Short Communication

Bat swing mechanical analysis with an inertial measurement unit: reliability and implications for athlete monitoring

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Objectives: The purpose of this investigation was to evaluate the intra- and intersession reliability of a new inertial measurement unit (ZEPP Sensor (ZS)) for bat swing mechanical analysis.

Design and Methods: This investigation included 16 male collegiate baseball players (89.53 ± 12.5 kg, 180.61 ± 6.5 cm, 20.12 ± 0.8 years). Following a whole body dynamic warm-up and 5 dry swings, 5 swings were recorded where athletes hit balls off of a tee with bats instrumented with a ZS. Data collection took place on 3 days. Intrasession reliability analyzed trial to trial data, while intersession reliability analyzed data from each of the 3 sessions. Both relative and absolute measures of reliability were calculated with intraclass correlation coefficients (ICC), coefficients of variation (CV), and limits of agreement (LOA).

Results: Within and between session acceleration/time related variables produced excellent relative reliability measurements (ICCs 0.882-0.988) as well as acceptable absolute measures of reliability (CVs 1.9%-9.2%). Variables derived from the gyroscope did not display the same consistency (intrasession vertical angle ICC = 0.492, intersession attack angle CV = 108.6%).

Conclusions: Considering acceleration/time data, the ZS appears to be a reliable method of monitoring bat swing mechanics, but not for the angular position variables. Changes in body position have been demonstrated with fatigue in jumping performance. Similarly, bat position changes may occur with fatigue and should be monitored, but coaches and sport scientists should use caution when selecting variables to monitor and only select those that are reliable.

(*Journal of Trainology* 2016;5:43-45)

Key words: athlete tracking ■ baseball ■ swing velocity ■ fatigue management

INTRODUCTION

Baseball is widely recognized as "America's Pastime" and remains vastly popular presently.[1-2] Although ratings for nationally televised baseball games in the United States may be declining, regional Major League Baseball productions still lead prime time ratings in their respective regions.[3] While the sport remains extremely popular, there is very little published research on methods of athlete monitoring and fatigue management in baseball.[2] Suchomel and Bailey compiled relevant baseball research and recommend multiple areas for monitoring and managing fatigue in baseball players in a recently published article. Briefly, those include: throwing velocity, pitch counts, sprint times, session ratings of perceived exertion, questionnaires, body composition and vertical jump testing.[2] All of these areas seem promising, but there is a lack of studies showing results of implementing these tests into athlete monitoring protocols.

One potentially promising area not outlined in the previously mentioned study is bat swing mechanics.[2] Bat speed and batted-ball velocity have been discussed previously as assessments of baseball-related performance.[4] But they were not described for monitoring purposes or for frequent evaluation. Furthermore, setting up equipment and recruiting personnel to operate it may prove problematic if done on a frequent basis (weekly or daily).

Recently, an inertial measurement unit (IMU) was attached to the knob of a bat and evaluated for the purpose of analyzing 3 dimensional bat swing mechanics.[5] Within the past year a similar technology has been made available to the general public (ZEPP© sensor (ZS)) and is marketed to several sports. With the availability of this new product, there is an opportunity for monitoring of more sport-specific variables for baseball. But, currently no research has been completed on the reliability of this unit, and repeatability of measures is paramount for athlete monitoring. Therefore, the purpose of this investigation was to evaluate the within (intra) and between (inter) session reliability of the ZS.

METHODS

Subjects for this study included 16 male collegiate baseball players (89.5 ± 12.5 kg, 180.6 ± 6.5 cm, 20.1 ± 0.8 years). Each subject was required to attend all 3 testing sessions in order to be included in the study. Prior to participation, all subjects read and signed informed consent documents approved by the college's Institutional Review Board.

Upon walking into the lab, all athletes were measured for height and weight and they selected a bat size for the test. They were allowed to pick their bat, but they were required to use the same bat for every swing and session. Prior to bat swing analysis with the ZS, athletes performed a dynamic warm-up, which focused on all major muscle groups. Tee

Received July 29, 2016; accepted September 12, 2016
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height and position from the tee were also standardized. Tee height was self-selected by each athlete, but the same height was used for every swing and session. Similarly, batter's position from the tee was also self-selected, but was the same for every swing and session. This was accomplished by measuring and labeling the position of the mid-point of the calcaneus of the rear foot for each athlete. Athletes then placed their heel just in front of their label on subsequent testing sessions. Allowing athletes to self-select their bat, tee height, and batting position helps to conserve ecological validity. Following the dynamic warm-up and position measurements, athletes performed five dry swings and then 5 swings hitting the ball off the batting tee. Next, the bats were instrumented with the ZS (see Figure 1) and each athlete performed three maximal effort swings, hitting a ball off of the tee.

