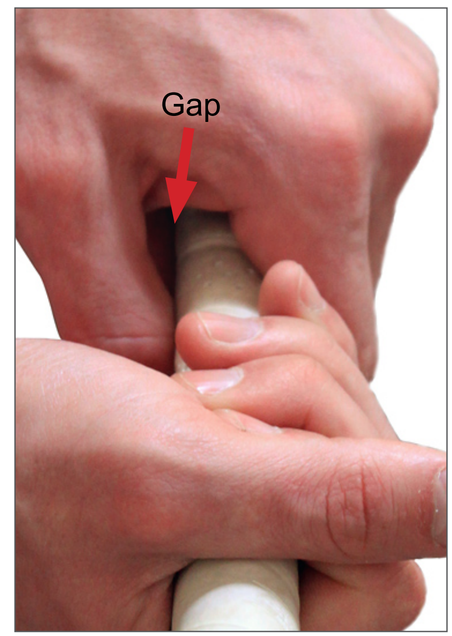


*Figure 16*

In contrast, there is no knob edge on the backside of the Axe handle. This means there is no wedging of the grip due to pivoting of the handle about a focused contact point on the palm. Instead, as shown in the focused view of the grip in Fig. 17, the contact over the edge of the player's palm is over a large area.

Figure 17

There is no impingement from the backside of the handle during the swing as demonstrated in the sequence of photographs in Figs 18-20. Because of the lack of the wedging effect, substantial interfacial contact between the back of the handle and the entire diagonal area of the palm is maintained even under the influence of centrifugal (A) and rotational (B) forces. The tendency for the lower grip to lift away from the palm during the swing is counteracted by the entire upper area of the handle grip being uniformly supported by the hypothenar area of the palm (area of the palm that is below the pinky finger and adjacent to the wrist) because of the absence of the rounded knob edge.

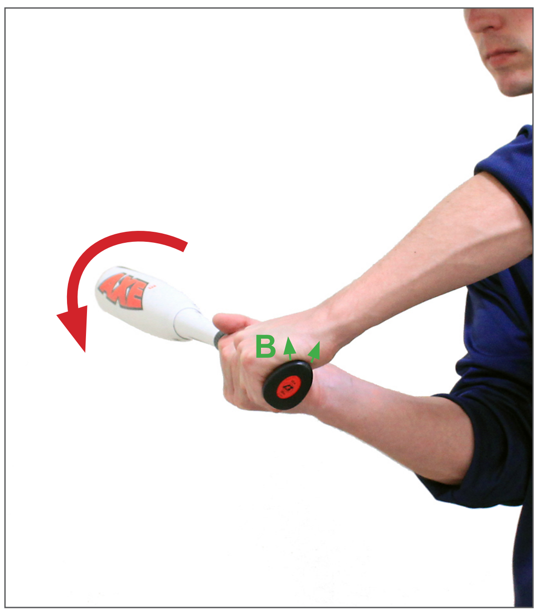


Figure 18


Figure 19


Figure 20

Compared with the round handle bat, the contact area in the axe handle is significantly higher. This results in the absence of any gaps caused by the wedging affect of the round knob within the lower grip area as demonstrated in Figs. 21 and 22.

**Conclusion**

With a round handle and round knob, the bat is insufficiently supported over a very small area of the palm, leaving the player unable to transfer full power to the ball. By removing gaps, the axe handle bat allows the hitter to exert force evenly over the entire length of their grip. This results in a significant increase in grip stability facilitating full power transfer to the bat.

