Batted Ball Speed as a Function of Swing Speed and Impact Location

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Introduction

Performance = batted ball speed

- Increased performance with metal bats suggests:
  - increased severity and frequency of injury from the batted ball, most likely to pitchers.
  - imbalance between offense and defense.
- Regulation of baseball bats is an inherent role for governing bodies of baseball.
Purpose

The purpose of this study was to determine the performance of two wood bat models and five metal bat models in a batting cage study.
Experimental setup in batting cage (Frozen Ropes, Franklin, MA)
Bats and balls with various reflective markers. Final marker design on wood bat.
## Methods

### Bats

<table>
<thead>
<tr>
<th>Model</th>
<th>L (in.)</th>
<th>W (oz)</th>
<th>W-L</th>
<th>Mass Center (in.)</th>
<th>Barrel Diam. (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W [W1 + W2] (n = 12)</td>
<td>34</td>
<td>31</td>
<td>-3</td>
<td>22.8</td>
<td>2.5</td>
</tr>
<tr>
<td>M1 (n = 6)</td>
<td>33</td>
<td>30</td>
<td>-3</td>
<td>20.6</td>
<td>2.625</td>
</tr>
<tr>
<td>M2 (n = 6)</td>
<td>33</td>
<td>28</td>
<td>-5</td>
<td>20.4</td>
<td>2.75</td>
</tr>
<tr>
<td>M3 (n = 6)</td>
<td>33</td>
<td>28</td>
<td>-5</td>
<td>20.8</td>
<td>2.75</td>
</tr>
<tr>
<td>M4 (n = 6)</td>
<td>33</td>
<td>28</td>
<td>-5</td>
<td>21.5</td>
<td>2.75</td>
</tr>
<tr>
<td>M5 (n = 6)</td>
<td>34</td>
<td>30</td>
<td>-4</td>
<td>21.3</td>
<td>2.625</td>
</tr>
</tbody>
</table>

### Balls

- Wilson A1001 (n = 120)
Methods

• Commercial batting cage facility (50 ft x 16 ft x 12 ft, Frozen Ropes, Franklin, MA)

• Rotating arm pitching machine (Iron Mike, Kansas City, MO.)
  – 45 ft from home plate

• Players (n = 19: 9 professional, 6 college, 4 high school)
  – Bat selection randomized
  – Players rotated hitting sessions (approx. 15 pitches per hitting session)
  – 3 days of data collection

• Ball and bat markers tracked with 4 x 500 Hz infrared cameras (Qualisys, CT)
Matlab Analysis

3D intersection of bat rotation axis with bat plane

bat markers (4)
battery
bat knob
bat linear fit (3D r.b. motion)
bat tip
bat impact location (3D line intersection)
ball velocity (3D linear fit)
ball out
ball in

0.002 sec frames
Results

- Data from all players pooled.
- Pitched ball speeds varied 48 mph – 65 mph
  - No differences found with ball speed, data pooled.
- A total of 1079 pitches recorded, but foul balls, pop-ups and strikes excluded from analysis.

<table>
<thead>
<tr>
<th></th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>158</td>
<td>88</td>
<td>78</td>
<td>99</td>
<td>50</td>
<td>65</td>
</tr>
</tbody>
</table>
3D Kinematic Data

- Instantaneous center of rotation (ICR)
- ICR at impact (n = 533)
  - $32 \pm 3$ in. from tip
  - $3 \pm 2$ in. off of long axis

- 0.004 sec between rendered frames
- ICR is intersection of HAM rotation axis with instantaneous plane of bat motion
Top 10% Hits

Different from wood

* p < 0.01
+ p < 0.05

<table>
<thead>
<tr>
<th></th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>15</td>
</tr>
<tr>
<td>M1</td>
<td>8</td>
</tr>
<tr>
<td>M2</td>
<td>11</td>
</tr>
<tr>
<td>M3</td>
<td>7</td>
</tr>
<tr>
<td>M4</td>
<td>10</td>
</tr>
<tr>
<td>M5</td>
<td>8</td>
</tr>
</tbody>
</table>
Percentage of Hits Above a Given Ball Speed

Cumulative Hits (%)

Batted Ball Speed (mph)

Wood
M1
M2
M3
M4
M5
Percentage of Swings Above a Given Impact Speed

![Graph showing cumulative swings by bat impact speed.](image)
• Postulate an optimal (one-to-one) batted ball speed exists for a given impact speed (bat speed at point of ball impact) for a “solid hit”
• Hits not “solid” (hits off of “sweet spot” and off of bat central axis) account for lower batted ball speeds
• Difficulty in making solid hits with higher bat speeds may account for observed lower batted ball speeds
Batted Ball Speed at Various Impact Locations

- Impact location measured from tip of bat
- “Sweet spot” defined as location of maximum batted ball speeds
How is Performance Increased?

Hypothesize that increased performance is due to increased swing speed and to a “trampoline” effect.

- Top 10% of batted ball speeds with bat M2 were 106.5 mph, as compared to 98.6 mph with wood.

- M2 swing speeds were 3 mph faster than wood for top 10% hits, accounting for an increase of about 4.5 mph in batted ball speed.

- At the average swing speed, the trampoline effect with M2 contributed about 4 mph increase in performance over wood.
"Sweet spots" not different

Normalizing for bat swing speed suggests existence of a “trampoline” effect.
Discussion

- In this novel study, some metal bats significantly outperformed wood bats.
- The performance measured in this study may not be valid for other bats (Four of the five metal bats are now illegal in NCAA play).
- Impact and deformation of ball and bat at impact could not be studied at 500 Hz.
- Kinematics of complete bat swing not analyzed.
Conclusions

- Metal bats can clearly outperform wood bats.
- Increased performance attributed to swing speed and trampoline effect:
  - Swing speed influenced by bat weight and weight distribution
  - Trampoline effect demonstrated indirectly only
Acknowledgements

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• We gratefully acknowledge the bat and baseball manufacturers who donated their products, and the players who participated in the study.