Figure 1 Baseball bat instrumented with the ZEPP sensor.

The ZS was recalibrated prior to usage for each athlete. The position of the ZS was also kept constant for each swing with the ZS button always positioned in the lower/posterior position. The variables obtained by the ZS include bat speed at contact (PV@C), max hand speed (PV), time to contact (TtoCon), vertical angle (Vert θ), and attack angle (Attack θ).

Statistical Analysis

All statistical analyses were performed with SPSS software (version 21, Armonk, NY). Measurement of relative reliability (intra- and intersession) was accomplished with intraclass correlation coefficients (ICC) in accordance with Bartko.[6] Interpretation of ICC values were based on the classification provided by Fleiss, where ICC > 0.75 = excellent, 0.40 – 0.75 = fair, < 0.40 = poor.[7] Along with ICC data, 95% confidence intervals were also included. Coefficients of variation (CV) were used to evaluate absolute reliability and similar to previous research, CV ≤ 15% were desired.[8] Bland-Altman plots and limits of agreement (LOA) were also completed by plotting the individual measurement differences against the average.[9] Prior to statistical analysis, data were evaluated for heteroscedasticity and log transformation would be completed if necessary. Heteroscedasticity was evaluated by determining the correlation coefficient between the trial to trial and session to session individual differences and variable means.

RESULTS

All data were transformed with the natural log as heteroscedasticity was indicated for most variables. Descriptive statistics prior to data transformation are displayed in Table 1. The results of within and between session reliability analysis are shown in Tables 2 and 3 respectively. Excellent relative reliability was observed for all of the acceleration-time and time variables (PV@C, PV, TtoCon) within and between sessions (ICCs ranging from 0.882 to 0.988). Similarly, absolute reliability was also acceptable for those same variables, with CVs ranging from 1.85 to 9.2%. Excellent relative reliability was seen within session for Attack θ (0.881), but the CV was slightly above the 15% threshold. Fair relative reliability was noted for within session Vert θ and between session Vert θ and Attack θ, but absolute measures of reliability were beyond the 15% threshold.

Table 1 Descriptive statistics (mean ± standard deviation) from all sessions prior to log transformation.

Variable	mean ± standard deviation
PV@C (m/s)	31.8 ± 2.9
PV (m/s)	11.9 ± 1.3
TtoCon (s)	0.2 ± 0.0
Vert θ (°)	-15.8 ± 18.2
Attack θ (°)	4.3 ± 13.9

PV@C = peak velocity at contact, PV = peak velocity, TtoCon = time to contact, Vert θ = vertical angle, Attack θ = attack angle

Table 2 Within and between session reliability results. Intraclass correlation coefficients (ICC) with 95 % confidence intervals ([lower bound, upper bound]) coefficients of variation (CV) and limits of agreement (LOA). Transfromed data exponentiated to present LOA as a dimensionless measure multiplied/divided by 2 standard deviations.

	Within Session			Between Session		
Variable	ICC [95% CI]	CV	LOA	ICC [95% CI]	CV	LOA
PV@C	0.959 [0.934,0.976]	2.0%	1.1 ×/÷ 0.1	0.969 [0.929,0.988]	1.9%	1.1 ×/÷ 0.0
PV	0.928 [0.883,0.957]	2.8%	1.1 ×/÷ 0.1	0.949 [0.882,0.981]	2.8%	1.1 ×/÷ 0.0
TtoCon	0.944 [0.910,0.967]	9.2%	1.1 ×/÷ 0.1	0.961 [0.911,0.985]	8.9%	1.1 ×/÷ 0.1
Vert θ	0.492 [0.179,0.698]	11.8%	2.4 ×/÷ 12.1	0.646 [0.183,0.866]	16.5%	1.9 ×/÷ 0.7
Attack θ	0.881 [0.808,0.929]	15.2%	1.6 ×/÷ 2.4	0.634 [0.155,0.861]	108.6%	1.5 ×/÷ 0.4

ICC = intraclass correlation coefficient, CI = confidence interval, CV = coefficient of variation, LOA = limits of agreement, PV@C = peak velocity at contact, PV = peak velocity, TtoCon = time to contact, Vert θ = vertical angle, Attack θ = attack angle

DISSCUSION

The primary purpose of this study was to determine the within and between session reliability of the ZS. The primary finding was that acceleration/time based variables were reliable within and between sessions, but the angular position measurements were not reliable. PV@C, PV, and TtoCon all resulted in excellent relative measures of reliability and acceptable measures of absolute reliability for both intra and intersession reliability (ICCs ranged from 0.928 – 0.969, CVs ranged from 1.85% – 9.20%). Therefore, using the ZEPP sensor to monitor these variables is recommended.

