STRIDE STRATEGY ON FASTBALL PERFORMANCE IN COLLEGIATE BASEBALL PITCHERS

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Our study aimed to determine if a baseball pitcher's stride strategy impacts pitching performance. Pitchers use two global strategies when striding down the mound. One strategy consists of dropping their center of mass (COM) and propelling forward the other consists of maintaining a higher COM when striding out. The effects of the stride phase on pitching velocity are not firmly established. In contrast to prior work, vertical COM displacement during the stride phase was used as a continuous variable to determine if the stride strategy impacted pitching velocity. Pitch velocity prediction models were improved by max negative COM displacement (lowest position) and max positive COM displacement (highest position) and timing of max positive COM displacement. Regardless of strategy, increasing vertical COM displacement in either direction increased performance.

KEYWORDS: Push off, Pitch Velocity

INTRODUCTION: Baseball pitchers broadly display two unique pitching styles related to their strides (Beaudry et al., 2022; Beaudry et al., 2023). Among these styles are a tall and fall and a drop and drive approach to striding down the pitching mound. The tall and fall style displays a higher pelvis than the drive-leg knee at foot contact. Thus, maintaining a higher pelvis results in a more vertical trajectory (Ryan et al., 1991), potentially capitalizing on the effects of gravity. The drop and drive style is characterized by greater drive-leg knee flexion, and upon landing, the pitcher portrays a lunge position with more lead-knee flexion (Chen et al., 2021). Compared to the tall and fall style, pitchers using the drop and drive approach accelerate forward with earlier and higher drive-leg kinematics involved in push off (Chen et al. 2021). Each of these stride strategies can support the pitch delivery.
A pitcher's stride pattern is thought to develop from training philosophies originating from Asia or America (Escamilla et al., 2002; Oi et al., 2019) and a pitcher's anthropometrics (Chen et al., 2021; Osinski, 1998). In either method, pitchers take advantage of specific characteristics (physical, environmental, informational, etc.) and adapt to find a stable movement solution to optimize performance (Davids et al., 2013). Prior research investigating stride strategy reported increased elbow kinetics (Chetlin et al., 2017) and risk of ulnar collateral injury (Beaudry et al., 2022; Beaudry et al., 2023) in pitchers adopting the tall and fall technique. Yet, risk factors such as pitch speed and anthropometrics were not accounted for and possibly impacted the results (Giordano et al., 2024). Limitations are present in determining clear mechanical cutoff points for classifying each stride style and the relationship of variables of interest can be distorted when dichotomizing a continuous variable (Cohen, 1983). Specifically, Chen's group classified stride type by sacral displacement from a straight line trajectory of the pelvis during the stride phase, and Beaudry's group classified from front knee angle at foot contact. This study investigated the effect of stride style on pitching performance when retaining stride style as continuous variables and accounting for anthropometrics.

METHODS: This study included in game, motion capture data on 64 Division I collegiate pitchers (1.89 ± 0.06m, 93.06 ± 9.44kg) from the southeastern conference. The university's Institutional Review Board approved this research under the exemption category. Included pitchers threw at least 4 four-seam fastballs in their respective outings and did not deliver the ball in a submarine (underhanded) manner.

An eight-camera, markerless motion capture system (KinaTrax, Inc., Boca Raton, FL) collected pitching data at 300 Hz. Cameras are permanently mounted around the host stadium and were digitally calibrated before each game. KinaTrax proprietary algorithms were used to process kinematic and temporal data, as well as detect critical pitching events during the motion. These were then paired with pitch metric data obtained by ball tracking technology (TrackMan, V3 Game Tracking, Scottsdale, AZ). Computed pose estimations were consistent with the International Society of Biomechanics recommendations (Wu et al., 2002, 2005) and filtered using a second-order, low-pass filter at cutoff frequencies of 6, 10, and 20 Hz for the legs, trunk, and arms, respectively, as set by KinaTrax.
Extracted variables from pitching trials were the global center of mass (COM) position in the vertical (upward) and anteroposterior (forward-backward) directions, which were later used to compute positive and negative vertical displacement that occurred during stride. Pitch velocity was determined from the point of release. All units are presented in their native form to foster the transfer of information to other users of the KinaTrax platform. However, SI unit conversions are included.
To retain a pitcher's stride style as a continuous variable, a custom MATLAB (Mathworks, Natick, MA) algorithm was used to process time-series KinaTrax pitching data. We tracked the body COM from the stride leg's peak knee height to foot contact in the vertical plane from the pitcher to the catcher, and that path was compared to a straight-line trajectory, or average path, between those points (Chen et al., 2021). In contrast to prior work that discretized stride style into categorical groups, we took the highest upward (maximum positive) and downward (maximum negative) vertical displacements from the body's COM path relative to a straight-line trajectory. We used these values as continuous independent variables. The term maximum negative displacement was used to avoid confusion for the reader and reflects the greatest distance below the straight-line trajectory from peak knee height to foot contact as opposed to "minimum displacement," which could be interpreted as lesser magnitudes of displacement. The percent of time between peak knee height (0%) and stride foot contact (100%) was then calculated where both the positive and negative maximum displacement occurred.
Separate multilevel models were run using maximum positive and negative COM displacement to predict ball velocity as our performance metric (Whiteside et al., 2016). Separate models were used for positive and negative displacement due to differing theorized mechanisms for power generation between tall and fall vs. drop and drive stride styles (Ryan et al., 1991). Each model predicting velocity was built into progressively more complex models, beginning with our covariate model of height and mass (Giordano et al., 2024). We then added level 1 explanatory variables of the pitcher's maximum COM displacement and maximum displacement timing while allowing random intercepts to vary across pitchers. We then allowed the slopes of height and mass to vary across pitchers. Lastly, we added a cross-level interaction between COM displacement and height to determine if the pitcher's height influences the relationship between COM displacement and fastball velocity.

