Undergraduate Review

Volume 9 Article 20

2013

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Kevin McElwee

Recommended Citation

McElwee, Kevin (2013). Preliminary Findings: Speed-Accuracy Tradeoff in Windmill Fastball and Change-up Pitching. *Undergraduate Review*, 9, 94-98.

Available at: http://vc.bridgew.edu/undergrad_rev/vol9/iss1/20

Preliminary Findings: Speed-Accuracy Tradeoff in Windmill Fastball and Change-up Pitching

Kevin McElwee

At the time of submission, Kevin McElwee was a senior majoring in Physics at BSU. This research began as an Adrian Tinsley Program (ATP) Semester Research Grant in the Fall of 2010 under the mentorship of Dr. Pamela Russell. His work was presented at the 2012 National Conference on Undergraduate Research in Ogden, Utah. Kevin currently works as an R&D Engineer in the Oncology Department at Angiodynamics.

Little data have been collected that compare the linear velocity of the ball at release versus the accuracy of the pitch in fast-pitch windmill softball pitching. Previous research suggests that accuracy of a task may decrease as the speed of the task increases. Little research exists that previously compares the speed and accuracy of fastball and change-up pitches in windmill softball pitching. These data may assist the batter in decoding the type of pitch being thrown before the ball is released from the pitcher's hand. It was hypothesized that the slower change-up pitch might be more accurate and the faster pitch less accurate. Three female subjects (20 ± 1 years old) volunteered to throw ten fastball and ten change-up pitches. Sagittal plane video data were recorded and analyzed with Dartfish Software (v5.5). The accuracy of the pitch, linear ball velocity, elbow and hip angles of the pitcher at ball release, and mean angular shoulder flexion velocity throughout the pitch were measured. Mean elbow angles at release were significantly different (t = 0.03), which suggests that the batter might be able to detect the pitch via elbow mechanics. Mean hip angles were similar and showed no significant difference (t=0.32), which suggests that the batter could not use hip mechanics to decode the pitch. Spearman Rho correlations (n = 30) between linear ball velocity at release and accuracy were not significant (fastball = .20; change-up = -.21); however, the change-up pitch best resembled the speed-accuracy relationship.

Introduction

Research supports an inverse relationship between the speed and accuracy of a task (Fitts, 1954). Fitts designed three different experiments to observe how the accuracy of a motor task changed as the necessary movement decreased and the target area increased. Fitts defined a motor task to be any movement of a particular limb, particular set of muscles, or a particular motor behavior. His findings indicated that increasing the necessary movement of a task leads to a decrease in the accuracy of the task. In this study, the authors examined the speed-accuracy relationship between the fastball and change-up pitches using the fast-pitch windmill softball pitching motion in an on-the-field scenario. Given Fitts's findings, the slower change-up pitch might be more accurate and the faster pitch less accurate. The author's purpose was to study the relationship between the linear velocity of the ball at release with the accuracy of the pitch upon reaching home plate. Understanding this relationship in softball pitching could help batters decode these pitches by recognizing differences in the speed-accuracy trade-offs of each pitch. Van

Den Tillaar and Ettema (2006) studied the speed-accuracy tradeoff with over-arm throwing in team handball with novice and expert players. Their results suggested that the speed-accuracy tradeoff did not exist in team handball. The authors of this study initially concluded that the training regimen of these players affected their data. After manipulating the goal of the task, the participants yielded similar results and thus determined that the lack of the speed-accuracy relationship in their results was not due to the players' training regimen. Additionally, Van Den Tillaar and Ettema (2003) examined how instruction specifically affected the speed and accuracy of over-arm throwing in team handball when both skills were emphasized at different magnitudes. The authors instructed the participants to focus on varying levels of concern to both the speed and accuracy of the throw. The authors noted that when they stressed accuracy, the velocity of the throw decreased. However, as the emphasis on accuracy increased, the accuracy of the throw did not continue to rise; though the velocity of the throw did continue to decrease. These findings suggest that the levels of instruction provided to the participants could severely affect data if the purpose of the study were to replicate an in-game scenario. Since this current study does attempt to replicate an in-game scenario, these findings are relevant. During this current study, the authors did not instruct the pitcher to focus more on the ball velocity at release rather than the accuracy or vice versa. Rather, the participants were instructed to throw as if they were participating in a live inning. Amongst this previous research, little data have been collected that studied the speed-accuracy trade-off in softball pitching. Thus, the purpose of this study was to examine how the linear velocity of the ball at release would affect the accuracy of the pitch in fast-pitch windmill softball pitching.

