# THE EFFECTS OF FOOTWEAR ON STRIDE LENGTH IN ADOLESCENT BASEBALL PITCHERS

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ABSTRACT

The baseball pitch is considered one of the most dynamic athletic motions. Due to its complexity, multiple variables are taken into consideration for risk of injury. Previous studies have investigated variables that influence factors of a baseball pitch such as fatigue and stride length; however, footwear has not been considered. This study's objective was to examine whether or not baseball footwear on different surface inclinations altered stride length. Eleven adolescent pitchers (Age: 13.18 ± 1.72 yrs.; Height: 179.01 ± 15.72 cm.; Mass: 61.00 ± 14.66 kg) participated in this study throwing in four shoe-surface conditions: flat ground (FG) x molded cleat (MC), flat ground x turf shoe (TS), pitching mound (PM) x molded cleat, and pitching mound x turf shoe. A 2x2 repeated measure analysis of variance (ANOVA) was used to determine stride length with an alpha level set at $p < 0.05$.

TABLE OF CONTENTS

LIST OF FIGURES & TABLES

# Chapter I

## Introduction

Baseball is known as America's favorite past time and can be traced all the way back to the 1700's. Specifically, Little League Baseball was created in 1938 and currently has 2.4 million children participating annually with its main goal to facilitate player development in younger athletes (Feeley et al, 2017). There are approximately 932 colleges/universities offering baseball as a varsity sport resulting in 31,688 student athletes (Feeley et al, 2017). Due to the overwhelming amount of athletes that play baseball, it is arguably the most popular sport in the United States of America (Feeley et al, 2017).

A byproduct of baseball's popularity is its economic impact from a healthcare perspective. The portion of youth involvement in baseball has increased over the years, and there has been a noticeable increase in the amount of pain reported in the throwing arm. Early position specialization is also increasing within the youth population and this is a possible contributor to the pain they're experiencing. Youth baseball pitchers are beginning this position specialization at such an early age that there may be some side effects from all the stress being created from the hours of practice (Feeley et al, 2017). This leads to an increase in overuse pathologic conditions in the upper extremities (Astolfi, 2015).

Athletes from ages 6 to 12 years have an increased risk of sustaining overuse injuries due to the high torque demands during pitching motions; this creates stress on immature musculoskeletal structures, particularly the humerus (Astolfi, 2015). At birth, the humeral head has large values of retrotorsion, but as the child grows the osseous tissue of the humeral head rotates into a position of relative antetorsion (Astolfi, 2015). The process of antetorsion continues until the child is about 16 years old. Repeated overhead throwing has been shown to increase the likelihood of injury in children such as injuring the epiphyseal plate in the shoulder as reported by Astolfi, 2015.

Besides overuse, the relationship between pitching mechanics and the shoe-surface interface is another potential risk factor for injury. The shoe-surface interface is the interaction of the athlete's shoe with the surface they are pitching on taking into consideration the inclination (flat ground or uneven surfaces) and material (natural grass or turf). These stressors can be increased due to stride length and potentially lead to an increase risk of injury. For example, if the lead leg is placed too far to the right of the pitcher then the hips cannot rotate properly. This introduces more possibility for microtrauma to the soft tissues in the body. While on the other hand, if the pitcher plantes his lead leg too far to the left it would cause his hips to rotate too early. This premature rotation will cause the force to be transmitted to the trunk too soon and the pitcher will lose some potential energy. This situation can cause the pitcher to try to make up for his lost force by straining other body segments such as the shoulder. This overexertion leads to an added amount of stressors on smaller body tissues, which can increase the risk of injury. The intrinsic factors of the shoe-surface interface include aspects of the athlete's body (weight, velocity, and height), while the extrinsic factors include the footwear and playing surface (Taylor, 2012). Therefore, the purpose of this study is to examine the effect footwear and surface inclinations in four different conditions (flat ground x molded cleat, flat ground x turf shoe, pitching mound x molded cleat, pitching mound x turf shoe) have on adolescent stride length in baseball pitching.

## Hypotheses:

**Stride Length:**

$H_{01}$: There will be no significant difference in stride length among all four shoe-surface conditions during an overhead baseball pitch.

