Effects of outsole shoe patterns on athletic performance

By

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ABSTRACT

The focus of this study was to investigate the effects that different basketball shoe outsole tread patterns have on the amount of slip and therefore the performance of the individual while undergoing normal basketball transitions. Tread grooves and therefore patterns must exist on the outsole of a basketball shoe because the chances of contamination and for practical durability. With the existence of so many basketball shoes with varying tread patterns and characteristics it presents the question of whether or not varying patterns affect traction, slip, and therefore athletic performance. This study evaluated the amount of slips of two pairs of basketball shoes with human participants running basketball drills on a hardwood basketball floor at Wartburg College. The results indicated that one shoe with a much more unique tread pattern performed better with fewer slips, and fewer severe slips, especially when considering lateral movements than the other shoe which had a tread pattern with similar tread characteristics to many other currently available market shoes.

CHAPTER 1: INRTODUCTION

Basketball is a popular sport around the world, but nothing captures its popularity quite like the NCAA Division 1 basketball tournament known as March Madness. “What else captures the whole country? War? Poverty doesn’t. The fight against cancer doesn’t. The election doesn’t. For one month college basketball unites the whole country. It’s an amazing phenomenon… it’s too damn good” (Krzyzewski, 2016).

In the 2010-2011 basketball season the NCAA reported that there were 17, 500 men and 15, 708 women that were playing college basketball for their respective college in one of its three divisions. The number of individuals playing basketball in the NCAA then rose in the 2011-2012 season to 17, 890 men and 16, 134 women. This is an increase of two percent and three percent in men and women playing basketball for the NCAA respectively. Over the years the numbers of people playing NCAA basketball has continued to rise. There has been a total increase of 6.25% over the course of just four years to 35, 286 individuals playing basketball in the NCAA (National Collegiate Athletic Association., 2015). While these numbers do include NCAA division 1, division 2, and division 3 colleges this is only a portion of people that play basketball competitively. These numbers do not account for NAIA colleges, junior colleges, or community colleges which also have a large number of individuals playing basketball. These numbers also do not include high school students, and those who graduate both high school and college and continue to play in park districts, recreational leagues, or just competitive pick-up games of basketball. According to a report of the National Federation of High School Associations there were 541, 479 boys and 429, 504 girls that played basketball in the 2014-15 school year for a total of 970, 983 individuals who played high school basketball (NFHS, 2013). Even more people can be included to these numbers if the scope of this search is widened beyond the United States. With the growth the game of basketball has experienced through the Olympics and international stars such as Manu Ginobli, Yao Ming, Tony Parker, Ricky Rubio, Pau Gasol, Marc Gasol, and Kristaps Porzingis only to name a few, it is easy to see that basketball has an extraordinary impact on a vast number of individuals.

In any sport, no matter the level of competition, the equipment that is used is an essential part of the game. In basketball as in any sport, one of the most important pieces of equipment a player needs to be conscious of is their shoes. The correct shoe can enhance performance, provide stability and shock absorption, and may even be able to prevent injuries (Caselli, 2006). Due to the nature of the game of basketball and the variety of movements that are utilized basketball shoes have an extensive list of desirable traits including durability, traction in a variety of directions, support, stability, and shock absorption for jump landings and high ground reaction forces (Caselli, 2006). In order to provide the desired characteristics it is important to understand the basic structure of shoes and how the individual pieces influence each of the desired traits.

All shoes consist of a large number of pieces that are all combined together normally on a mold. This mold that gives a shoe its shape is called a last (Amoros-Gonzalez, Jimeno-Morenilla, & Salas-Perez, 2013). Typical athletic shoes can often be thought of as consisting of two main parts, the upper and the sole. When trying to design basketball shoes to aid individuals with ankle support the upper of the shoe is the primary component usually considered. The upper portion of the shoe covers the lateral, medial, and dorsal sections of the foot. Traditionally uppers for athletic shoes were made of cloth or leather, but as shoes have evolved so have the materials they are made of (McPoil, 1988; Caselli, 2006).

Nowadays uppers usually consist of nylon and other lightweight synthetics for durability, flexibility, and breathability (Caselli, 2006; McPoil, 1988). Many basketball shoes are characterized with a high upper, often referred to as high top shoes. Arguments have been made however, that high top shoes are not best for all types of basketball players, and thus low top shoes are also an option (Caselli, 2006). The stability that high top basketball shoes are intended to provide could also mean a reduction in range of motion and a possible increase in mass of the shoes. Players that are not worried about the ankle support and are seeking the lightest fastest shoe possible may be more interested in low top shoes in order to increase their speed and therefore performance, particularly if speed is a large component to that individual's skill set (Caselli, 2006). However, with ankle injuries being one of the most common injuries to occur among basketball players it could be recommended that higher levels of stability and support would be beneficial (McGuine, Brooks, & Hetzel, 2011; Powell & Barber-Foss, 1999). While there has been some debate about the benefits of high top shoes it has been shown that high top shoes can assist in the resistance of ankle moments particularly ankle inversion, a very common mechanism for ankle sprains (Richard, Schulties, & Saret, 2000; Ottaviani, Ashton-Miller, & Wojtys, 1995; Shapiro, Kabo, Mitchell, Loren, & Tsenter, 1994).

Playing competitive basketball for the past decade has given me a great deal of insight into the game of basketball, the movements and proper form of said movements, and the thoughts of basketball players. Traditionally point guards were the primary ball handlers of the team meant to use speed and quickness to bring the ball across the half court line, break full court pressure, and initiate a team's offense. Under this traditional view of a point guard it could be seen that low top shoes could be beneficial, however as the game of basketball has progressed so have many of the traditional positions. Nowadays point guards are not just ball handlers and assist leaders; they are also explosive when driving to the basket through a large number of opponents, defensive rebounders, and shooters. Often times ankle sprains occur when an individual lands on an inverted foot, on another individual's foot, or some other obstacle such as a ball (Shapiro, Kabo, Mitchell, Loren, & Tsenter, 1994). With the involvement of the point guard in every aspect of the game they are just as likely to experience this injury as a player in every other position. A player must then consider the benefits of high top and low top shoes to determine what is best for them. Low top shoes have the benefit of possibly being lighter, and not restricting range of motion. While it would make sense that a lighter shoe would increase an athlete's performance in sprinting and jumping a previous study found that a small change in mass of 166 grams did not have an effect on sprinting or jumping (Wannop, 2013). Granted this small change could have a difference over an extended period of time, or if the change in mass was greater, yet this study seems to indicate that the mass of a shoe may not have a large effect on an athlete's performance. Due to this it would seem that the most influential tradeoff a basketball player must consider when deciding between high or low top basketball shoes is a full or restricted range of motion for added support and possible protection from ankle injury.