Methods

Participants. Three females (20.00 ± 1.00 yrs; 1.69 ± 0.02 m) volunteered to participate in this study. Our participants had a mean pitching experience of 11.00 ± 3.10 years and each participant provided University-approved informed consent to participate. Each subject listed high school or college pitching experience as highest level of play.

Experimental Setup. The pitching mound was set up 13.11m (NCAA regulation) from a regulation-size softball home plate (Abrahamson, 2010). The target, representing the strike zone, was taped onto the wall. The distance between the floor and the center of the target was 0.86m. The center of the strike zone was centered with the pitcher's mound. Sagittal plane video data were recorded at 60 Hz with a Sony Handycam DCR DVD650 positioned perpendicular to the plane of movement at a height of 1.07m to maximize the image of the pitching motion.

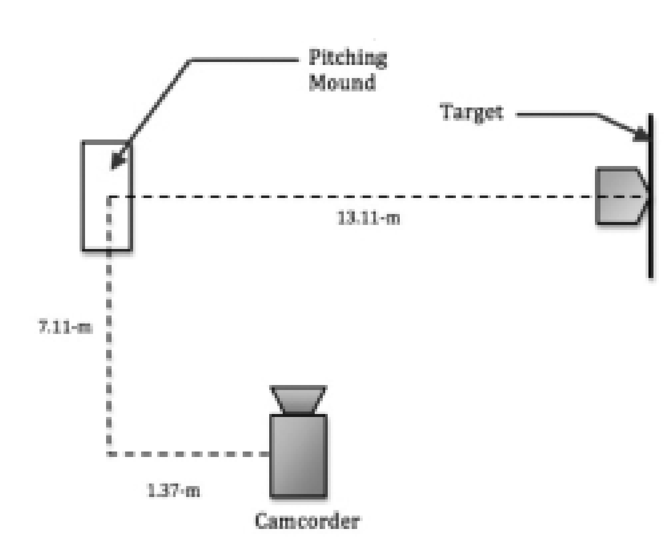

Figure 1. **Experimental Setup**. Aerial view of our experimental setup. McElwee photo.

The target, used to measure accuracy, was composed of carbon paper overlaid on white paper (0.91m by 0.91m each). Five concentric circles were drawn on the white sheet of paper. The first circle was 7.62 cm in radius.

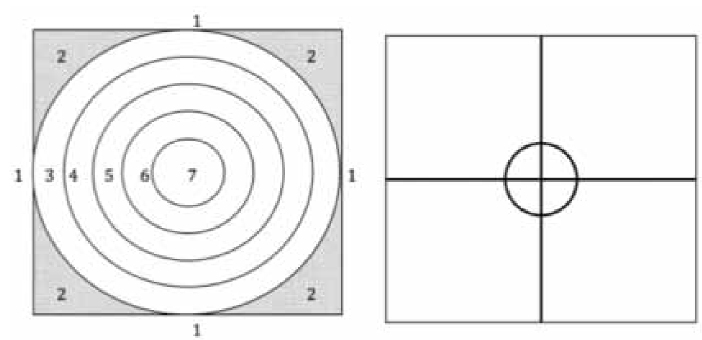

Figure 2a (left). **Strike Zone Bull's Eye**. Target with point values for each area, ranging from 7 (most accurate) to 1 (least accurate). (McElwee photo).
Figure 2b (right). **Strike Zone Target**. The pitcher saw this as they threw at the target. (McElwee photo).

Each successive circle increased by 7.62 cm in radius. A final sheet of white paper was overlaid on the carbon paper with a cross hair (the cross hair in Figure 2b was the same size as accuracy zone 7 in Figure 2a). Each pitcher was given ten minutes to warm up as if she were preparing for a game. Once ready to pitch, the authors placed joint markers on several bony landmarks: acromion process, lateral epicondyle of the humerus, greater trochanter of the femur, proximal fibular head, and the distal radio-ulnar joint (all on the same side of the pitching arm).

Figure 3. **Joint Markers**. Joint marker placement: (1) acromion process, (2) lateral epicondyle of the humerus, (3) greater trochanter of the femur, (4) proximal fibular head, (5) distal radioulnar joint. McElwee photo.