$H_{A1}$: There will be a significant difference in stride length among all four shoe-surface conditions during an overhead baseball pitch

Out of all the different shoe-surface conditions, I anticipate to see the greatest difference in the condition where participants are throwing from the pitching mound while wearing molded cleats. I believe the most noticeable variation will be observed in this condition because the pitcher will have more momentum and interaction with the ground. Due to the elevated surface of the pitching mound the pitcher will consequently have more force driving him forward as opposed to moving forward on flat ground. This force contributes to the pitcher's propulsion, hence aiding him in achieving a greater stride length. In regards to the molded cleats, the pitcher will have more articulation with the ground, and that gives him a more stable point from which to drive forward. This greater articulation between the shoe and the ground helps the pitcher generate more force going into his stride length phase.

## Operational Definitions:

**Pitching Mechanics:** A coordinated sequence of body movements and muscular forces that work together to produce maximum ball velocity and targeted accuracy (Calabrese in 2013).

**Proximal-to-Distal Sequencing:** A greater force being generated at the proximal segment and then transferred to the distal segment. This allows the distal segment to reach a maximum velocity greater than the adjoining proximal segment. The summing of the individual speeds of each segment involved in the sequence allows the velocity to build (Putnam, 1993).

**Stride Leg (lead leg):** The leg that is placed forward during the stride phase of the baseball pitch (Escamilla, 2007).

**Stride Length:** It averages between 76-78% of the pitchers height and is defined as the calcaneal distance between the drive ankle at peak knee height during the wind-up to the stride ankle at stride foot contact (Crotin et al., 2014).

**Torque:** Rotational force (Thomson, 2015)

**Trail Leg:** The leg that lags behind the lead leg throughout the pitching motion (Escamilla, 2007)

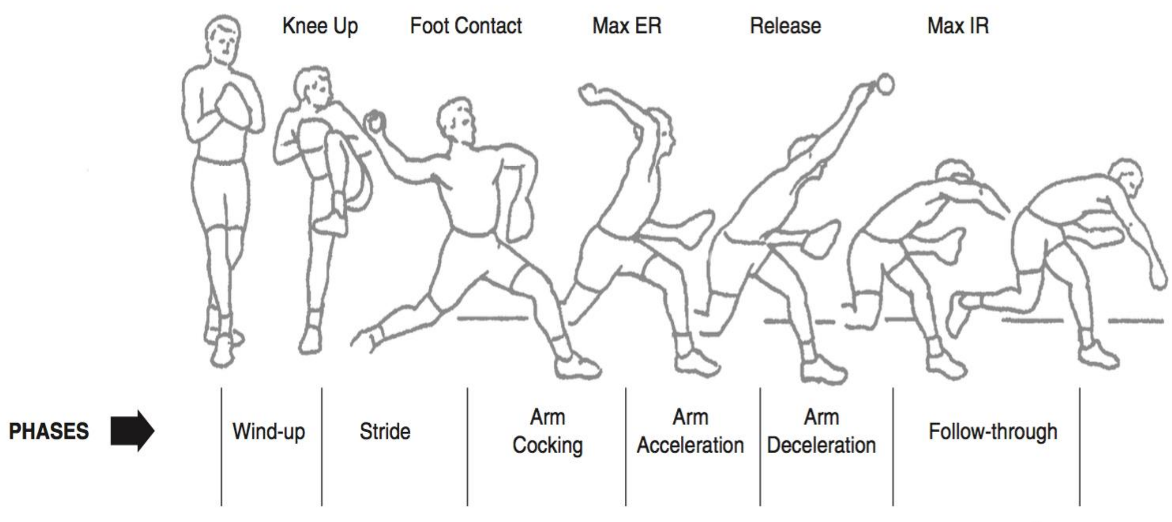
## Chapter II

## Review of Literature

In the past ten years, there has been an increase in injuries among baseball pitchers (Feeley, 2017). Early sport and/or position specialization and year-round overhead throwing has been shown to place undue stress on an athlete's upper extremity, specifically the shoulder and elbow (Chalmers et al, 2015; Crotin et al, 2014; Escamilla et al, 2007; Hibberd, 2015; Nissen et al, 2013; Olsen, 2006). Upper extremity arm pain was reported in 39% and 45% of 9-22 year olds regarding shoulder and elbow pain, respectively (Chalmers et al. 2015). With common upper extremity injuries sustained from pitching including impingement, rotator cuff, shoulder instability, labral tears, and elbow ulnar collateral ligament (UCL) injuries (Hibberd, 2015), most required at least ten or more days of rest. These sports-related injuries cause a noticeable strain on the health care system. Treatment of high school athletes alone cost more than $2 billion annually (Taylor, 2012).

