# Baseball Bat Swing Sensor Validation

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**Summary**
A baseball swing analyzer was developed by Blast Motion, Inc. (Carlsbad, CA) and compared with similar sensors from Zepp (San Jose, CA) and Diamond Kinetics (Pittsburgh, PA). The error in swing speed was measured by comparing the results from each sensor to bat speed calculated using 3D motion analysis. All sensors were within 15% of the motion-captured bat speed with the Blast swing analyzer exhibiting the lowest error (7%, $p < 0.01$).

## Methods

*Subjects:*
Fifteen (15) male subjects (age > 17) with no known injuries at the time of testing were included. Each participant was recruited from the local college and minor league teams currently training at the Brickyard Batting cages (San Diego, CA).

*Procedures:*
All 15 subjects swung a baseball bat (33”, 30 oz.) that was equipped with 4 reflective markers (9 mm DIA), which allowed 3D motion analysis of the bat during each swing through an 8 motion capture cameras (Motin Analysis, Santa Rosa, CA) that captured the 3D locations of the markers at a sampling rate of 300 Hz. Three baseball swing sensors were tested in this validation study: 1) Blast Motion, 2) Zepp, and 3) Diamond Kinetics. Each of the 3 baseball swing sensors was attached to the bat in random order and subjects hit a basball off a tee 10 times with each sensor while marker locations were captured from the motion capture system. All trials were performed in a 100’ x 15’ batting cage area.

Baseball swing data were recorded from each sensor using each of their respective sensor mobile applications. Marker data was processed in Cortex (Motion Analysis, Santa Rosa, CA) and a 1-segment baseball bat was created to model the bat based off the 4 reflective markers on the bat.

Each sensor had its own calibration protocol after powering up. The sensors were calibrated prior to each subject starting their 10 swings. The Blast Motion sensor required the creation of a bat for the trial. Required information was brand, nickname, length and weight of the bat. The sensor was then attached to the knob of the bat and a light shake activated and calibrated the sensor. The Zepp sensor required the selection of right or left handedness and then a three second calibration wherein the batter held still in their load position. Movement during the three seconds would result in a failed calibration. The Diamond

Kinetics sensor also required the selection of handedness as well as connecting the sensor through the iPhone bluetooth settings vs. in app like the other two sensors. Once connected the calibration required the bat to be laid horizontally across home plate. After pressing the "Ready" button, the subject then picked up the bat, held still in their load stance for one second and then swung to contact with the ball.

Swing speed (MPH), angular speed (RPM), and bat elevation angle of each swing were then calculated based on the location of the bat's "sweet spot," defined as 6" from the end of the bat. However, angular speed measurements were not available for the Zepp and Diamond Kinetics (DK) sensors. These were compared between sensors using an error value expressed as a % of the respective criterion measured from motion capture. In addition, Pearson correlations were used to estimate the concurrent validity of bat speeds measured with each sensor with respect to that measured with motion analysis. They were then analyzed across all subjects using a 3-level RM-ANOVA at a significance level of $\alpha = .05$. Post hoc pairwise comparisons were made using dependent *t* tests where significant results were found.

**Results and Discussion**

Set-up time for both the Blast and Zepp sensors averaged 90 seconds to complete while the DK sensor took 5 to 10 minutes due to the more involved calibration procedures required. The app for the DK sensor was also not as consistent in detecting readings from the swings. The findings of this validation test showed that the errors in measuring bat speed (mph) for the Blast, Zepp, and DK sensors were 6 ± 2%, 11 ± 6%, and 8 ± 3%, respectively (Figure 1) and were statistically significant ($p < 0.01$). In absolute units, these percentages correspond to errors of 3.4 ± 1.2 mph, 6.5 ± 3.3 mph, and 5.2 ± 2.4 mph. Post hoc testing revealed that the difference in the bat speed errors between the Blast and Zepp sensors was statistically significant ($p < 0.01$) as well as between the Zepp and DK sensors ($p < 0.05$). However, the bat speed error in the Blast sensor was not significantly different from that of the DK sensor ($p > 0.05$). These results show that on average, the BLAST and DK sensors estimate bat speed with up to 94% accuracy.