The other main component of athletic shoes is the sole. The sole of an athletic shoe is made up of a number of components as well, two of which are the midsole and the outsole (Caselli, 2006; McPoil, 1988; Hilgers, Mayer, & Walther, 2009). The outsole of a shoe is the part of the shoe that comes in contact with ground and provides traction. The midsole of a shoe is the portion of the shoe that is between the foot and the outsole. The midsole is one of the most important aspects of a basketball shoe because it is the primary source of cushioning and shock absorption (Caselli, 2006; Even-Tzur, Weisz, Hirsch-Falk, & Gefen, 2006). Over the years a number of major shoe companies have gone in different directions in attempts to increase the cushioning and shock absorption of their basketball shoes.

Fila had previously used an air cushioning design that utilized pressurized air pockets for shock absorption before transitioning to a matrix of high performance thermoplastic cylinders (Gorant, 1997). Reebok went a different direction when they designed a shoe with an active airflow system meant to transfer air into different parts of the shoe as the foot applies pressure throughout a step (Gorant, 1997). Nike was one company that early on used EVA foam for cushioning in the midsole (Gorant, 1997). This EVA (ethylene vinyl acetate) foam is the most popular material currently utilized for midsoles because of its lightweight cushioning and the ability to manipulate its properties (Even-Tzur, Weisz, Hirsch-Falk, & Gefen, 2006; Caselli, 2006). The ability to manipulate the properties of the EVA foam such as the elastic modulus through density and thickness in turn affecting the stiffness is important when attempting to reduce overuse injuries of the heel pad from running or jump landings (Even-Tzur, Weisz, Hirsch-Falk, & Gefen, 2006).

Shock absorption is an important characteristic in basketball shoes for a number of reasons, primarily because of the large number of times basketball players will land from jumping during the course of a game or practice. A previous study looked at the effect that basketball shoes have on ground reaction forces during two different types of landing. The first type of landing was an anticipated jump landing and the second was an unanticipated drop landing. While having well cushioned basketball shoes instead of a control shoe did not improve the ground reaction forces in the anticipated jump landings, the more cushioned basketball shoes did improve the ground reaction forces experienced in the unanticipated drop landings (Fu, Liu, & Zhang, 2013). While it seems obvious that a player would expect all of the landings they experience from jumping in a basketball game, there are a lot of factors that can change how an individual tries to land. Some of these factors include possible contact the player may experience in the air and if there are any obstacles someone is trying to avoid landing on when coming down. Both of these conditions could create a situation in which a player could be inadequately prepared to land in the original manner in which they were expecting to. The evidence of the previous study shows basketball shoes would be beneficial in reducing the impact forces experienced during these landing types.

One of the other components of the sole, as previously mentioned, is the outsole of the shoe which comes in contact with the ground and provides traction. Traction is an extremely important factor in an individual's ability to perform athletic movements. There is a large variety in the types of movements that basketball players utilize including sprint starts, sprinting, stopping, shuffling, backpedaling, and jumping. With the large range of movements and the large number of directions these movements are executed in, it can be easily understood that a high level of traction is needed in a variety of directions.

There are a lot of factors that can add to the level of traction a basketball player experiences on a court including court conditions such as the floor type, when it was last cleaned, and the amount of dust and dirt other individuals may bring onto the floor with their own shoes. While it is not typical for these factors to be in the control of players, the one thing players can control that could affect the amount of traction they experience is their own shoes. This problem can also be seen through the actions of players on the court and the development of products that assist in the removal of dirt and dust from player's shoes and to provide better traction for basketball players. Often times basketball players can be seen wiping their shoes with their hands during the middle of the game, and occasionally even licking their hands before wiping their shoes. These actions are an attempt to gain more traction by wiping off possible dirt or dust that may have accumulated on the shoes over the course of play. To some players it may become somewhat of a habit, but it still started as an attempt to provide more traction for shoes. Products such as traction sticky mats and mission court grip are another attempt at maintaining the highest amount of traction possible. Professional basketball player for the Miami heat, Dwyane Wade, assisted in the testing and development of mission court. His interest in a product like this can be seen as when he said, "My game is all about traction – all about change of direction. When I step on a dusty court, I feel like I can't make the moves I want to make. Plus, I'm more at risk for injury" (Phillips, 2011).

Traction is an influential factor in how individuals perform. One particular study looked at the bending, mass, and traction of basketball shoes, and found the shoe property that had the largest impact on sprinting, jumping, and cutting was traction (Wannop, 2013). Not only can traction affect an individual's actual performance, but it can also affect how they attempt to play. When there are adverse conditions players cannot play to their full potential, and they may begin to develop expectations that can affect how they complete different movements. If a player recognizes non-optimal conditions they may begin to develop an anticipatory response and not run as hard, try to stop shorter than normal on closeouts, begin breaking down their steps for various movement transitions earlier than normal, and more. All of these small adjustments could be the difference in their opponent getting a shot off, attempting to drive to the basket, or getting to a particular position on the floor faster. These expectations that lead to these small adjustments might decrease the risk a person experiences while playing, but it also decreases their performance and could be the difference in winning or losing a game.

While much of this comes from personal experience a preliminary survey was conducted to find out if other current basketball players had similar experiences and thoughts of basketball shoes, floor conditions, and slipping. Over seventy percent of the participants surveyed reported that the level of traction that they experience or expect to have has an impact on the way they play. With further explanation participants reported that when they believe the floor conditions are not optimal it can hinder the aggressiveness they might play with affecting how an individual may cut or move, or how fast they may be willing to try play. One individual reported that they would be more reserved in the amount of effort they give when experiencing lower levels of traction.