Baseball pitching mechanics is one of the most dynamic movements in athletics (Calabrese, 2013). Force is generated and then transferred up the kinetic chain beginning from the lower extremity, pelvis, and trunk. Through proximal-to-distal sequencing, potential energy is transferred throughout the body segments reaching the shoulder and elbow, allowing maximal ball velocity to be achieved. Proximal to distal sequencing is the primary principle during this motion due to the greater force being generated at the proximal segment and then transferred to the distal segment. This allows the distal segment to reach a maximum velocity greater than the proximal segment (Putnam, 1993). This principle states that the velocity of the ball can be greater at the distal end by building on itself within the system by summing the individual speeds of each segment involved in the sequence (Putnam, 1993). Due to the transfer of this energy from a larger body segment (trunk) to a smaller body segment (shoulder and elbow), a large output of work can be placed on the baseball.

**Figure 1. Six Phases of the Baseball Pitch (Escamilla, 2007)**




Pitching Mechanics:

According to Dillman et al. (1993) and Werner et al. (1993), the baseball pitching motion is categorized into six sequential phases: wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Figure 1). The wind-up phase begins when the pitcher initiates movement and ends at the balancing point which is when the knee of the stride leg is at maximum height.

The purpose of this phase is to allow the pitcher to get into a position to carry out the rest of the pitching motion. While trying to maintain balance, it is recommended to avoid neck flexion and scapular retraction because these two factors put the shoulder girdle in a position where proceeding may result in an increased risk of injury by involving the trapezius in the movement (Crotin et al. 2014). The momentum gained in the wind-up is then transferred to the stride length of the athlete. Stride length, which averages between 76-78% of the pitcher's height (Crotin et al., 2014), is defined as the calcaneal distance between the drive ankle at peak knee height during the wind-up to the stride ankle at stride foot contact (Crotin et al., 2014). The stride length aids in creating linear velocity for the acceleration of the arm in the next phase and assists in properly positioning the trunk and pelvis in order to transfer energy from the lower extremities to the upper extremities by increasing the distance and time the trunk can rotate. Therefore, shorter stride lengths produce less potential force because the trunk does not have ample distance or time to rotate in a way that would generate optimal force. Potential factors that can limit stride length are flexibility in the lead leg's hamstrings and the stance leg's hip flexors. The lead leg's knee and hip extensors act as a means to complete the stride to foot contact position. Strength of the lead leg, the external range of motion of the hip, and internal rotation of the stance leg are vital for an optimal stride length to occur.

Control of the lead leg's hip is orchestrated via the gluteus maximus and minimus, piriformis and obterator internus musculature while stance hip internal rotation is controlled via the tensor latae, gluteus medius along with the hamstrings (Calabrese, 2013). Lead leg foot contact should be in the direction towards home plate, or what is termed "closed" when pointing towards third base for a pitcher that is right handed.

Possible alterations of proper foot placement of the stride foot are caused by restriction of the lead leg hip external rotation and the internal rotation of the stance leg's hip. If a right-handed pitcher were to have an excessively closed foot contact position their arm would then be ahead of their shoulder rotation, and this would cause them to throw across their body to effectively reach the strike zone. This foot position "locks off" the pitcher's lead leg's pelvis and hip which would not allow optimal transfer of energy to the arm for pitch velocity (Calabrese, 2013). The pitcher's arm therefore has to speed up after losing this momentum to get to the correct ball release point, and this would place excessive stress on the anterior shoulder, scapular stabilizers, and medial elbow. Open foot contact position can potentially create reduced ball velocity aside from early pelvic rotation. Also, open foot contact in the direction of first base can change the temporal rotation between the upper and lower torso and therefore increase stress on the anterior shoulder tissues. Open foot contact is typically associated with a shorter stride length and a lower lead leg knee height (Calabrese,2013).

