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Exploring Lower Extremity Kinematics In Adolescent Baseball Players: Inside Vs. Outside Pitches From A Tee Stand

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by

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Chapter 1: Play Ball

In 2021, an estimated 15.6 million athletes, starting from six years of age, participated in baseball in the United States (Statista, 2024). Baseball research focuses heavily on pitchers, specifically elbow and shoulder injuries, due to the high prevalence and risks of injury. Hitting has received less attention due to the lower chance of injury, however, hitting remains a crucial activity for the sport (Fortenbaugh, David M., 2011). When a hitter steps up to the plate, there are three primary goals: 1) bring runners home; 2) become a base runner themselves; and 3) advance runners to other bases to drive them home to achieve more runs (Horiuchi & Nakashima, 2023). Meanwhile, hitters must have the ability to move the bat at a high speed and proper location to hit it into the field (Orishimo et al., 2023). Hitters need to recognize the pitches speed and trajectory to then swing the bat efficiently, aiming to make contact with the ball and achieve a walk or base hit (Orishimo et al., 2023).

In baseball hitting, the kinetic chain creates a rubber band effect, transferring force from the hips and torso to the arms and hands (Horiuchi & Nakashima, 2023). This mechanism allows for a greater transfer of momentum upon bat contact with the ball, especially with increased bat speed (Fortenbaugh, Dave, Fleisig, Onar-Thomas, & Asfour, 2011). Similar to golf, baseball hitting utilizes the X-factor to enhance torque and bat head speed by increasing separation between shoulder and pelvis rotations (Chu, Keenan, Allison, Lephart, & Sell, 2015). This separation maximizes muscle recruitment through the stretch shortening cycle, positively impacting bat head speed and ball contact (Brown, Selbie, & Wallace, 2013). Thus, generating mechanical energy from both hip joints is crucial for optimizing bat head speed during the swing (Horiuchi & Nakashima, 2023). Posture and ground reaction forces from the stride foot can enhance mechanical energy transfer from the hip joints to increase bat head speed (Horiuchi &

Nakashima, 2023). Sonnenfeld and colleagues analyzed hip torque contribution to rotational movement and the effect of stance, elbow, and knee flexion on batting performance have highlighted significant findings (Sonnenfeld et al., 2021). Professional batters exhibit greater knee extension and back arm velocity, while youth players demonstrate faster pelvis rotation (Dowling & Fleisig, 2016). Further investigations by Sinclair and colleagues explored energy transfer and ground reaction forces in high school and collegiate baseball players, revealing differences in energy efficiency and muscle recruitment among skill levels (Sinclair, Hollings, & Freeston, 2017). These studies underscore the importance of adhering to the kinetic chain for optimal swing performance and the correlation between ground reaction forces and bat speed (Schneider, Aguinaldo, & Takata, 2023), however, in much of the previous hitting literature, hitters' preferred pitch location has been used (Katsumata, Himi, Ino, Ogawa, & Matsumoto, 2017) to expand knowledge of hitting mechanics. While this is useful in obtaining foundational information regarding swing mechanics, it may not be transferable to in-game scenarios.

In baseball games, pitchers are intentionally, especially at higher playing levels, not pitching to hitters' preferred locations (Tago, Kanekol, Tsuchlokat, & Ishl,). When batting, hitting an inside pitch requires the hips to rotate externally more when compared to an outside pitch, therefore, an inside pitch has the capacity to induce greater pelvis angular velocity about the vertical axis (Ae et al., 2022). A study found that faster and more open pelvic rotation during inside pitches was linked to higher batting effectiveness, which raises concerns that young hitters may overly rely on arm strength and underutilize the hip (Fortenbaugh, Dave et al., 2011). Previous research using non-preferred pitch locations have found no significant differences in the location of the batted ball, suggesting similar hitting mechanics between the two conditions despite variations in ball delivery accuracy (Katsumata et al., 2017). Previous s`tudies have revealed that the hip joint has greater potential to generate mechanical energy and affect the pelvis and trunk rotation than the knee and ankle joints (Kazimuchi, 2022, investigation of optimal). Therefore, the importance of the lead leg in generating the necessary posterior, or ‘braking’, forces to convert the forward momentum of the body into rotational energy (Orishomo, 2023). . Additionally, previous research has also only studied collegiate and professional playing levels in hitting, but not adolescent-aged players. As such, the aim of this study was to investigate lower extremity hitting mechanics of adolescent baseball hitters in non-preferred locations, specifically, inside, and outside pitches. Analyzing the peak angular velocities of the lead hip in the frontal plane, pelvis and trunk in the transverse plane. It was hypothesized that variations in mechanics will arise due to the differing pitch locations, but creating no significance between the trunk, pelvis and lead hip angular velocity.