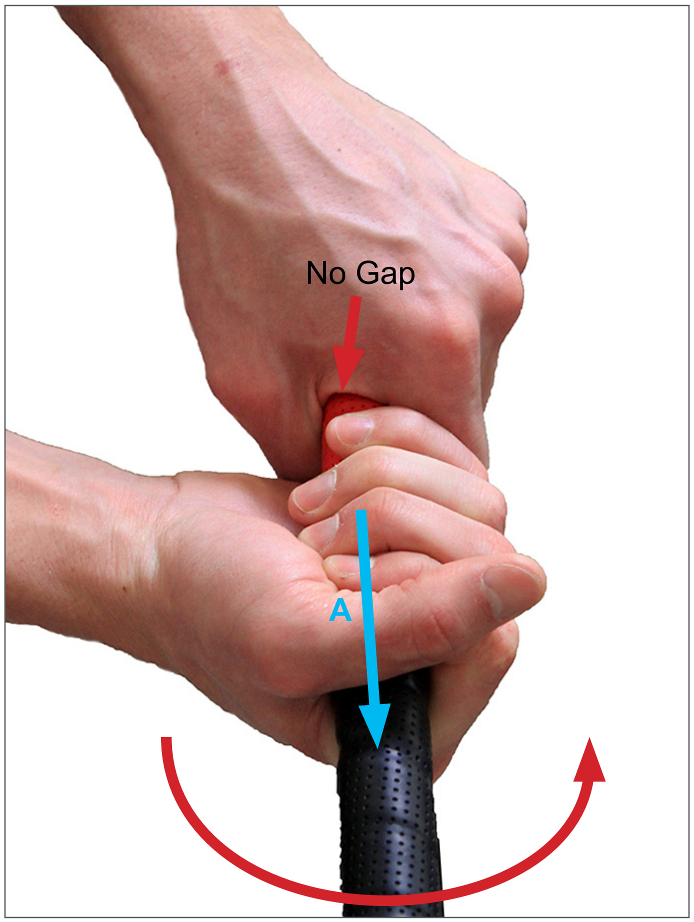


*Figure 21*

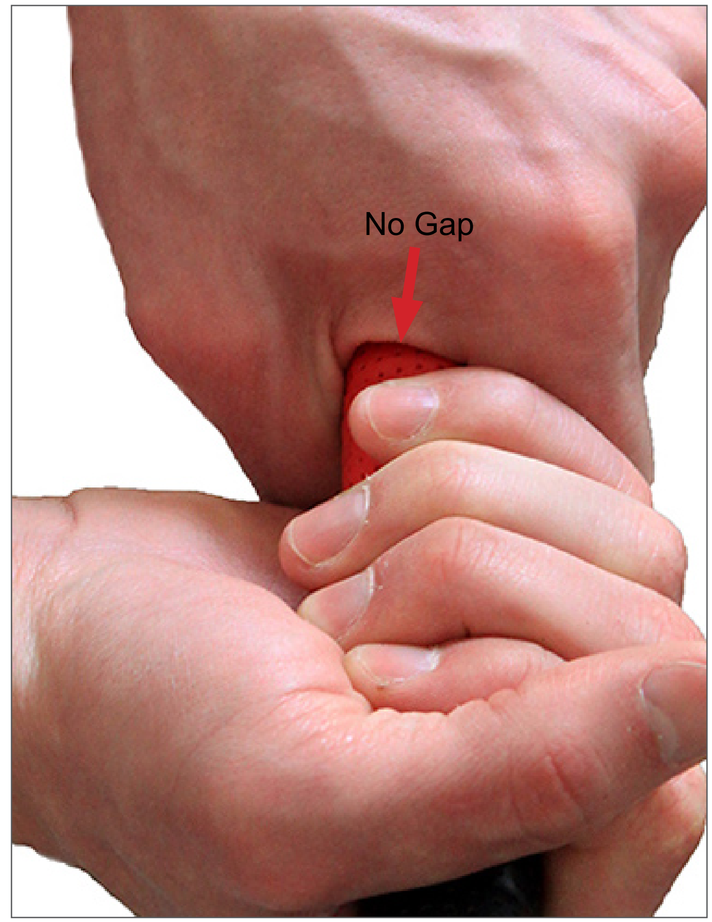


*Figure 22*

## More Power to the Ball through Tension Free Grip and the Wrist Whipping Effect

### Grip Tension

The most common grip position for high level players is the angle grip, which has the batter wrapping their fingers around the handle of the bat with the lower finger resting on the knob as shown in figure 4. This grip allows the player to align their wrist and forearm with a less acute angle than a flush grip, providing increased range of motion in wrist flexion (figure 23). This is a desired position because wrist flexion gives the batter the ability to engage additional muscle groups through the swing (the forearm) to whip the bat prior to contact with the ball. This addition of whip lets the player achieve increased bat speed by continuing to accelerate the bat after the hips and shoulders have spent their contribution to the swing.

However, as illustrated in figure 24a, by gripping a traditional bat handle in this position, a gap is produced between the portion of the palm that is pressed into the knob and the top metatarsal. This gap localizes grip pressure to two points on the palm, greatly increasing the amount of pressure in those two areas. By providing batters with little surface area, the hand must generate large forces at these two localized points in order to achieve sufficient grip stability through the swing. This requires greater tension in the muscles of the batter's hand and forearm.