The arm cocking phase begins once the pitcher has completed their stride. The shoulder externally rotates while the upper torso and pelvis rotate in order to be facing the target. As the shoulder reaches maximum external rotation and the trunk faces the batter, the arm cocking phase ends. At the end of this phase the momentum of the athlete has been maintained and will lead into the arm acceleration phase. Beginning at maximum external rotation and ending at ball release, large eccentric loads are then placed on the shoulder and elbow joint to end the arm-cocking phase. The trunk of the body produces the mass amount of force that is then transmitted to the upper extremities during the arm acceleration phase. The work produced will determine ball velocity upon release. During the deceleration of the arm, large loads are generated to slow down the fast-moving arm and prevent abrupt distraction at the shoulder and elbow joints. This is where the rotator cuff primarily comes into play, acting as the primary stabilizer of the shoulder. Due to the rotator cuff having a large range of motion, it is often injured in slowing the arm down during deceleration. Distraction aids in slowing down the kinematics involved that were used to put a high velocity on the ball. This is important because if no distraction happened, then the risk of subluxation would be significantly increased along with increased risk of rotator cuff injury. Finally, the motion of the baseball pitch is concluded with the follow through. The function of the follow through is to allow the body to have more time to slow down during the arm deceleration phase, gradually slowing the arm.

The baseball pitch is complex and contains many factors that can lead to injury. By the seventh inning of a game, the athlete usually begins to exhibit muscle fatigue, a decline in the muscle's ability to generate force (Escamilla et al., 2007). Throwing at maximum effort for long periods of time will eventually create a significant decrease in ball velocity due to the athlete's trunk being significantly closer to a vertical position (Escamilla et al. 2007). Since the athlete's trunk is closer to a vertical position they would make other efforts to maintain their pitching performance by trying to force the motion at the level of performance they want by generating that force from the ground. Many kinematics involving contact with the ground are associated with the upper extremities: front foot position, front foot orientation, shoulder abduction, and shoulder horizontal adduction. Data suggests that the force generated via the leg is an important factor of overarm throwing kinematics linking to arm velocity (MacWilliams, 1998). This force is facilitated largely by the playing surface the athlete is performing on, and since the beginning of baseball the playing surfaces have changed significantly.

Playing Surfaces:

In 1966, the Houston Astros of Major League Baseball (MLB) first unveiled an artificial playing surface which became later known as AstroTurf® (Taylor, 2012). Artificial turf, according to Livesay et al. (2006), is the first synthetic playing surface to be developed with monofilament knitted nylon fibers (Livesay et al., 2006). Due to its durability and applicability in different sporting events, maintenance costs were significantly reduced, increasing the demand. However, in the game of baseball, teams started to move away from these artificial playing surfaces because natural grass was deemed a much safer playing surface (Taylor, 2012). The reason for this shift is because as years progressed, artificial surfaces began to be suggested as a likely culprit of an increase in injuries among players, and there is an increasing caution of having players spend more time on artificial turf than on natural grass (Taylor et al., 2012). Adkison et al. (1974) reported higher rates of musculoskeletal injury in athletes playing on AstroTurf® than in those playing on natural grass (0.63 vs 0.51 injuries/game) over the course of two high school football seasons (Adkison, et al., 1974). Biomechanical studies such as Taylor et al. (2012) have shown that the interaction between the athlete's cleat and the playing surface has a serious impact on the frequency and injury severity. They found that the injury rate of athletes playing on artificial turf was 27% higher than those playing on natural grass. These findings suggest that the amount of torque being generated via the shoe-surface interface on artificial surfaces creates significantly more strain on the athlete compared to when they play on natural grass (Taylor, 2012).

Similarly, Nissen et al. (2013) analyzed surface inclination during a baseball pitch and discovered that pitching from a mound increased stress on the shoulder and elbow of adolescent pitchers as compared with that from flat ground. Results showed the shoulder, elbow, wrist, and forearm kinematics, including flexion, extension, rotation, velocity, and acceleration, were similar in both conditions. The lower extremity kinematics of both the lead leg and the trailing leg between the two conditions showed a number of notable differences at the hip, knee, and ankle. The shoulder and elbow joints exhibited greater rotation angles from the mound in comparison with the flat-ground condition; maximum shoulder internal rotation on top of the mound was 3560 ± 500 degrees/second, while on flat ground the value was 3396 ± 400 degrees/second. Elbow extension values were 1808 ± 192 degrees/second on top of the mound and 1742 ± 206 degrees/second on flat ground. This is largely due to the delayed lead-foot contact when participants pitched from the mound. The incline of the mound increases the time from the beginning of the motion to lead-foot contact because the pitcher requires more time to make contact with the mound due to the slope (Nissen et al, 2013).