METHODS

Participants

An a priori power analysis (G*Power v3.1, Dusseldorf, Germany) was performed with data from Kazumichi et al. (2018) where they analyzed the kinetic functions of the lower limbs at different hitting-point heights in collegiate athletes to determine the minimum sample size. Based on a proposed effect size of 0.47, power of 0.95, alpha of 0.05, a minimum sample size of 14 was determined to provide adequate statistical power. Such, fourteen children and adolescent athletes between the ages of 9-17 years old were recruited for this study. The inclusion criteria for this study included participants who do not present with an upper or lower body injury within the last six months, have had no orthopedic surgeries within the last year, and are on an active team roster with at least three years of playing experience. Once parental permission and participant assent were obtained, participant age, height, mass, and related medical history were collected;

additionally, participants' history of injuries and play time (including years of play, and hand dominance) were asked and recorded.

Procedures

Fourteen adolescents (12.35 ± 1.98 years; 1.58 ± 0.16 m; 46.33 ± 14.46 kg) were recruited for this study. Data was collected using an algorithm-based approach that captures video data from multiple camera views and estimates the human pose for data analysis. A six-camera system, equipped with Sony RX0II cameras (Sony Electronics Inc., San Diego, CA), interfaced with Theia3D were positioned around the area that participants were performing their trials. Prior to experimental conditions, participants completed a ten-minute full-body warm-up, including stretching, and dry swings. Participants were then asked to stand inside the batter's box in their stance as they would in a real-life game situation. They were asked to imagine the trajectory of a fast-pitch ball that was passing through a particular location within the strike zone; with the end of the barrel of the bat, they were to locate where the bat-ball collision is expected to happen. The tee stand was leveled at the expected bat-ball collision (or preferred) height of the participant.. Two experimental conditions of inside and outside pitches on the tee stand were randomized. Ten successful trials were collected with one to three-minute breaks taken as necessary between conditions. For the trial to be considered successful, the participant need to hit the ball into the net two meters away from the tee stand. When a participant hit the tee instead of the ball, the collection was disregarded and recorded again.

Data Reduction

Raw marker trajectories were exported to Visual3D Biomechanical Software Suite (C-Motion, Inc., Germantown, MD, USA) and were filtered with a fourth-order Butterworth low-pass filter with a cut-off frequency of 13.4 Hz (Fleisig et al., 2016) to remove high-frequency noise. An eight-segment model was constructed and includes the trunk, pelvis, left and right thigh, leg, and foot segments. Once the model was constructed, peak angular velocities of the lead hip in the frontal plane, pelvis and trunk in the transverse plane were calculated via a command window in Visual 3D (C-Motion Inc., Maryland, USA).

Statistical Analysis

Aggregate means and standard deviations were calculated and used for analysis. Paired t-tests (α=0.05) were conducted to determine if significant differences existed between the inside and outside tee stand heights for trunk, pelvis, and lead hip angular velocity. All statistics were performed utilizing SPSS Version 29 (IBM, NY).

Chapter 2: Results and Discussion

Results

The lead hip angular velocity was statistically significantly lower in the inside condition (86.20 ± 49.45 °/s) compared to the outside condition (92.94 ± 52.45 °/s; t (139) = -2.01, p = 0.04) (Figure 1.1). For the trunk, angular velocities demonstrated no significant difference between inside (807.63 ± 209.73°/s) and outside (789.83 ± 224.36°/s) conditions in the transverse plane (t (139) =1.95, p = 0.05) (Figure 2.1). Lastly, the pelvis angular velocities demonstrated no significant difference between inside (550.79 ± 149.49°/s) and outside (550.22 ± 153.93°/s) conditions in the transverse plane (t (139) = 0.06, p = 0.94) (Figure 3.1).