*Figure 4*

*Figure 23*

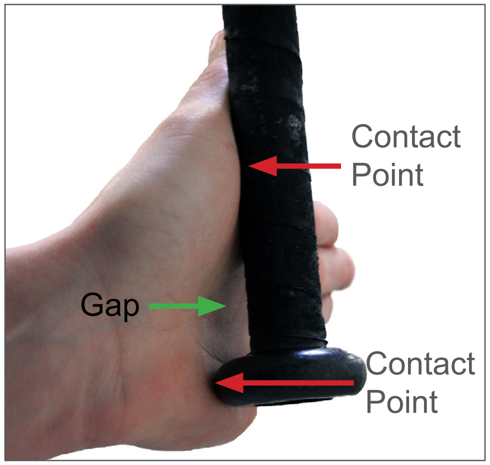


*Figure 24a*

In comparison, the axe handle has no protrusion on the back quarter of the knob. It also angles down to match the natural angle of the hand. Both these features are illustrated in figure 7. The standard grip on an axe handle bat is able to achieve an even more obtuse wrist angle than that of the angled grip on a round handle bat. However, because the angle of the knob matches the natural angle of the bottom of the hand, there is no portion of the palm that hangs off the end of the knob. Also, because the back third of the axe handle is mostly flush with the rest of the bat grip, there is no protrusion to lift the palm off the handle. Thus, unlike the round knob bat, there is no gap between the palm and the handle of the bat (Fig 24b). These two features of the axe handle result in a dramatic increase in area of contact between the palm and the grip of the bat.

**Conclusion**

With the angle grip on a round handle bat, the palm of the bottom hand must control the grip through two contact points. The hand must generate tremendous forces to maintain grip with so little surface area, creating large amounts of localized pressure on the palm and a high amount of muscle tension in the hand and forearm. Because the axe handle allows the hand to maintain contact with the bat along the full length of the palm, less force is required to maintain grip. Thus the hand is able to achieve greater grip with less muscle tension. Also, by reducing the tension in the hand and forearm, the wrist is capable of greater range of motion through flexion, allowing the batter to achieve more rotational acceleration (whip) up to the point of contact.

*Figure 7*


*Figure 24b*

## Additional Whip

The flush grip moves the palm of the bottom hand above the knob, changing the angle of the hand to match the perpendicular protrusion of the knob. With this grip, the angle of the wrist is acute (Fig. 27 and 28) and almost already fully flexed. The angled knob profile of the axe handle results in a tension-free obtuse wrist angle (Fig. 29 and Fig. 30).