The effects of shoe type and cleat length have been shown to affect athletic performance. Torg and Quedenfeld (1971) examined how footwear affects the severity of knee injuries and concluded that footwear with more cleats that are shorter in length showed a decrease in the number of injured participants. Therefore, results showed a decrease in both incidence and severity of knee injuries among players when the traditional cleat with molded soles and shorter cleat lengths were worn (Torg and

Quedenfeld, 1971). It is speculated that joint loads are affected by how the proximal segments of the body move throughout the duration of the pitch.

A study conducted by Aguinaldo (2007) across various age groups and levels of play yielded no significant differences in trunk movement across all age groups except for the starting time of trunk rotation, and there were some differences in rotational torque at the throwing shoulder. Peak shoulder internal rotation torque occurred when the throwing shoulder reached max external rotation in the late cocking phase. The players with more experience pitching began their trunk rotation much later in the cocking phase than compared to more inexperienced pitchers. Aguinaldo's study finds that the sequence of body segmental motion was altered when the trunk rotated too early in the participants, who were not professionals, and the participants lost rotational energy. Due to this loss in energy, the participants attempted to regain the lost energy by placing extra stress on the joints of the upper extremity. In order to generate some of the energy they lost due to their premature trunk rotation, younger pitchers use the ground to deepen their interaction between their cleats and the surface on which they are playing. This shoe-surface interface becomes more risky for the players involved due to the increased articulation creating more stress on the pitcher's joints. Therefore, it is important to take into consideration the type of interaction that is being utilized between the pitcher's cleats and the playing surface to ensure there is no unnecessary stress being placed on the athlete (Aguinaldo, 2007).

<u>Footwear</u>:

Shoe designs have evolved significantly over time. The turf shoe has elastomeric studs placed all over the sole of the shoe. Newly developed turf shoes now include a midsole cushioning to absorb forces created by contact with the ground. Alternatively, the conventional cleated shoe can range from 7-12 cleats with the cleat length varying from 3/4 to 1/2 inches. The shape of the cleat can alter the shoe-surface interaction and they are categorized as edge-type, bladed, conical, cup-shaped, tapered, triangular, or elliptical (Taylor et al., 2012).

<u>Shoe-Surface Interaction:</u>

Considering that the pitcher's muscles are already experiencing fatigue, the shoe-surface interface could determine the severity of a possible injury (Escamilla et al., 2007). When the articulation between the athlete's shoe and the ground is deeper, more stress will be placed on the ligaments (Drakos, 2013). Due to this variance of stress, the type of injury that could possibly occur could also vary in severity. Baseball pitchers have a particularly interesting dynamic involving the shoe-surface interface due to the effects of torque on both the upper and lower extremities. The shoe-surface interface describes how cleated footwear interacts with the underlying playing surface, and the cleats act as mediators between the athlete and the playing surface. Molded cleats and turf shoes are the most common types of shoe used in the sport of baseball, and it is suggested through previous research that rates of injury are higher on artificial turf than on natural grass (Drakos, 2013). It is believed that the athlete is two-times more likely to endure a lower extremity injury the more the athlete's shoe interacts with the ground due to the development of rotational traction from pivoting (Thomson, 2015). Higher levels of rotational traction were found to increase lower limb injury risk. Due to these findings it is safe to say that both the type of shoe and playing surface play a significant role in preventing injury (Thomson, 2015).

Baseball pitching requires physical exertion, but the shoe-surface interface may be the key in preventing injuries by minimizing unnecessary forces acting on the body (Dillman, 1993). Overuse, proper mechanics, and strength and conditioning are other big factors contributing to injuries among baseball pitchers. Pitchers on average throw around 75 pitches per game and the pitch type varies on each pitcher's personal preference (Pitch Smart). There have been regulations placed on pitch counts and other aspects of play in regards to young pitchers in order to minimize risk of injury. The Little League enacted a rule stating that the number of pitches per game will be determined by age; for the age group of 10 year-olds the maximum pitch count is 75 pitches per day. The only time a 10 year-old pitcher may pitch in two games on the same day is when he has pitched 20 pitches or less (Pitch Smart). A 10 year-old pitcher most likely will throw a fastball over other pitch types because they have not had enough years of experience to perfect other more skilled pitch types (Wang, 2016). The fastball is the most physically demanding of all the pitch types due to the effort being exerted by the pitcher in order to put the highest velocity they possible can on the ball (Wang, 2016). Therefore, a combination of high pitch counts and a difficult pitch type increases the risk of injury. They are also a unique population because compared to older populations they have lower valgus angle and higher elbow ranges of motion in flexion, supination, and pronation movements, and higher total ranges of flexion to hyperextension and pronation to supination (Wang, 2016). Due to these notable factors, special attention must be given to the elbow in adolescent baseball pitchers to prevent and or minimize their injury risk (Wang, 2016).