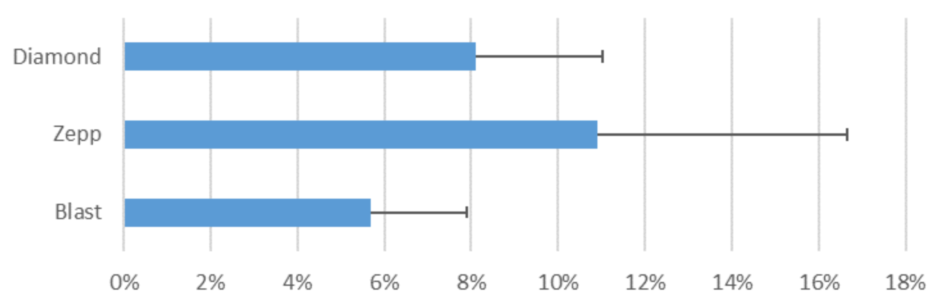


**Figure 1** Error in bat speed (% of motion analysis criterion) for the Blast, Zepp, and Diamond Kinetics sensors.

The bat speeds measured from each sensor are plotted against the corresponding speeds measured with motion analysis in Figure 2. Blast, Zepp, and DK estimated bat speeds with concurrent validities of 0.96, 0.81, and 0.89, respectively. When the correlational analysis was expanded to include all within-subject trials (n=150), the concurrent validities were 0.87, 0.68, and 0.71 for Blast, Zepp, and DK, respectively (Figure 3). Although the total within-subject correlation coefficients are slightly smaller in magnitude as compared to the between-group correlations, both measures of concurrent validities indicate that the sensors, particularly the Blast and DK sensors, can be useful in estimating average bat speed over time in individual players as well as estimating bat speed at any given time for any given player.

Although the elevation angle of the bat swing with each sensor was measured, the comparative data was inconclusive ($p > 0.05$). The motion capture system measures bat angles (azimuth, elevation) using global rotations that are defined from the markers on the bat with respect to the global coordinate system. It is unclear how each of the sensors produce rotations of the bat but in order to reconcile each of their respective estimations with the motion capture angles, they need to transformed into the same reference frame.

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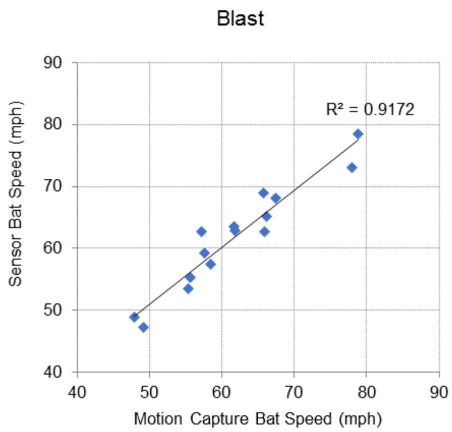


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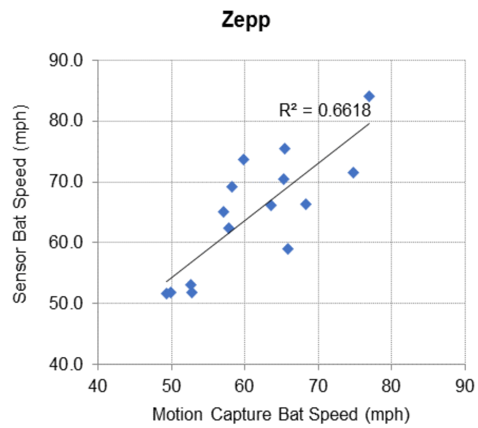