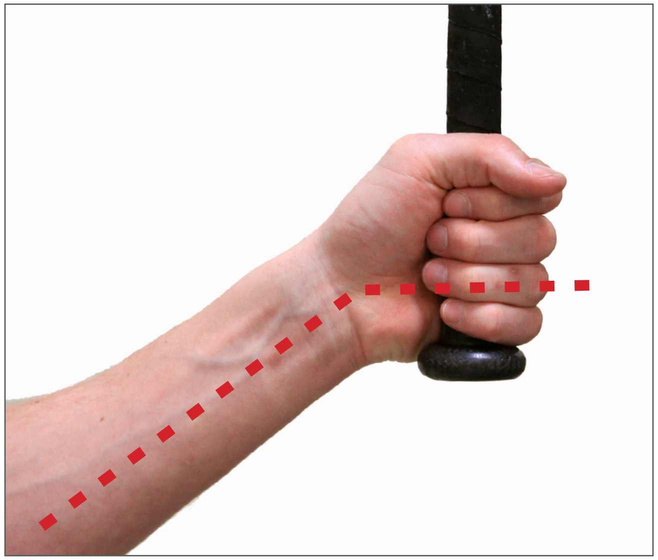

*Figure 27*

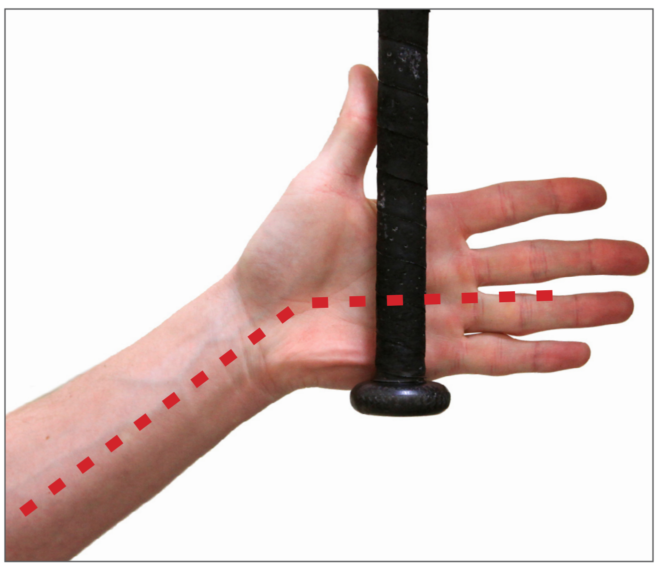

*Figure 28*

*Figure 29*

*Figure 30*

The acute wrist angle created by the round knob allows little counterclockwise rotation of the wrist in the plane of the forearm (for a right hand batter) towards the oncoming ball (Fig. 31 & 32).

Fig. 34 shows the maximum in-plane rotation that is possible up to the ball strike. This extra capacity for wrist rotation also acts as a cushion to reduce the dynamic impact force on the wrist by increasing the momentum arrest time of the Axe bat at the end of the swing. This should result in much lower forces on the wrist of a hitter.

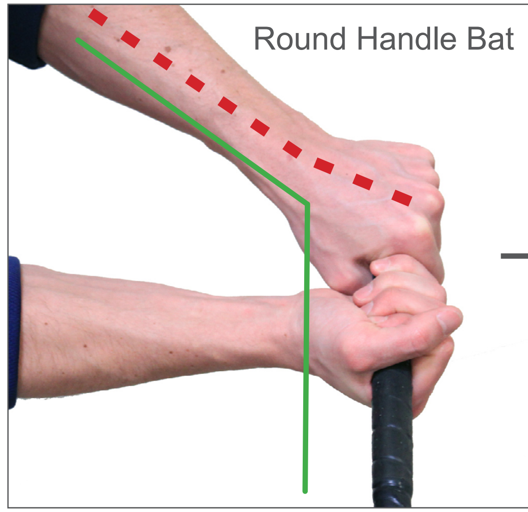


*Figure 31*

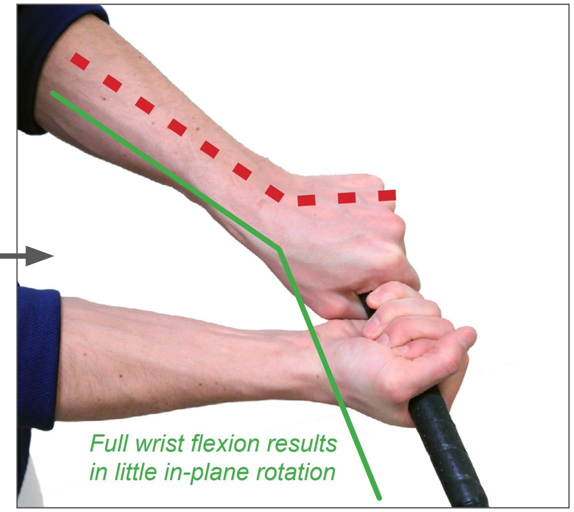


*Figure 32*

### Conclusion

The axe handle bat puts the wrist in a more neutral position at the onset of the swing. Also, by eliminating the impingement caused by the back protrusion of the round knob, the same amount of wrist flexion moves the barrel a greater distance. These two factors combine to provide the hitter with 15-20 degrees of additional bat whip and a larger window of opportunity to accelerate the bat. This additional whip can be used to generate greater bat speed at the point of contact with the ball.