Olsen in 2006 researched 95 adolescent pitchers. The sample size included pitchers who had undergone shoulder or elbow surgery and those who never have experienced a significant pitching-related injury. Olsen concluded that the injured group pitched significantly more overall and recorded a higher pitching velocity than the uninjured group. The participants who were previously injured sustained injuries because of overuse of the muscles, which results in muscular fatigue. Overuse can be easily sustained in baseball due to the fact that all players are pitching several times a day at practice and during a real game. This is a problem because pitchers will begin to compromise their correct form in order to produce the desired force in order to pitch a high velocity ball. This is where muscular fatigue can go from soreness to full on injury, and due to the commonality of overuse of the muscles it is very important to look at how the athlete is generating their force in order to produce a higher pitch velocity. The increased pitch velocity causes more strain on the shoulder complex due to the power generated in the larger body segment being transferred to the smaller and more distal body segments (Olsen, 2006).

When the foot does make contact with the ground the shoe-surface interface comes into effect. Accumulation of research over the years has much to offer in support of the idea that shoe type and surface incline may be a serious factor in athletic injuries. Biomechanical studies state that the shoe-surface interface has a significant influence on the frequency and type of sport-related injury, implying that the amount of torque and resultant strain generated while playing on artificial surfaces is more intense than that generated when playing on natural grass (Taylor, 2012). Therefore, the shoe-surface interface in conjunction with the stride length of the athlete is very vital to the athlete’s performance.

When the athlete becomes more stressed, the likelihood of them compromising their proper biomechanics increases significantly. A specific area where this can be seen is pitching velocity. Pitching velocity can be altered by the length of the stride the athlete takes. Some athletes may use this to their advantage in order to pitch a faster ball when their muscles begin to approach muscular fatigue. However, this alteration could possibly be very hard on the ligaments and joints involved in this motion. The extra stress put on the ligaments due to longer strides lead to a higher risk in injury, not just in the lower extremities but the upper extremities as well (Sgroi, 2015). Stride length affects not only the extremities being used to create the stride length but also the whole body. Therefore the stride length plays a huge role due to how closely it interacts with the shoe-surface interface. The combination of these two variables play an enormous role in the overall performance of the athlete, and that is why they were chosen to be investigated further in order to gain a deeper understanding of their effects. Therefore, the purpose of this study is to determine how pitching off a pitching mound and flat ground in both molded cleats and turf shoes affects the stride length of youth and adolescent pitchers.

# CHAPTER III

# METHODS

## A) Participants:

Eleven youth male baseball pitchers (Age: 13.18 ± 1.72 yrs.; Height: 179.01 ± 15.72 cm.; Mass: 61.00 ± 14.66 kg.) participated in the study. All participants actively played in a travel baseball organization and partook in practices and games while wearing either molded cleats or turf shoes for a minimum of one hour per week. Participants and their legal parents/guardians signed an assent and consent form, respectively, while a Physical Activity Readiness Questionnaire (PARQ) determined if participants were free from musculoskeletal injuries.

## B) Equipment:

1. Footwear:

In conjunction with the playing surface, a counterbalanced design was implemented for the footwear [New Balance 4040v3 Low Youth Baseball Cleat (MC; Figure 2) and New Balance 4040v3 Turf Shoe (TS; Figure 3)] to allow for controlled variation between participants. All footwear was previously worn by the participants, ensuring a proper fit.

**Figure 2: New Balance 4040v3 Low Youth Baseball Cleat**

**Figure 3: New Balance 4040v3 Turf Shoe**

2. Surfaces:

The flat ground (FG) condition was composed of a 6x14 ft. strip of 34 mm synthetic turf with a Styrene-Butadiene rubber infill. The pitching mound (PM; Proper Pitch Mounds, Garner, NC) met Little League specifications.