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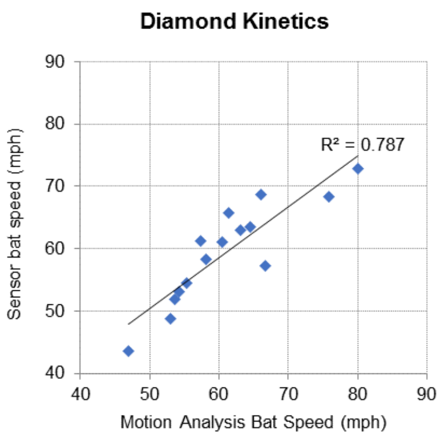


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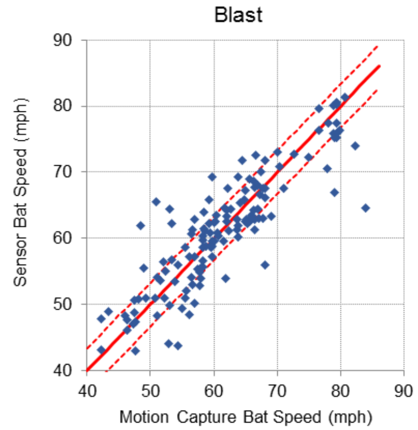
**Figure 2** Bat speed concurrent validity (between-group) for a) Blast, b) Zepp, and c) Diamond Kinetics sensors

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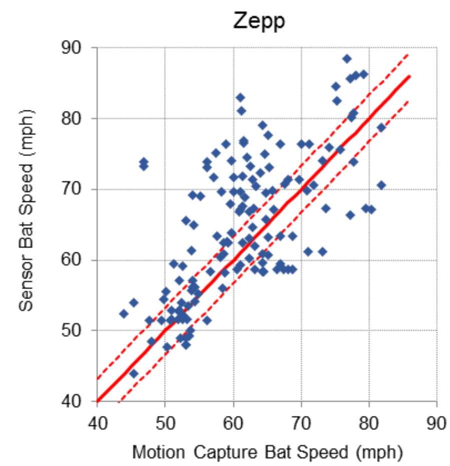


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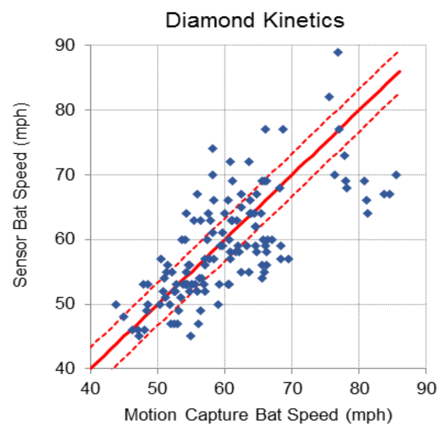


c)

**Figure 3** Bat speed concurrent validity (within-subject) for a) Blast ($r^2$ = 0.759), b) Zepp ($r^2$ = 0.465), and c) Diamond Kinetics ($r^2$ = 0.503) sensors

The average time to contact for the Blast, Zepp, and DK sensors were 0.20 ± 0.10 s, 0.16 ± 0.04 s, and 0.22 ± 0.05 s, respectively, and are shown in Figure 4.

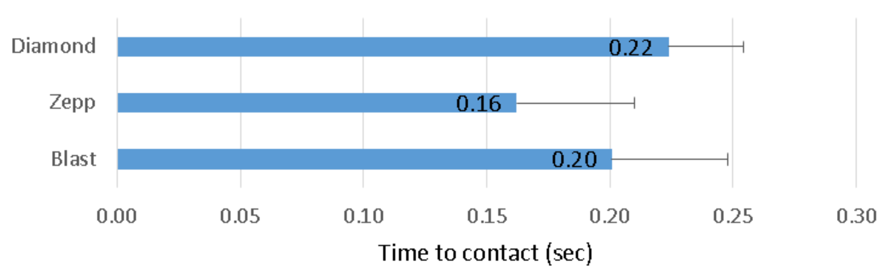


**Figure 4** Time to contact (sec) for Blast, Zepp, and Diamond Kinetics sensors.