Throwing velocity has been indicated as an appropriate measure of fatigue in adolescent baseball players and it seems logical that bat swing velocity would follow the same trend.[10] However, to the current authors' knowledge, no research has been completed on the validity of bat swing velocity to indicate acute or chronic fatigue. The current authors recommend monitoring bat swing velocity as a measure of chronic fatigue, but further research needs to be completed to fully justify and validate this recommendation.

Concerning the bat position measurements, the reliability results were not as good. Within session reliability was excellent for Attack θ (ICC = 0.808), but this was not the case for Vert θ or for either Attack θ or Vert θ between sessions. Within session absolute reliability was acceptable or very close to it (Vert θ = 11.80%, Attack θ = 15.24%), but this was not the case for between session reliability (Vert θ = 16.54%, Attack θ = 108.56%). Based on the results of this study, the gyroscope and the position/time related variables are not reliable. As a result, monitoring bat position with the ZEPP sensor is not recommended.

Fatigue has been shown to alter body position in vertical jumping tasks.[11] Similarly, alterations in bat position throughout a swing may be related to onset or accumulation of fatigue. But similar to bat swing velocity, more research is required to validate this speculation. The finding of a lack of consistency in angular position measurement is unfortunate in that coaches and sport scientists will not be able to analyze and make decisions based upon changes of these variables. The probable culprit for these poor reliability measures in this study is likely the gyroscope or the integration of the gyroscope with the acceleration/time data. It should be noted that this study utilized the same unit for all swings/subjects. While this may not be likely, if the gyroscope or any part of the unit was faulty, it could negatively influence the results of all subjects.

Heteroscedasticity was present for several variables, thus necessitating data transformation. The existence of heteroscedasticity indicates that athletes may have different levels of variability if they are producing values at either end of the spectrum (high or low). While this can influence validity and regression, this may not be an issue for athlete monitoring. But, this assumes that the variability is similar and always in the same direction, thus preserving reliability.

PRACTICAL APPLICATIONS

The reliability findings of this study indicate that the ZS can be used for tracking velocities and TtoCon in an athlete monitoring program specific for baseball and possibly softball athletes. Changes in bat swing velocity may be indicative of fatigue and should be monitored throughout a season and training program. Changes in bat position during the swing could also be a symptom of accumulated fatigue throughout a season. Unfortunately, due to the poor reliability results of the angle measurements in this study, the authors cannot recommend tracking them with the ZS.

CONCLUSIONS

The primary finding of this investigation was that the ZS appears to be a reliable method of monitoring acceleration/time related bat swing mechanics variables, but not for the angular position variables. Changes in bat swing mechanics may occur with fatigue and should be monitored, but coaches and sport scientists should use caution when selecting variables to monitor and only select those that are reliable. Future research should be directed at IMU derived bat swing variables in areas of validity, acute and chronic fatigue monitoring, associations with baseball offensive performance variables and baseball monitoring variables, as well as alterations throughout a full season.

ACKNOWLEDGEMENTS

The authors would like to thank the LaGrange College baseball players for participating in this study as well as the undergraduate exercise science students who helped out with data collection. This study was not funded by any source.

REFERENCES

1. Asser J. Major League Baseball still going strong in USA's sporting popularity race. Retrieved 11/24, 2015, from http://sport360.com/article/us-sports/39716/inside-story-major-league-baseball-still-going-strong-usas-sporting
2. Suchomel TJ, Bailey CA. Monitoring and managing fatigue in baseball players. *Strength Cond J* 2014;36:39-45.
3. Brown M. MLB Completely Dominated Local Prime Time TV During The 2014 Season. Retrieved 11/24, 2015, from http://www.forbes.com/sites/maurybrown/2014/10/03/mlb-completely-dominated-local-prime-time-tv-during-the-2014-season/
4. Spaniol F. Baseball athletic test: A baseball-specific test battery. *Strength Cond J* 2009;31:26-29.
5. King K, Hough J, McGinnis R et al. A new technology for resolving the dynamics of a swinging bat. *Sports Engineering* 2012;15:41-52.
6. Bartko JJ. The intraclass correlation coefficient as a measure of reliability. Psychological Reports 1966;19:3-11.
7. Fleiss JL. *Reliability of measurement. The design and analysis of clinical experiments*. New York, NY: Wiley, 1986.
8. Stokes M. Reliability and repeatability of methods for measuring muscle in physiotherapy. *Physiother Theory Pract* 1985;1:71-76.
9. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307-310.
10. Freeston J, Adams R, Ferdinands RED et al. Indicators of throwing arm fatigue in elite adolescent male baseball players: A randomized crossover trial. *J Strength Cond Res* 2014;28:2115-2120.
11. Pupo JD, Dias JA, Gheller RG et al. Stiffness, intralimb coordination, and joint modulation during a continuous vertical jump test. *Sports Biomech* 2013;12:259-271.