**Figure 4. Flat Ground (artificial turf)**

**Figure 5. Pitching Mound (artificial turf)**

3. Motion Capture

A Vicon Nexus 3D motion capture system (Oxford, UK) equipped with 8 near-infrared T-series cameras was used to record the variables of interest. A modified version of the Helen Hayes marker system for the entire body was utilized during data collection. The data collected was sampled at a rate of 240 Hz.

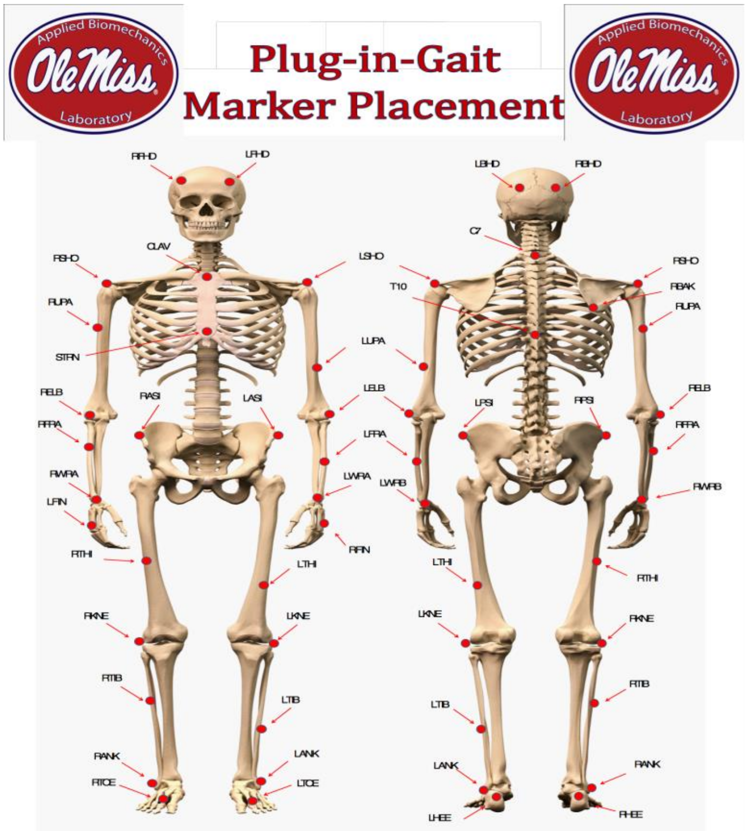



**Figure 6. Retroreflective Marker Location**

**C) Procedure:**

Each participant, and their parents/guardians, visited The University of Mississippi Applied Biomechanics Laboratory for one, two-hour session. Upon completion of the initial paperwork, participants changed into their personal compression shorts and a lab-issued compression shirt with customized sewn-in strips of VELCRO® (Manchester, NH, USA) placed on the trunk and upper extremity anatomical landmarks. A warm-up was completed as if they were about to pitch in a regular baseball game, meaning there were no restrictions in regards to time or the number and type of pitches. Upon completion of the warm-up, participants put on the necessary footwear for the first of four counterbalanced conditions (MC x FG, MC x PM, TS x FG, TS x PM) Retroreflective markers were then placed on anatomical landmarks based on the full body plug-in-gait model (Figure 6) in order to track their motion. After a static capture was collected, participants threw ten fastballs into a net ten-feet away with a designated strike zone mimicking the same technique as if it were a game situation. A rest period of thirty seconds was given between pitches and a ten-minute break between conditions where the participants sat comfortably without any footwear on. This process was repeated for each one of the three remaining conditions.

**D) Data Analysis:**

The phases of the pitching motion were broken down by Dillman et al. (1993) into six phases: wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through. The pitching cycle begins with the wind-up and ends with the follow through. Participants threw ten fastballs throughout the four different conditions and stride length was the factor of interest during data analysis. Stride length is defined as the point from the calcaneal distance between the drive ankle at peak knee height during the wind-up to the stride ankle at the stride foot contact (Crotin et al., 2014). In our study, our methods of collecting stride length measurements were the same as those of Crotin et al in 2014. Stride length measurements were taken from the drive foot calcaneal marker at peak knee height to the stride foot calcaneal marker at stride foot contact.