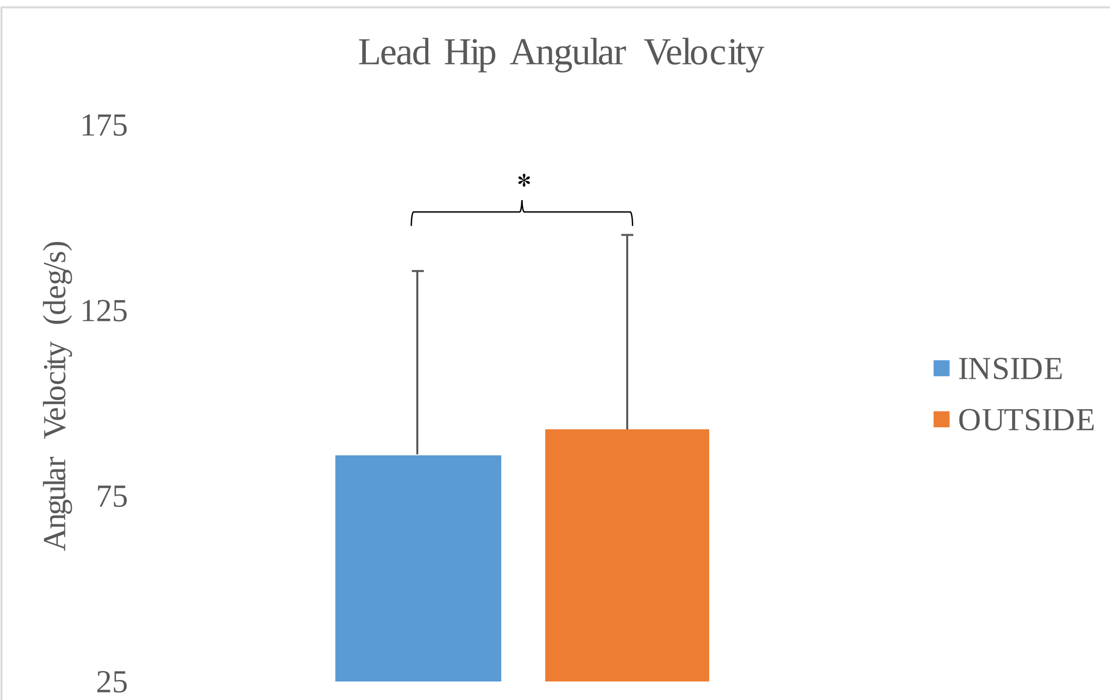

Figure 1.1: Lead Hip Angular Velocity

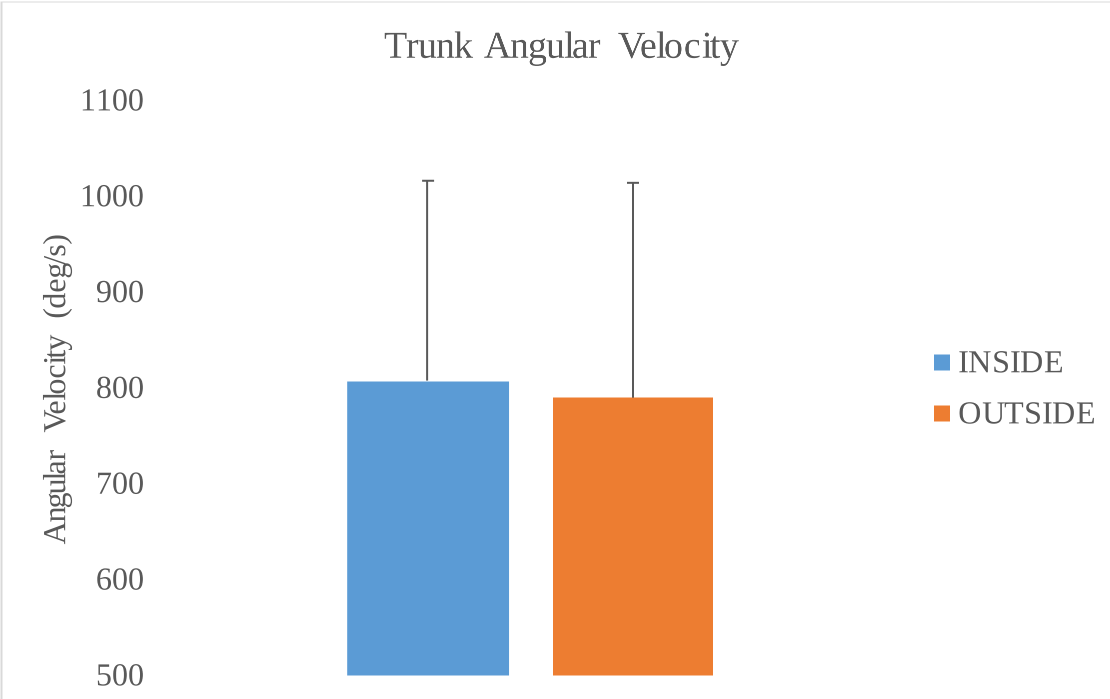

Figure 2.1 : Trunk Angular Velocity

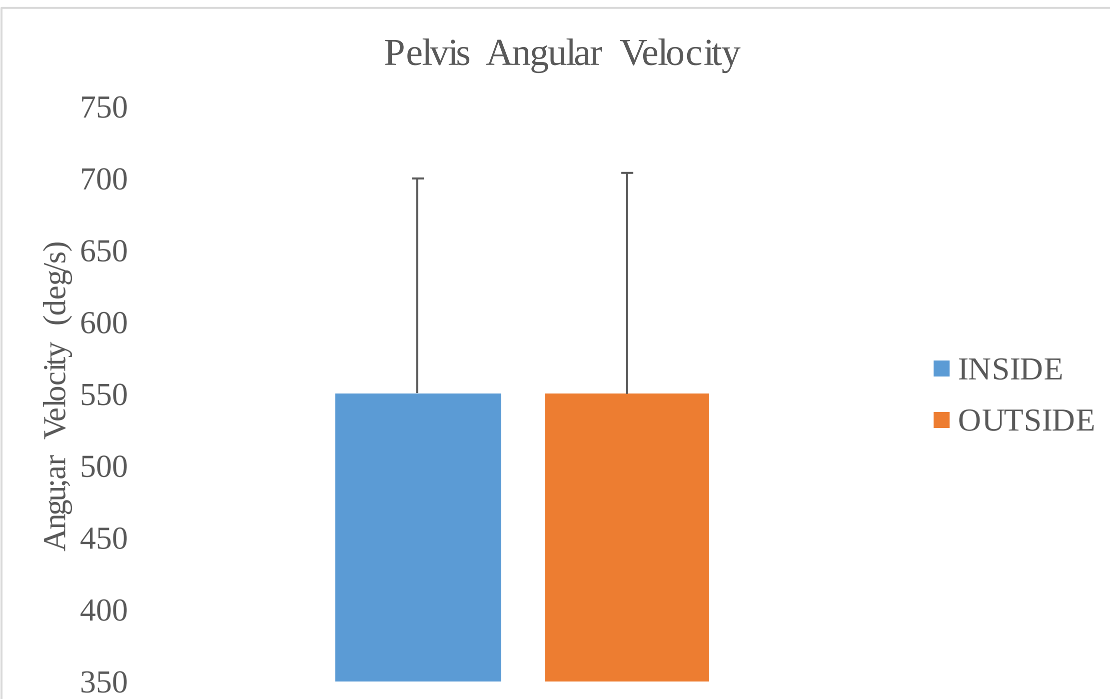

Figure 3.1 : Pelvis Angular Velocity

Discussion

The purpose of this study was to investigate the hitting mechanics of adolescent baseball hitters in non-preferred locations, specifically, inside, and outside pitches. It was hypothesized that different variations in mechanics would arise due to the differing pitch locations, necessitating adjustments by the batter to achieve successful hits. This study revealed that the hip abduction angular velocity was significantly greater for the inside tee location as opposed to the trunk and pelvis, which did not achieve statistical significance. These findings offer insight into the mechanical adjustments hitters might make when trying to make contact with the ball from different pitches.

Ball contact for an inside pitch requires greater shoulder and bat rotation depending on the length of the bat and arms (Katsumata et al., 2017). The role of the lead hip is not only for the initiation of the pelvis velocity but also to control the pelvis rotation as to avoid over rotating when completing a swing (Ae, Burke, Kawamura, & Koike, 2022). Schneider and colleagues (2023) found that college athletes are more successful at transferring energy through the kinetic chain with a proximal to distal (pelvis to torso) movement coordination. On the other hand, high school players transfer their energy distally into the torso before transferring it into the pelvis (Schneider et al., 2023). Thus, older adolescents reach peak pelvis angular velocity before peak trunk velocity as opposed to the younger athletes who reach peak trunk velocity before peak pelvis velocity. Being able to properly coordinate and engage the proper segments at the appropriate timing could improve performance and bat-ball contact. In this study, the pelvis angular velocity was not statistically different between inside and outside pitches, which may be due to less training using body mechanics in younger populations.