RESULTS: Descriptive statistics for fastball velocity, maximum negative vertical COM displacement, timing of maximum negative vertical COM displacement, maximum positive vertical COM displacement, and timing of maximum vertical COM displacement are reported as within pitcher means in Table 1. Timing values are represented as a percentage of the stride phase (peak knee height to stride foot contact) when the maxes of the variables occurred.

Table 1: Descriptive statistics.

Variable	Mean ± SD
Fastball Velocity (m/s)	40.54 ± 1.29
Max Negative Vertical COM Displacement (m)	-0.023 ± 0.012
Timing of Max Negative Vertical COM Displacement (%)	18.1 ± 5.75
Max Positive Vertical COM Displacement (m)	0.044 ± 0.029
Timing of Max Positive Vertical COM Displacement (%)	65.7 ± 7.8

For investigating the drop and drive pitching style, the covariates of height (β = 7.75, p = 0.10) and weight (β = 0.014, p = 0.73) did not improve the model predicting ball velocity. Negative COM displacement improved our model's ability to predict ball velocity (β = -0.45, p = 0.021), where each 0.0254m (1 inch) of vertical displacement beneath the COM straight-line trajectory resulted in a 0.20 m/s (0.45 MPH) increase in fastball velocity. The timing at which the maximum negative displacement occurred did not influence ball velocity (β = -1.55, p = 0.36). Allowing height and mass slopes to vary across pitchers resulted in an unstable model. It did not improve the predictability of ball velocity, resulting in cross-level interactions not being added to this model.

For investigating the tall and fall pitching style, adding the covariates of height (β = 9.06, p = 0.050) and mass (β = 0.013, p = 0.74) improved the overall model (ΔAIC = -1.18) predicting ball velocity, with height being the driving contribution. Positive COM displacement (β = 0.54, $p < 0.001$) and timing of maximum positive COM displacement (β = 1.82, p = 0.023) reduced inter-pitcher variance by 9.9% and improved our model's ability to predict ball velocity. Once again, allowing random slopes for height and mass resulted in unstable convergence of the model. Therefore, we did not proceed to add a cross-level interaction to this model.

Differences in the covariate contribution can be attributed to fifty-two pitches excluded in the negative COM displacement model. This was due to maximum negative COM displacement occurring just before foot contact rather than during the stride when considering the "drop" in "drop and drive."

DISCUSSION: The results of this study suggest that greater displacement of the COM from a straight-line path will result in increased fastball velocity in collegiate baseball pitchers. Specifically, for every 0.025m (1 inch) of COM displacement below the straight-line trajectory (a pitcher displaying more 'Drop and Drive' strategy) resulted in a 0.20 m/s (0.45 mph) increase in fastball velocity. Additionally, each 0.025m (1 inch) of COM displacement above the straight-line trajectory (a pitcher displaying more 'Tall and Fall' strategy) resulted in a 0.81 m/s (1.82 mph) increase in fastball velocity. These results taken together identify that there may be more room for performance enhancement for pitchers who demonstrate pitching mechanics that are associated with a 'Tall and Fall' strategy. However, when including the COM displacement variables, there was a larger reduction in between-pitcher variance rather than within-pitcher variance, suggesting that the fluctuations in a pitcher's COM displacement from pitch to pitch did not explain substantial performance variance.

Surprisingly, only the timing of the maximum positive vertical COM displacement influenced pitch velocity, where the later the maximum occurred, the higher the fastball velocity was. This finding suggests that those using the 'Tall and Fall' strategy may benefit from keeping their COM higher and holding it higher for longer. While the vernacular of 'Tall and Fall' and 'Drop and Drive' were used in this paper to conform to prior literature, a fundamental difference was the lack of categorizing pitchers into discrete groups of stride styles. This caused every pitcher's positive and negative COM displacements to be used in their respective model, so we are unable to specifically state there is a "better" strategy, which aligns with Beaudry's work that did not identify velocity differences between stride styles. However, because both positive and negative COM displacement were positively associated with pitch velocity and temporal differences of when maxima occurred, aspects of both strategies may be implemented when attempting to increase pitch velocity.

CONCLUSION: Greater maximum positive or negative vertical COM displacement increased in-game fastball velocity in collegiate baseball pitchers. Additionally, the timing of the maximum positive COM displacement positively influenced pitch velocity. These findings suggest that lower body stride strategies ('Tall and Fall' and 'Drop and Drive') may improve fastball velocity. Further, according to each lower body strategy, elements of either one may be incorporated to improve fastball velocity. Coaches and players may interpret this data to conclude the appropriateness of adopting preferred stride patterns without sacrificing performance, while also incorporating aspects from different stride teaching methods to potentially improve performance.

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