On the other side of things, if a player does not make any adjustments in adverse conditions they are at risk for slipping. While slipping has the potential to cause injury, non-injuring slips can still be detrimental for a team's performance. Slips can lead to fouls, travels, other types of turnovers, breakdowns in defensive rotations, and more. All of these things negatively affect a team's performance and overall chance of winning a game. In the preliminary survey that was previously mentioned participants reported slips that have occurred from hard cuts, trying to stop quickly or close out as a defender, under dusty or dirty floor conditions, and when the floor was wet.

Slipping definitely has the potential to cause injuries. Slips can happen for a number of reasons, often the most dramatic of which are caused from contaminants, such as sweat or water being on the floor's surface. However, these contaminants are not the only cause for slips; as previously mentioned there would not be a need for products such as court grip or sticky mats if dusty dirty floors did not exist and were not a problem. The preliminary survey reported that individuals have experienced injuries from slipping while playing basketball in the past, even in non-contaminated conditions.

Slips can have varying degrees of severity, particularly if an individual may be expecting somewhat of a slip. A rather severe slip could result in an individual falling. There are a number of injuries that can occur because of slips that result in a fall. In particular if an individual falls, often times a normal reaction is for an individual to try to brace themselves by extending their upper extremities. Falling with extended arms could cause an injury in the shoulder, elbow, or wrist depending on the circumstances of the fall (Whiting & Zernicke, 2008). If an individual were to fall back on an outstretched arm it could lead to hyperextension of the wrist or elbow, a shoulder dislocation, and more (Whiting & Zernicke, 2008). If an individual falls and is not able to break the fall at all it is possible they could experience a concussion with the impact force being from the head moving backwards and hitting the unyielding floor surface (Whiting & Zernicke, 2008).

While slips that are severe enough to cause a person to fall have risks, less severe slips still have their own risks for injuries as well. If a player slips and the feet separate farther than intended it could lead to a groin injury. Alison Quinn mentions basketball as being one of several sports in which groin injuries are common (Quinn, 2010). Among other risk factors for groin injuries poor running surface or footwear is included (Quinn, 2010). Even minor tweaks from a slip could be detrimental to a player, even if they do not want to report it and would rather play through the pain. This could lead to overcompensation elsewhere in the body which could lead to more serious injuries and more time away from the game that they want to continue playing.

CHAPTER 2: LITERATURE REVIEW

One large aspect of shoes that determines the amount of traction a person has is the coefficient of friction between the shoe and the floor surface. It has been shown that body position affects an individual's ability to accelerate and sprint; as a person's body position changes it may allow them to direct forces more in the horizontal direction increasing their performance (Kugler & Janshen, 2010; Morin, Eduard, & Samozino, 2011). This body position change is not possible however without an increase in coefficient of friction (Luo & Stefanyshyn, 2011) This study found that with a higher coefficient of friction there is more mechanically available traction and an individual can then lean in a particular direction in order to direct the ground reaction forces in the horizontal direction better. This can be achieved up to a particular value before limitations of the body became the limiting factor in athletic performance (Luo & Stefanyshyn, 2011). The coefficient of friction was manipulated by changing the material on the outsole that came in contact with the floor surface. They found the body began to become the limiting factor with a mechanical traction coefficient beyond 0.8 (Luo & Stefanyshyn, 2011). Other research suggests higher coefficient of friction values are necessary for basketball shoes. Suggestions of a coefficient value of 0.6 in the lateral direction, 0.8 for rapid breaking, general minimum requirements of 0.8 to 1.0, and basketball shoes with a coefficient of kinetic friction ranging from 1.0 to 1.2 on a urethane wood surface exist (Valiant, 1993; Frederick, 1993).

One solution to the problem of slipping would be to just increase the mechanically available traction to a value that is more than what is required to eliminate slipping (Luo & Stefanyshyn, 2011). This however also can present an issue as too much traction could lead to greater risks of injuries. This typically occurs with an increase in rotational friction (Valiant, 1993). Resistance to rotational movements creates moments around various joints in the lower extremities which can lead to injury as the foot stays in place and the body continues to move and rotate. This is most typically seen in studies that deal with cleats, grass, and artificial turf surfaces as the shoes would lock into the ground material, but the issue could still be present in basketball shoes with differing outsole patterns (Valiant, 1993). The goal then must be to find the minimum level of traction or the lowest coefficient of friction that eliminates slip. Current basketball shoe treads do not completely eliminate slip as has been observed and reported in the preliminary survey.

One particular factor that can greatly affect the coefficient of friction an individual's shoes may have with the floor is the presence of any possible contaminants on the floor. Ideal basketball floor conditions would not have any contaminants on the floor, but throughout the course of the game players sweat. If a player drips sweat on the floor, or if a sweaty player is knocked to the ground it can often leave a large spot on the floor that can be very slippery if it is not cleaned up properly. There have been a number of studies that have tested different properties of various treads while walking on contaminated floor conditions. In one of these studies Li, Wu, and Lin after citing factors affecting coefficients of friction such as material, surface geometry of the contacting surfaces, and possible contaminants, tested the shoe sole tread groove depths and widths with three different floor types to investigate the effects on coefficient of friction (Li, Wu, & Lin, 2006). The authors found that both tread width and tread depth were statistically significant factors that affected coefficient of friction measurements (Li, Wu, & Lin, 2006). However all of the tests that were performed had some level of contaminants on the floor surface with no uncontaminated control conditions tested. They found that tread grooves with a width of nine millimeters performed significantly better than grooves with a width of only three millimeters (Li, Wu, & Lin, 2006). In addition the authors also found that the shoe sole treads with deeper grooves had higher coefficients of friction for all widths and contaminated conditions, but the groove widths were more significant in determining coefficients of friction than the groove depths (Li, Wu, & Lin, 2006). It was recommended that the groove depth be deeper than the depth of the contaminant on the floor which intuitively makes sense when there is contaminant present (Li, Wu, & Lin, 2006). This suggests one possible reason for grooves on basketball shoes, because although it is not expected for there to be contaminants on the basketball floor sweat droplets and large wet areas on the floor from individuals getting knocked down, can form which creates possibilities for this shoe and contaminated floor interaction with a high chance of slipping.

In a previous but similar study some of the authors of the aforementioned study also examined various materials for shoe sole treads, groove widths, and the orientation of the grooves (Li & Chen, 2005). All tests were again performed on contaminated floor conditions without any non-contaminated floor conditions tested (Li & Chen, 2005). Again tread groove width was a statistically significant factor in the determination of the coefficient of friction with the groove width of nine millimeters having a larger coefficient of friction (Li & Chen, 2005). Groove orientation was also shown to be statistically significant with tread grooves parallel to the walking direction being undesirable and tread grooves perpendicular and at an oblique angle to the walking direction having a higher coefficient of friction on contaminated surfaces (Li & Chen, 2005).