Each pitcher threw ten fastball pitches and ten change-up pitches. The pitcher was told to aim for the center circle of the target. Twenty pitches per pitcher created a fair balance between a realistic number of pitches thrown by a pitcher in one inning and a high number of data points, which was ideal for analysis. The type of pitch thrown first (i.e., fastball or change-up) was randomized to reduce order effect. After each pitch, the researchers recorded the accuracy score by observing the mark left by the softball on our target. The authors chose the accuracy score based on the location of the central mark left by the ball.

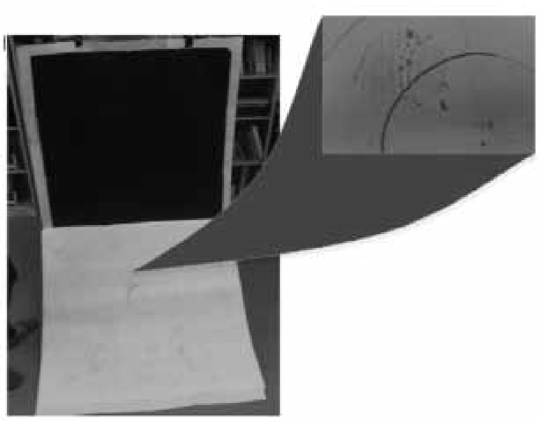

Figure 4. **Ball Marking**. Actual target with a magnified view of the mark left by the softball. McElwee photo.

Data Analysis. Using Dartfish Software (v 5.5), shoulder angles were measured by finding the angle between the lateral epicondyle of the humerus, acromion process, and the greater trochanter of the femur. Elbow angles were measured between the acromion process, lateral epicondyle of the humerus, and the distal radio-ulnar joint. Hip angles at release were measured between the acromion process, greater trochanter of the femur, and the proximal fibular head. Angular shoulder flexion velocities were calculated between each frame (1/60 sec.) from the twelve o'clock stage of the pitch until release using the measured shoulder angles. These individual angular shoulder flexion velocities were averaged throughout the entire pitching motion to create an average angular shoulder flexion velocity for each pitch. The average shoulder flexion velocities were compared to find potential differences between fastball and changeup pitches. These data might help indicate any variations in the pitching motion, which may tip the batter with knowledge of which pitch type was being thrown before the softball left the pitcher's hand. Furthermore, linear ball velocities at release were calculated by measuring ball displacement from the point of release until one frame afterwards. Linear ball velocity data were correlated (Spearman rho) with the accuracy scores to assess the relationship between speed and accuracy. A paired two-tailed t-test ($p < .05$) was used to find significances between elbow angles and hip angles during the fastball and change-up pitches.

Figure 5a (left). **Elbow Angle at Release**. Elbow angle of each pitcher's throwing arm at release. (McElwee photo).
Figure 5b (right). **Shoulder Angle at 12 O'clock.** Shoulder angle near the 12 o'clock position. (McElwee photo).

Results & Discussion

The elbow angle of the throwing arm at release was 156.87 ± 8.94° (fastball) and 152.20 ± 11.25° (change-up). A t-test comparing the elbow angle between the two pitches showed a significantly strong difference ($t = 0.03$). This indicates that there is a significant difference between the elbow angles at release for fastball versus the change-up pitch. The batter might be able to detect which pitch type was about to be thrown based on the detection of elbow mechanics. Whether or not the batter is capable of detecting these mechanics in the time it takes the ball to travel from the pitcher's hand to home plate is not covered in this study. This study attempts to show that the elbow mechanics are different, which demonstrates that there is an opportunity for the batter to detect the type of pitch being thrown based on the elbow mechanics. The hip angle at release was 167.79 ± 5.93° (fastball) and 166.86 ± 6.58° (change-up). A t-test between these two measurements showed no significant difference (t = 0.32), suggesting that the batter would not have the opportunity to decode fastball versus change-up pitch type by looking for a difference in the pitchers' hip angle.