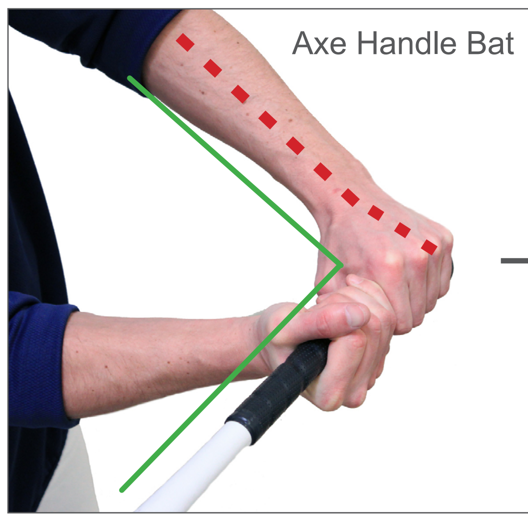


*Figure 33*

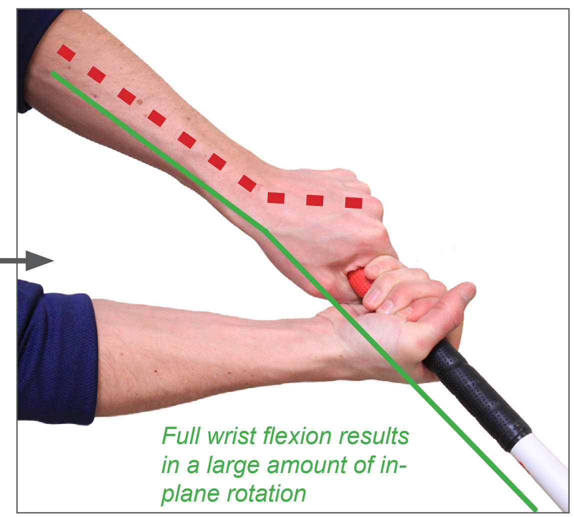


*Figure 34*

## High Speed Video Analysis

Now we consider the mechanics of the bat handle during ball strike. When the ball impacts the bat, the knob area of the handle moves away from the palm surface towards the fingers as the bat rotates about an axis located within the upper hand. This is true for both the round knob and axe handle bats.

Instantly, this releases the pressure from the hypothenar area of the palm. However, this relief is temporary for the round knob bats as the knob is able to attain significant velocity prior to striking the fingers, primarily because the wedging effect creates a movement space and loosening of the lower grip prior to ball impact. The knob then rebounds and strikes the hypothenar area of the palm with a high velocity leading to the generation of a large dynamic force. This violent oscilation increases the farther the ball strike is from the sweet spot.

The slow motion movie *Round 1* demonstrates these movements for one of the batters. The oscillations of the knob seen in the video are also caused by the flexural vibrations initiated upon ball impact. As seen clearly in the video, the wedging effect amplifies these oscillations and results in the knob pounding the hypothenar area of the palm with a significant velocity. The video also shows significant jostling of the various carpal, phalangeal, and metacarpal joints due to the excessive bat handle movement. Repeated insults from the knob can lead to hamate bone fracture over time.

As discussed above a strong player can avoid the above movements by over tightening the grip by placing a large force over the small area of the round knob. In this case a large dynamic force is still generated but is transferred from the bat knob over a very small area on the hypothenar directly above the ulna nerve and hamate bone. The smaller area significantly increases the pressure, which is the biomechanical parameter that controls the injury to the hamate bone and the ulnar nerve. The mechanisms for these injuries are discussed in the next section.

Since the Axe handle conforms nicely to the palm and remains in contact with little or no movement of the lower grip prior to ball contact, the edge of the bat does not attain large velocity upon ball impact. For the same reasons, vibrations resulting from a hit away from the sweet spot are also not amplified in the Axe bat. This can be seen in the slow motion movies *Round 2* and *Axe 1*, comparing similar hits with a round handle bat and a Axe handle bat.

It is also noteworthy that even if large vibrations were to occur such as for a badly hit ball, there will be no pounding of the hypothenar area because of the absence of any raised round edge on the backside of the Axe grip. A larger impact area of the bat on the palm also reduces the pressure, which as discussed next, reduces the probability of injuries to the hamate and ulnar nerve.

## Biomechanical Advantages with Respect to Ulnar Nerve and Hamate Bone Injuries

*Thrown Bats and Hamate Bone Breaks*

The ulnar nerve innervates the muscles in the hypothenar region. It also innervates the pinky and ring fingers which are significant in providing a strong grip on the bat handle. The hamate bone is also located in the hypothenar area of the palm.

As shown in Fig. 35, both the ulnar nerve and hamate bone lay directly underneath the area of the palm where the round knob of the traditional bat pushes into the palm. As discussed above, the dynamic forces are transferred to the palm over a very small, raised-edge area of the knob in the traditional round knob handle bats. This results in building up of a substantial pressure on top of the hamate bone and the root of the ulnar nerve.

At higher bat speeds, this pressure can pinch the nerve leading to the loss of brain signal and momentary relaxation of the grip provided by the hypothenar muscles and the index and ring fingers. If this occurs prior to contact with the ball it can affect consistency and transfer of power to the ball. This pressure can increase even higher if the player misses the ball in which case the rear edge of the round knob continues to push into the palm and delivers the highest pressure when the momentum of the bat is arrested at the end of the swing. In fact, thrown bats occur when the ulnar nerve is pinched significantly when the player misses the ball. Slow motion movies of thrown bats have confirmed that it is always the lower hand that comes off from the handle first which as discussed above bears the largest pressure over the ulnar nerve in a missed hit.