In a study by a separate group of authors using a different type of shoe tester confirmed the above results about the tread groove parameters and their effects on coefficient of friction (Blanchette & Powers, 2015). The authors of this study tested twenty seven pairs of shoes with three different tread groove widths, depths, and orientations all on the same contaminated floor condition (Blanchette & Powers, 2015). This study found an interaction between the three variables, but orientation was the most significant determinant in values of coefficient of friction (Blanchette & Powers, 2015). The data from this study builds off of some of the findings of the previous study about the orientation of the grooves. Previously it was found that perpendicular or oblique angled grooves performed the same, but this study suggests the oblique angled grooves may be more beneficial due to their ability to channel contaminant away from the shoe floor interface while maintaining the high level of resistance in the desired direction of movement (Blanchette & Powers, The influence of footwear tread groove parameters on available friction, 2015).

Noting one of the limitations of all of the above studies, Mark Blanchette continued his work by using human subjects to test tread groove orientation and its relationship to slip outcome and severity again on a contaminated walking surface (Blanchette, 2013). Participants were assigned one of two shoes with tread grooves either parallel or perpendicular to the length of the shoe. As expected, participants with parallel groove orientation slipped more often and for a greater distance than the participants with perpendicular groove orientation (Blanchette, 2013). This shows that not only do tread grooves affect the amount of times an individual slips, but also the severity to which an individual may slip.

A large number of the previous articles discussed all tested shoes and footwear pads under contaminated floor conditions. While this can be useful and must be considered in the design of outsole shoe treads it does not address the current problem that there are still slips in basketball under non-contaminated conditions. However, the tread parameters discussed in these articles may still have implications for non-contaminated conditions. A large number of the previous studies also used mechanical testing devices and only a few used human subjects. Of the studies that did use human subjects they did not test transition points or a variety of types of transitions and types of shoe patterns.

Other factors that can affect frictional characteristics include other court conditions beyond contaminations, such as dust, and shoe tread patterns. One particular study tested various shoes on squash court surfaces under varying conditions (Chapman, Leyland, Ross, & Ryall, 1991). Squash courts being wood and having a similar finish to basketball courts are very comparable. This study conducted a drag test and a human test where an individual performed a typical maneuver on a force plate (Chapman, Leyland, Ross, & Ryall, 1991). The results of this study showed court conditions and different shoes create different levels of traction (Chapman, Leyland, Ross, & Ryall, 1991). Different shoes may have differences other than the outsole pattern, but it would not be expected that different shoes have the same outsole pattern. The same shoe had varying coefficients of friction on differing surfaces and conditions of those surfaces (Chapman, Leyland, Ross, & Ryall, 1991). Different shoes had different coefficients of friction on the same floors conditions (Chapman, Leyland, Ross, & Ryall, 1991). This study shows that court conditions and different shoes with different outsole patterns have an effect on the amount of traction an individual may experience.

Previous literature has also supported that shoe sole geometry can affect traction (Tisserand, 1985). One such article explains that basketball shoe outsoles create high levels of traction based on the amount of material that comes in contact with the playing surface (Valiant, 1993). It also explains that with a higher normal load that is put on the rubber material that basketball shoe outsoles are made out of the amount of traction will actually decrease (Valiant, 1993). This article claims that a completely flat rubber shoe sole would have much more available traction than would be necessary and could actually be too high, but completely flat soles would not be practical because of the amount of wear they would experience (Valiant, 1993). On top of this reason, a completely flat sole would not be practical because of the increased chance of hydroplaning, known as the hydrodynamic squeeze film affect that would be due to a lack of tread grooves that can channel contaminants away from the shoe-floor interface (Di Pilla, 2003). For these reasons a herringbone pattern is often used in an attempt to maintain a large amount of material in contact with the playing surface while the relationship previously mentioned, a decreased coefficient of friction with an increase in normal load, is greatly decreased (Valiant, 1993). Shoes can be designed based on the desired characteristics. If the intent is to increase translational traction forces pressure mapping can be used to determine areas of a shoe where materials and design can be appropriately utilized to increase traction (Valiant, 1993). If the intent is to decrease rotational traction and possibly injury, the areas of a shoe that have the highest normal pressures during this type of movement can be adjusted accordingly (Valiant, 1993). This article does not give any indication of how to appropriately adjust or design treads based on desirable characteristics, or the appropriate drills and tests in order to determine the effectiveness of new designs.

Transition points are often the types of movement that put the most strain on basketball players and their shoes. Basketball players utilize a variety of movements in a variety of directions. In order for players to change directions and movement types they have to go through a transition. One example of a transition is if a player is on defense and is sprinting out to a different offensive player who just caught the ball. In order for the player on defense to stay in position, between the player with the ball and the basket, they need to be ready to move in different directions. In order for the defensive player to do this, he needs to be able to stop sprinting, and push off in the desired direction. This stop and push off characterizes the transition point. There are a variety of transition points based on the directions and types of movements that can be changed. During these transitions, players count on their shoes to allow them to move exactly as they are expecting and intending to. One of the factors that determines if a player will move the way they want to is the shoes they are wearing. If shoes do not have enough traction during one of these transition points it could cause a player to slip or fall. This slip or fall can not only put a player at a disadvantage, but it could also cause an injury.

"Within the marketplace, outsole tread designs are highly variable with few visual consistencies. Currently, there are no published guidelines on how to design outsole treads to meet specific levels of slip resistance" (Blanchette & Powers, 2015). There is a need for further study of current basketball shoes, their tread patterns and frictional characteristics, and the types of transitions and drills that lead to the largest slip potentials to appropriately test new shoe tread pattern designs.

CHAPTER 3: METHODS

Phase 1: Preliminary Survey

Due to the extensive experience the preliminary investigator has had, a large portion of the problem being addressed in this study came from personal experience. To discover if much of these personal experiences were shared among other basketball players a preliminary survey was conducted. This survey further justified the identification of the problems of slipping, the expectations, and the anticipatory response associated with slipping that affects athletic performance on a basketball court. To solve this problem the shoe-floor interface must be considered. An individual cannot always control floor conditions before play, but can control the shoes and the associated tread pattern with those shoes.