Previous research also supports the results of this study as well by the lead hip influencing how much rotation can be allowed or restricted in the movement (Ae, Koike, & Kawamura, 2020). For each trial, participants would step differently when initiating the swing. The cue given to the participants was to stay within the batter's box, however, when performing an inside pitch swing the majority of the participants would step back to the edge of the box. When performing an outside pitch swing the participants would step closer to the plate as to be able to achieve bat-ball contact. This strategy allows the location of the ball to be within the range of the arc (defined by the lengths of the arms and bat) that is allowed by the arms and the trunk rotational movement. This means that the pelvis and trunk in baseball batting is not utilized for the generation of mechanical energy but acts as a pathway for the transfer of mechanical energy (Horiuchi, Nakashima, & Sakurai, 2021). It can also be noted that although bat weights weren't recorded for standardizing a swing for each participant, the differences in the weight can influence how fast or a slow a swing is made. The study highlights that hitting inside pitches requires greater hip abduction velocity compared to outside pitches, suggesting a need for more hip abduction. The role of the lead hip in initiating and controlling pelvic rotation is crucial to maintaining balance and coordination during swings. Older athletes exhibit more efficient movement through the kinetic chain, leading to higher bat velocity, whereas younger athletes may rely more on arm strength. Understanding these biomechanical differences can aid coaches in developing targeted training programs to enhance young players' hitting mechanics and overall performance. There is uncertainty regarding whether the movement strategies observed in adolescents will continue to be similar as they transition into older age. As athletes mature, their movement mechanics often become more coordinated and optimized due to increased experience and physical development. Consequently, it is unclear if the movement strategies of younger athletes will evolve in a manner consistent with those of the other athletes, who typically demonstrate greater efficiency and proficiency in their movement patterns.

Limitations and Future Studies

There were some limitations that existed in this study. First, the ages of participants included fourteen adolescents between the ages of nine and seventeen. Since this is the male population, some participants may be going through puberty which could lead to differences in their in strength by testosterone directly stimulating the growth of contractile tissue (Round, Jones, Honour, & Nevill,). Noting these differences could have a more complete analysis if they were compared between experience levels instead of age. There can be older adolescents who have been playing for a smaller amount of time as compared to some younger adolescents who could be playing for a longer amount of time. By stratifying by experience levels, the outcomes may have revealed greater insight into lower extremity swing mechanics depending on pitch location. Another limitation was the fact athletes were responsible for picking their tee height at which they felt they could successfully hit a ball into the net. Some tees were placed by the pelvis, and others would be placed a little higher near the belly button or about a third way down from the pelvis, that emphasized different heights for each participant independently but with the same goal which is to make ball contact. Having the tee higher or lower makes it easier to envision a successful bat-ball contact which mechanically takes a small load off since it is not a game-time reaction or swing that we are analyzing. When going through the experimental conditions the participants were asked to keep both feet inside of a simulated batter's box; visually assessing an inside pitch, participants would make minor adjustments by stepping slightly out of the batter's box to align with the ball's location. Conversely, when evaluating an outside pitch, participants would step closer to the plate to better position themselves for the ball.. Finally, it can be noted that testing for this study was conducted in a laboratory setting, which does not replicate in-game action. Therefore, it is possible that some participants may not have swung as they would in a regular game, although they were instructed to function as if it was a real game scenario.

When a failed swing happened, or there was an interference with the collection, they were encouraged to keep swinging with full effort which can be seen with the increasing velocities per trial. This could create outliers in the collections that could be disregarded, however, all swings were analyzed to understand swinging mechanics at a preferred height. Regarding future hitting studies, using different variable such as time of impact, bat head speed, and ground reaction forces would allow for a more comprehensive understanding of hitting mechanics. Also, taking additional anthropometric measurements (muscle mass, body composition, etc.) may allow for additional covariates to normalize the data further, making outcomes more comparable across the subjects.

Conclusion

An estimated 15.6 million athletes participated in baseball in the United States, with research traditionally focusing on pitcher injuries due to their prevalence. Hitting, being essential for scoring, involves transferring force through the kinetic chain from hips to hands to optimize bat speed and contact efficiency. Studies emphasize the crucial role of hip mechanics and ground reaction forces in achieving optimal swing performance across different skill levels and pitch locations, underscoring the need for hitters to adapt their mechanics for effective contact in varied game scenarios. This study compared angular velocities of the trunk, pelvis, and hips between inside and outside pitch conditions in adolescent baseball hitters. Results showed no significant differences in trunk and pelvis angular velocities, but a statistically significant higher hip angular velocity was observed for inside pitches. These findings underscore the importance of hip rotation in adapting to different pitch locations and suggest potential biomechanical differences in hitting mechanics that coaches should consider when training young players for optimal performance and injury prevention.

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Vita

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