**E) Statistical Analysis:**

A 2x2 repeated measure analysis of variance (ANOVA) was used to determine stride length with an alpha level set a $p<0.05$. If main effect significance was found, a Bonferroni post-hoc adjustment looked for simple effects. Participant body composition measures were analyzed using the SPSS 21 statistical software package (IBM SPSS® Statistics V21.0, Armonk, NY, USA) while stride length was analyzed using State, version 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

# Chapter IV

## Results

A 2x2 repeated measure analysis of variance (ANOVA) determined there was no significant difference in stride length between all four shoe-surface conditions ($p>0.05$). As seen in the table below, our results were very similar amongst all four pitching conditions.

**Table 1.**

Stride Length

| | **Pitching Mound (PM)** | **Flat Ground (FG)** |
|---|---|---|
| **Molded Cleat (MC)** | 1.07 +/- 0.2 m | 1.08 +/- 0.1 m |
| **Turf Shoe (TS)** | 1.06 +/- 0.1 m | 1.08 +/- 0.2 m |

# Chapter V

## Discussion

The purpose of this research study was to examine stride length when adolescent pitchers were placed in varying shoe-surface conditions (FG x MC, FG x TS, PM x MC, PM x TS). The results of this study are similar to those found by Nissen et al. (2013), who examined the amount of stress placed upon adolescent pitchers when they were pitching from a mound as compared to flat ground. In their study they observed the stride lengths of the participants to be shorter when they threw from ground level (1.12 m) as opposed to throwing from the mound (1.14 m). Our study showed that adolescent pitchers had a stride length of 1.07 m and 1.06 m on a pitching mound (PM) using molded cleats (MC) and turf shoes (TS), respectively; while throwing off a flat ground (FG) yielded a stride length of 1.08 m and 1.08 m in the MC and TS. Based on our results and those of Nissen et al. (2013), the measurements were found to be so minute in difference it was deemed statically nonsignificant ($p>.05$ ) (Nissen et al. 2013). The consistently insignificant stride length data between the studies could be explained by the fact that both studies investigated younger and less experienced pitchers.

Our results from this study do not resemble those found in a study done by Sgroi et al. (2015), who observed noticeable differences in stride lengths that were based off of height differences. Sgroi states that according to research done by Aguinaldo (2007), torque and force can be normalized by the participants’ height. Aguinaldo’s explanation behind this normalization is that as players increase in height they will have a longer lever arm, allowing them to exert more torque and force on the ball. Greater differences in stride length were observed because his study contained a greater height variation between subjects than our study. Due to our small sample size we were not able to substantiate the results found by Sgroi that stride length increased for every 10% increase in the participant’s height, leading to a greater ball velocity. Differences between the current study and those found by Sgori et al. (2015) may also be due to large sample size variations. Sgroi found that stride length increased, which was proven by the observed increases in ball velocity (1.9 +/- 0.4 mph) throughout his study (Sgroi, 2015). The increase in ball velocity is relevant to differences in stride length because greater ball velocity is correlated to a greater stride length (Fortenbaugh, 2009). Fortenbaugh found that the max linear wrist velocity was related to max forward force of the lead leg. Additionally, decreases in stride length decreased velocity while increases in stride length produced a higher velocity without influencing accuracy (Fortenbaugh, 2009).

Results found in Chalmers et al. (2015) showed that three specific variables could accurately predict 77% of injury histories in pitchers. The variables included height, ball velocity, and how many teams the pitchers pitched for. Chalmers et al. (2015) observed that if a player presented a 10 inch increase in height, he would experience a 20% increase in injury history. Therefore we can reasonably assume that pitchers who have greater stride lengths are much more likely to have sustained an injury. In our study, we observed virtually no difference in stride length between our four simulated conditions.

This leads us to believe that among the four conditions tested, pitchers are at no greater risk of injuring themselves due to the shoe-surface interface.

To our knowledge, this is the first study that has examined stride length based upon shoe-surface interactions in four different pitching conditions (FG x MC, FG x TS, PM x MC, PM x TS). Our study looked into how youth baseball pitchers may potentially alter their stride lengths depending upon their shoe-surface interaction. While our results rejected my hypothesis, our research study can still offer athletes and coaches proper techniques for improved pitching mechanics. Correcting a pitcher's mechanics can optimize their ball velocity and also decrease their potential injury risk. In regards to future research, the examination of similar footwear in other surface conditions (clay surfaces or natural grass) might yield more significant results.

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