Twenty eight men at least eighteen years of age who have been playing basketball in a competitive environment in at least the last month completed this survey (Appendix A).

Phase 2: Drill Completion

Participants:

5 male, local collegiate athletes that were familiar with the drills and movements asked of them participated in this study. This specialized group of individuals has extensive experience in the completion of the movements associated with these drills. Each participant read and signed an informed consent before participating. Participants were then asked to complete a brief warm-up. After the warm-up participants were randomly assigned one of two pairs of shoes. Participants were then asked to run through a series of four speed and agility drills common to basketball training, conditioning, and practices. While participants ran these drills each transition that each participant made in each of the drills was video recorded for later analysis.

After completion of the first four drills participants were given a chance for a short break and were asked to change shoes to the other pair that had not yet been tested. Each participant ran the same drills in the second pair of shoes while each transition was again recorded for later analysis. All drills were run in Levick Arena of Wartburg College. After each participant finished running through the drills they completed a short semi-structured interview to gauge their expectations and thoughts of the shoes (Appendix B).

Drills: (Appendix C)

Speed drill was chosen for the variety of types of transitions it exhibits. Transitions that change the type of movement, the movement direction, and the movement direction that is not a 180 degree direction change are all performed in this drill. The shuffle drill was chosen because of the large amount of shuffling and change of direction when shuffling during a typical basketball game. The half-court and full court drills were chosen because of their similarities with transitions to in-game situations and because of their frequent use in basketball conditioning and practices. The drills were separated to better analyze the different transitions as to whether a shorter distance to generate momentum, slow, and change direction would be different from a full court length transition where there is adequate time and distance to generate momentum, slow that momentum, and change direction.

Shoes:

After examining thirty current market basketball shoes for common tread patterns and characteristics (Appendix D.) two pairs of shoes were identified for the purpose of this study. The first is the 2015 Nike Hyperdunk Shoes. This pair of shoes was chosen due to its common characteristics to many other commercially available basketball shoes. The herringbone pattern on a large portion of the outsole, the concentric circles on the ball of the foot, the break lines across the front of the outsole, and the lack of treads on the arch and middle of the heel are all characteristics that can be seen in many basketball shoes. The second pair of shoes chosen is the Under Armour Lockdown Shoes. This shoe was chosen because of its variation in tread pattern. The tread pattern is unlike any other tread pattern consistent with the outsoles of the basketball shoes that were examined in the market analysis. The tread pattern is the shape of an hourglass that is perpendicular to the longitudinal axis of the shoe fit together in a tessellation. This pattern is consistent over the entire outsole of the shoe except for a few break lines.

2015 Nike Hyperdunk Shoes

Under Armour Lockdown Shoes

Phase 3: Lab Transition Recreation and Force Testing

To further examine and explore the underlying forces and moments that are experienced when performing a transition, lab tests with a force plate were conducted. This was performed in an attempt to further understand if there are any possible differences between basketball shoes, and to understand which basketball transition types require the highest forces and therefore would be influential in tread pattern testing. In a closed lab environment on a polyurethane finished wood surface the transitions of the previously mentioned drills, and a defensive close out were recreated. The transitions were performed with the plant foot of the transition occurring on a force plate to measure the forces and moments generated and experienced in each transition type and each shoe. The force plate's surface was identical to the surface of the rest of the experimental environment.

Lab Testing Surface

Lab Test

Hypotheses:

Performance based on shoes:

1. The Nike Hyperdunk pair of basketball shoes will have a lower percentage of transitions that experience slip.
2. The Nike Hyperdunk pair of basketball shoes will have a lower percentage of larger or more severe slips.

Hypotheses 1 and 2 were formulated because the of the common tread patterns observed in the Nike Hyperdunk Shoes and a large number of the other current market shoes that were analyzed. The Under Armour Lockdown Shoes were expected to not perform as well due to the uniqueness of the tread pattern on the outsole of this shoe.

Performance based on transition:

3. The full court transition will have highest percentage of slips and the highest percentage of larger or more severe slips. This will then be followed by the half court transitions, which will be followed by the free throw line and shuffle transitions, followed by the sprint to back pedal transition of the speed drill.

4. All of the other speed drill transitions will have little to no slip.

Hypotheses 3 and 4 were formulated based on the ideas of momentum. Larger distances were expected to show large slips and amounts of slips because the amount of change in momentum is the greatest. With extensive space to hit top speed participants would be expected to have a large amount of momentum, and as they near the transition, they would be expected to attempt to reduce their momentum to zero before generating the same amount of maximum momentum in the completely opposite direction in as little distance around the transition as possible to increase performance based on the completion time of the drill. The following order of transitions then follows similar logic based on the amounts of momentum participants would be able to generate assuming they would not achieve their top speed in these reduced distances. The other speed drill transitions are not expected to have much slip due to the direction change being less than one hundred eighty degrees; because of this it is expected that participants would round the corners and perform the transition without a firm plant step.

Times:

5. If there is no slip detected in both of the trials of a drill the shoe that the participant expected to have more slip in will have an increased time to complete due to an increased anticipatory response.

6. If there was either no expectation of one shoe that would be better than the other, or if slip is detected the times to complete drills will not show a statistically significant difference.

Hypotheses 5 and 6 were formulated based on the ideas of a developed anticipatory response to an expectation of slip. However, because it is unknown which shoe, if any, will perform better, and more consistently perform better the times will not be significant as slips can affect completion times and could occur with either shoe during any transition. Along with this there are a variety of factors that could affect time solely based on the participant's effort and their ability to complete the drills as instructed throughout the duration of this study.

Data Analysis:

The time for each participant to complete each drill in each shoe was recorded and collaborated by the video recordings taken. Upon review of each of the videos every transition was given a rating of 0, 1, or 2. 0 was an indication of zero or unnoticeable slip. 1 was an indication of a small amount of slip. 2 was an indication of a larger or more severe slip. The distinction between a rating of 1 and 2 depended partially on the observed distance of the slip, as well as the participants' response to the slip. Any type of fall, or unnatural step, indicating the participant was recovering from a slip was a given a rating of 2 as well as slips that displayed a relatively large distance of slip. If there was noticeable slip, but the distance of the slip was relatively small, and the participant seemed unaffected or to account for this slip in the performance of the drill the transition was given a rating of 1. Instances of participants attempting to clean or wipe off shoes was observed throughout the duration of the study as well as any mentions of court conditions.