Table 1. Accuracy and Linear Kinematics

	Fastball Mean + SD	Change-up Mean + SD	p
Elbow Angle (°)	156.87 ± 8.94	152.20 ± 11.25	0.03
Hip Angle (°)	167.79 ± 5.93	166.86 ± 6.58	0.32
Release Velocity (m/s)	23.87 ± 3.67	17.14 ± 1.25	0.00
Accuracy (points)	3.50 ± 1.94	1.73 ± 1.23	0.00

Mean shoulder flexion velocities were 886.89 ± 371.21 $°s^{-1}$ (fastball) and 810.06 ± 321.12 $°s^{-1}$ (change-up). Use of a mean value over the entire delivery and variability in skill level may account for such large standard deviations in angular velocity. Mean shoulder flexion velocities were calculated in order to observe if there was a quantitative difference in the shoulder flexion velocities between the fastball and change-up pitches. This could prove to be an advantage to the batter if the batter could determine the pitch type during the pitching motion. Mean linear ball velocities at release were significantly different between the fastball (23.87 ± 3.67 m/s) and change-up (17.14 ± 1.25 m/s) pitches. Since little research exists that is similar to this study, no data can be compared to the author's data. Furthermore, mean accuracy scores were also significantly different between the fastball (3.50 ± 1.94 points) and change-up (1.73 ± 1.23 points) pitches. Spearman Rho correlations (n = 30) between linear ball velocity at release and accuracy were not significant (fastball = .20; change-up = -.21). The change-up tended to resemble the speed-accuracy relationship more than the fastball. This could be due to the fact that a successful fastball pitch is designed to be thrown at a faster linear velocity. Therefore, throwing a fastball pitch at a slower linear velocity could make it more difficult to throw, thus less accurate. As a result, the linear ball velocity and its accuracy are proportionally related, which contradicts the speed-accuracy relationship. Likewise, the change-up pitch is designed to be thrown at a slower linear velocity. Therefore, throwing a change-up pitch at a faster linear velocity could make it more difficult to throw, and thus less accurate. The relationship between the linear ball velocity and the accuracy of the pitch shows that the two measurements are inversely proportional, which matches the speed-accuracy relationship.

This research study encountered three limitations. One, while the strike zone target successfully measured for accuracy, it was not realistic to a game scenario. The pitchers preferred to aim at the corners of the target since they were accustomed to this while playing in a game. They tended to feel uncomfortable throwing at the center bull's eye of the author's target, which would be located at the center of a batter's strike zone when pitching in a game scenario. A different strike zone should be used when measuring accuracy. This strike zone should not only measure for accuracy, but it should also better resemble a strike zone used in a game scenario. Perhaps four bull's eyes could be placed in the four corners of a square strike zone and the pitcher could aim for a specific bull's eye on each pitch. Furthermore, the frame rate capture of the video camera used for recording video of the pitcher's throwing motion was mediocre. While 60Hz was sufficient, 120Hz would be a much better frame rate for measuring the linear ball displacement at release in order to calculate the linear ball velocity at release. Finally, two subjects listed college experience as their highest level of play and one listed high school experience as her highest level of play. This disparity in experience could affect data if the data are different between college and high school pitchers. If continued further, additional studies should choose high school or college pitchers instead of using subjects from both groups. In doing so, comparisons can be drawn between the velocity and linear kinematics between different levels of skill or age groups. If there are differences, then combining subjects from multiple skill levels or age groups into one study could lead to higher standard deviations in data. Data were similar between the two skill levels in this study, which minimized the effect of this limitation on this study.

Conclusion

This study set out to determine if the speed-accuracy tradeoff existed in fast-pitch windmill softball pitching. Three subjects threw ten fastballs and ten change-up pitches. By comparing the linear velocities of the softball at release with the accuracies of each pitch based on a point system with our target, it was determined that the change-up pitch best resembled the speed accuracy tradeoff. The accuracy of the fastball pitch tended to increase as the linear velocity of the ball increased at release.

This could be due to the fact that a fastball pitch is intended to be thrown at a faster linear velocity rather than a slower one. Thus, throwing a fastball pitch at a slower linear velocity could result in a decrease in accuracy, which disagrees with the speed-accuracy relationship. The change-up pitch, however, did follow the speed-accuracy relationship. Since a change-up pitch is intended to be thrown at a slower linear velocity, throwing it faster may decrease the pitch's accuracy. Thus, the change-up pitch would follow the speed-accuracy relationship. Both correlations, however, were weak. While statistically similar mean hip angles at release suggest that the pitcher's mechanics during the fastball and change-up pitches do not appear to be different to the batter, statistically different mean elbow angles suggest that the batter might be able to detect the pitch type before it leaves the pitcher's hand.

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