Repeated high pressure insults can also fatigue the hamate bone and lead to its fracture at its hook where it has the smallest cross-section. In contrast, because of the large contact area in the axe grip, the pressure is significantly lower and distributed more uniformly over the grip.

With low pressure comes comfort and consistency, as grip remains strong with no possibility of grip loss due to nerve pinching. The probability of hamate fracture is also significantly reduced in comparison to traditional round knob bats.

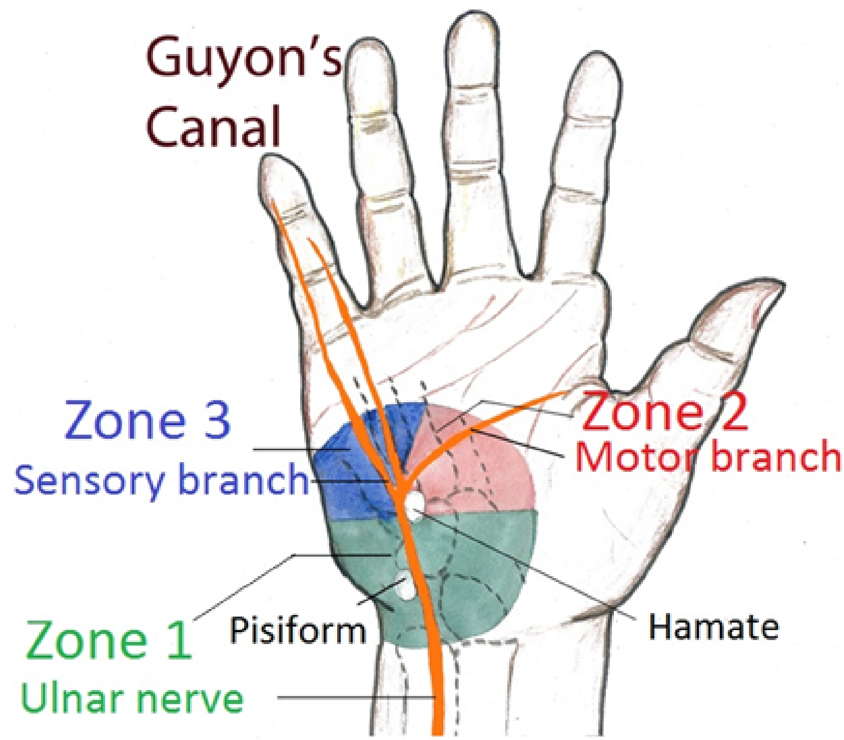


*Figure 35*

## Conclusion

Players report that the Axe bat, having an angled knob with a flush backside profile, performs well. This biomechanical study confirms the reasons for this. The Axe bat 1.) Is more comfortable. 2.) Improves performance based on bat handle kinematics and enhanced grip stability 3). Delivers more efficient power from the hands to the bat, through reduced tension. 4.) Creates additional bat rotational speed by adding force over a greater swing angle, 5.) Improves bat control and reduces pain by controlling the velocity of oscillations which hammer the knob between the fingers and hypothenar area of the palm, and 6). Reduces hamate bone and ulnar nerve injuries, and incidents of thrown bats, by removing localized pressures from the hypothenar region.

## Biography of Vijay Gupta, Ph.D.

Vijay Gupta is a Professor of Mechanical and Aerospace Engineering, Professor of Materials Science and Engineering, and Professor of Bioengineering, at the University of California Los Angeles. He received a Bachelor of Technology degree (1985) in Civil Engineering from the Indian Institute of Technology (Bombay), a M.S. in Civil Engineering from the Massachusetts Institute of Technology (1987), and a Ph.D. in Mechanical Engineering from the Massachusetts Institute of Technology (1989).

Vijay Gupta started his professional career at Dartmouth College as an Assistant Professor, and after only five years of finishing his Ph.D. degree, he was offered a Full Professorship with tenure at UCLA to become one of the youngest full professors in the United States at age 30. His research includes sports biomechanics with special interest in development of materials for reducing impact forces for TBI and concussion applications. His publications are in excess of 140, with three U.S. Patents awarded and several others pending. He is a Fellow of the American Society of Mechanical Engineers.