The times for drill completion in each shoe were averaged across the participants and compared through a two sample t-test. The total slip instances and the larger or more severe slip instances over all transition types between shoes was compared based on a two proportion z-test. This was then broken down by transition type and the slip instances and the larger or more severe slip instances were also compared based on a two proportion z-test. To gain further understanding of the transition types that experience larger slip instances, transitions regardless of shoe type were compared based on the slip instances and larger or more severe slip instances through the two proportion z-test again.

The lab recreation of transitions on a force plate consisted of all of the transitions participants completed in the drill completion portion of this study and a closeout pushing off at a forty five degree angle back, testing both directions for a total of fourteen transitions. Each transition was tested three times in each pair of shoes for a total of eighty four trials. The transition peak forces were used to establish a simplified coefficient of kinetic friction.

CHAPTER 4: Results

The starts of each drill could be seen as a type of transition due to the fact that an individual will be starting at rest and changing their movement type and direction; however, due to the static nature of the individuals before the start of each drill greatly reduces the chance for slip and thus the starts of each of the previously mentioned drills was not included in this analysis.

Comparison of Shoes Over All Transitions:

The results of the analysis comparing the two pairs of shoes across all transitions contradicts hypothesis 1. The results of this study does not simply support that the Nike Hyperdunk Shoes are not better, but the results actually support the idea that the Under Armour Lockdown Shoes performed better based on a lower slip percentage.

Table 1: Comparison of Shoes across all transitions

	UA	Nike
Transitions with instances of slip	25	36
% of transitions with slip	34%	49%
P-Value	0.033	

Hypothesis 2 is also contradicted in that the instances of larger or more sever slips between shoe type were not shown to be statistically different. However there is near significance that they are different, but again contradicting the hypothesis because the Nike Hyperdunk Shoes had a larger instance rating of more severe slips.

Table 2: Comparison of Shoes across all transitions: larger slips

	UA	Nike
Transitions with instances of more severe slip	2	6
% of transitions with more severe slip	3%	8%
P-Value	0.073	

<u>Comparison of Transitions:</u>

Figure 1 depicts the order of transitions based on their slip percentage. This evidence contradicts the order of the transitions that was expected from hypothesis 3, with the half court sprint to sprint transition being the highest followed by the shuffle, free throw length sprint to sprint and the sprint to sprint full court length transition.

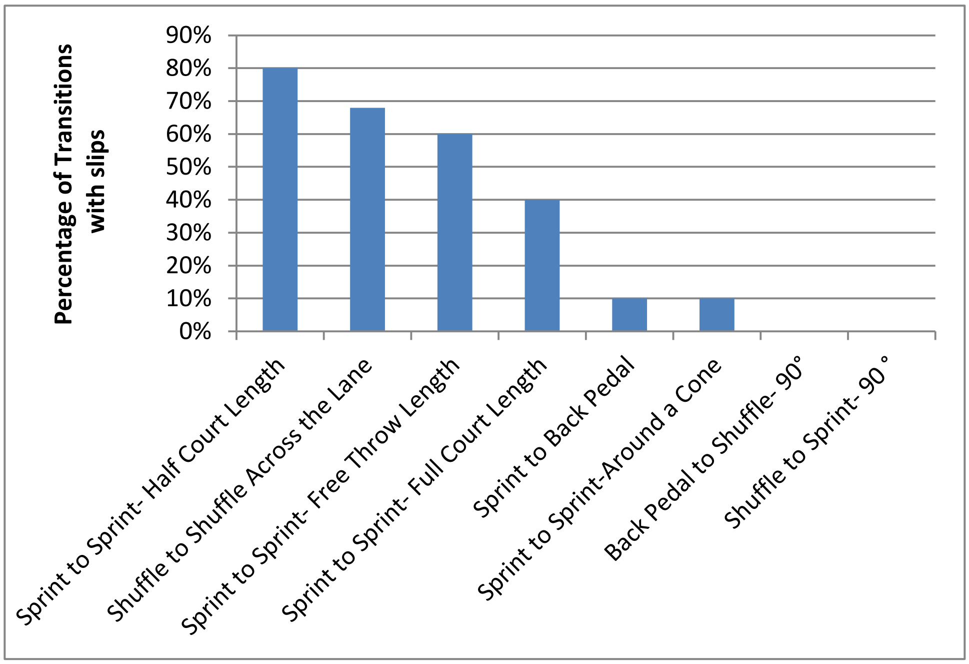

Figure 1: Percentage of slips by transition type

The statistical analysis tests, Table 3, reveal that the full court transition is indeed significantly different in the percentage of slips from the half court transition and the shuffle to shuffle transition. This contradicts the order hypothesized despite the lack of significance found between the other transitions with high levels of slip instances. This data does however support the idea that the shuffle to shuffle transitions and free throw length transitions have similar instance ratings as they were not shown to be statistically different. Hypothesis 4 also has support from the findings of this study in that the transitions occurring with a direction change of ninety degrees have very little to no slip.

Table 3: Significance of drills with large amounts of slip

	Half court length	Full court length		Free throw length	Shuffle
Instances	8	4	Instances	12	34
% with slips	80%	40%	% with slips	60%	68%
P-Value	0.018		P-Value	0.262	
	Free throw length	Full court length		Full court length	Shuffle
Instances	12	4	Instances	4	34
% with slips	60%	40%	% with slips	40%	68%
P-Value	0.150		P-Value	0.047	
	Free throw length	Half court length		Half court length	Shuffle
Instances	12	8	Instances	8	34
% with slips	60%	80%	% with slips	80%	68%
P-Value	0.137		P-Value	0.225	

Comparison of Shoes Separated by Transitions:

To further understand the possible differences in performance based on shoe tread the transitions were separated and an analysis of the two pairs of shoes was performed. Table 4 shows the shuffle to shuffle transition is the only transition that shows a statistically significant difference in favor of the Under Armour Lockdown shoes. The half court transition is close to being significant in favor of the Under Armour shoe, but the sprint to back pedal transition is the only transition type that is near significance in favor of the performance of the Nike Hyperdunk shoes.

Table 4: Shoe Comparisons Separated by Transition Type

	Sprint to Sprint-Free Throw Length		Sprint to Sprint-Half Court Length		Sprint to Sprint-Full Court Length		Shuffle to Shuffle-Across the Lane	
	UA	Nike	UA	Nike	UA	Nike	UA	Nike
% of transitions with slips	50%	70%	60%	100%	40%	40%	52%	84%
P-Value	0.181		0.057		0.500		0.008	
	Sprint to Back Pedal		Back Pedal To Shuffle		Shuffle to Sprint		Sprint to Sprint-Around a cone	
	UA	Nike	UA	Nike	UA	Nike	UA	Nike
% of transitions with slips	20%	0%	0%	0%	0%	0%	0%	20%
P-Value	0.068		0.500		0.500		0.146	

<u>Times:</u>

Due to the number of slips detected in many of the drills and trials hypothesis 5 is void because the slips may have had a negative effect on the participants' time to complete a drill that cannot be quantifiably determined from the observations collected. Hypothesis 6 then is supported from the results of this study in that none of the shoes had a statistical time advantage for the completion of the drills. Due to the small sample size and to account for fatigue the results were also analyzed comparing the averages of the first set of trials to the second set of trials regardless of shoes and the times were again found not to be statistically different.

<u>Participant Slips:</u>

Due to the small sample size the data was analyzed to ensure one particular participant did not overly affect the slip data by possible anthropometric differences, effort differences based on preferred brands, etc. The slip percentages of the participants can be seen in table 5.

Table 5: Slip Instances by Participant

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Average	Standard Deviation
% of transitions with slips	39%	30%	42%	36%	36%	37%	4%
% of transitions with more severe slips	6%	3%	6%	0%	9%	5%	3%

Force Plate Data:

All of the transition types that were completed by participants in phase 2 of this study were completed as well as a normal closeout transition on a force plate for phase 3. Each transition, varying in its direction and movement type changes could result in maximum peak forces in either the x or y direction. After averaging all of the peak forces in the x and y directions for each recorded trial in each transition category regardless of shoe, the averages were compared to find which direction had the largest force. Using the direction with the largest recorded force a simplified coefficient of kinetic friction was calculated using the primary investigator's mass in kilograms as he completed all of these transition tests.

Equation 1: $$\mu_k = \frac{f_{x/y(max)}}{N} = \frac{f_{x/y(max)}}{kg*9.81}$$

Because peak values were obtained and analyzed from every trial the following results in figure 2 are the maximum coefficients of kinetic friction that would be required when completing these types of transitions. The minimum, average, and maximum, of the maximum coefficients of kinetic friction are shown, which reach values of 1.34.

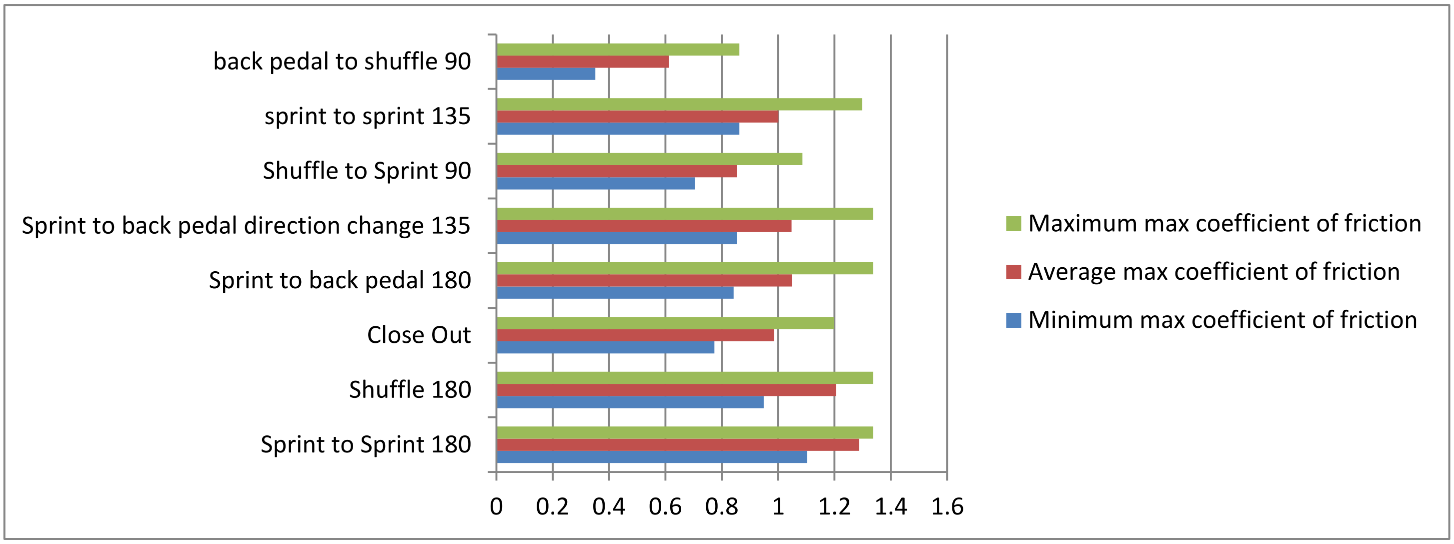

Figure 2: Coefficients of Friction

CHAPTER 5: Discussion

While it is not well documented it is evident from this study that a problem of slipping while performing transitions under dry, non-contaminated court conditions exists. On average each of the participants slipped on thirty-seven percent of all of the transitions that they completed. These drills are often performed regularly in conditioning training and basketball practices; while the transitions can often be seen in regular game play. This problem of slipping during the completion of transitions can be detrimental not only to individual performance but could also put players at risk for injury if the slip is severe enough.

Traction and tread pattern, while not always thought to be a high priority of characteristics when purchasing basketball shoes could have one of the largest impacts on athletic performance, particularly on lateral movements. In this study the Under Armour Lockdown basketball shoes had significantly less instances of slips when considering all of the transitions. When broken down by transition it is clear that the shuffle drill in particular seemed to be one of the drills that most influenced this difference.

While the shuffle transitions were the only ones to show a statistically significant difference between shoes, a number of the sprint to sprint transitions of varying lengths were not far from also being significant. This could be explained from the way the body moves as this transitions is made. Almost all of the sprint to sprint transition changes made that had a one hundred eighty degree direction change, planted with the final step being perpendicular to the initial direction and final direction of movement. This last plant step is the same type of plant step taken in the completion of the shuffle to shuffle transitions.

One possible explanation for this difference in performance is the amount of available traction based on the tread patterns of each shoe. The tread patterns on the two pairs of shoes of this study are clearly different. Due to the drastic differences in tread pattern it is difficult to identify any single characteristic or group of characteristics that could cause the performance differences between these shoes. One possible explanation to account for the performance differences is based on the idea of the amount of surface area that comes in contact with the floor during the transition which can vary based on differing tread patterns (Valiant, 1993). The influence of tread pattern may influence traction based on the pattern and direction of tread grooves, but it also could influence the amount of surface area that comes in contact with the floor. In both cases tread pattern has an influence on traction and therefore performance.

While the Under Armour Lockdown basketball shoes seemed to perform better than the Nike Hyperdunk shoes, the Nike shoes performed better in one transition type, the sprint to back pedal transition. The Nike shoes were not shown to be statistically different, yet with a larger sample size it is possible that the difference could become more pronounced. This could suggest that the Nike Hyperdunk shoes could be better for transitions involving forward to backward movement changes, while the results of this study indicate that Under Armour Lockdown shoes slip less often during transitions that exhibit a lateral plant step.

The Under Armour Lockdown shoes having a lower instance rating of slip was not shown to be statistically different from the Nike Hyperdunks when analyzing more severe slips and all of the transitions were combined. While there was not a statistical difference the p-value of .073 is near showing significance. When broken down by transition type, the one transition type that showed a significant difference in more severe slips was the shuffle transition with the Under Armour Lockdown shoes having fewer instances of severe slips. This would again support the idea that the Lockdown shoes perform better particularly in lateral type movements.

With the further break down of drills and transitions, support for and the development of a number of explanations behind the differences in slip instances between transitions can be seen. The first is the support from the results of this study that indicate very little to no slip on drills that have a ninety degree direction change. This lack of slip could largely be due to the idea that players tend to deviate from the straight lines that are created by the cones of the drill. This rounding of corners can be related to the findings of the previous study that examined the body angle and the ability to direct the forces in the horizontal direction (Kugler & Janshen, 2010; Luo & Stefanyshyn, 2011). With the rounding of corners players begin to direct the horizontal forces in the new desired direction of movement without having to drastically reduce the momentum generated from the original direction of movement.

The results of this study somewhat contradict hypothesis 3 in that the order of transitions that experience the most instances of slip do not follow a pattern based on the amount of distance covered before the transition is made, as was expected. While it was expected that the full court transition would have the largest instances of slip because of a greater speed and therefore momentum, the larger amount of time spent and distance covered at this top speed and momentum could allow for the player to identify the most appropriate place to begin decelerating before the transition is made.

In the half-court transition, however, it is possible that the top speed and momentum is not reached by the time the individual needs to start decelerating. This then becomes a more critical decision for the player as they must determine where to begin decelerating. If a player is trying to optimize performance based on time they would want to maintain high speeds and decelerate for as short of a period of time as possible. This puts tremendous pressure on the transition and the plant step, particularly if the individual begins decelerating later than needed, as this step would require a larger change in momentum with this plant experiencing larger forces and therefore being more at risk for slips.

The free throw length transition while similar to the half court transitions does not have as great of a distance to allow for the same amount of acceleration. While the decision is still necessary the top speed and momentum that is achieved does not put as much pressure on the transition plant step as the half court transition. The results from this study do support the end of hypothesis 3 that the free throw length transitions and shuffle transitions will be similar. This could largely be due to the similar distances covered and the similar direction of the plant foot step as previously described.

While the force plate data that was taken is specific to my body type, the extensive experience I have of the movements, and my body type can be considered somewhat representative of at least a portion of basketball players. At six foot six inches, two hundred ten pounds I may not be representative of a normal population; but for basketball this height is not the smallest, but it is definitely not the tallest either. In basketball a variety of body types can be seen from thicker, bigger players to smaller, thinner, quicker players. Again while these tests are specific to my body type there are likely many basketball players with similar physiques to my own. This being said the force plate data that was collected and used to calculate coefficients of friction during these transitions exceeds the values that have been previously mentioned as minimum requirements (Valiant, 1993; Frederick, 1993). These values that reach up to 1.34 supports the idea that there is a need for better tread patterns with increased coefficients of friction. Along with this there may be a need for more realistic testing of basketball shoe tread patterns to better understand if they meet the minimum requirements of transition type movements. The fact that the required coefficient of friction values vary between transition type also supports the idea that different transitions have different requirements for an individual's shoe based on movement type and direction change.

Limitations:

While this study has found significant and meaningful results there are several limitations that should be noted. The first limitation is from the sample sizes that were taken. While this study did show significant results, larger samples of participants, and more trials of each of the transitions would further strengthen this study.

A second limitation comes from the large differences that are displayed in tread pattern. While large differences in tread pattern may initially show that tread patterns do influence athletic performance and traction, it does not assist in the explanation of what particular characteristics influence traction and in what ways. Further limitations about the shoes include the other varying differences. While weight and forefoot bending stiffness have shown to be less important than traction (Wannop, 2013), this study is making the assumption that all other factors between the shoes are negligible and the tread pattern is the only difference.

The third limitation is considering phase 3 of this study. While I may be somewhat representative of a portion of basketball players, the results are very focused to my body type. With more participants of varying anthropometric characteristics a better idea of the required frictional characteristics of the shoes could be discovered.

Future Work:

This study while having its limitations shows potential to further understand the effects of outsole shoe tread patterns on athletic performance with the following recommendations. First, obtain larger samples of data. With larger samples of data the results of this study may be strengthened, and new trends may be discovered. In order to accomplish this it is recommended to focus on the transition types that have displayed the larger instances of slips with more trials from more participants.

Regarding the shoes it is recommended that the same base shoe be used to eliminate the assumption that all other shoe characteristics other than the outsole are negligible. Along with this it is recommended to test more tread patterns that are more similar in style by altering only one or two of the tread pattern characteristics in order to discover how smaller changes may effect overall performance. This would allow researchers to report more specific findings about the effects of tread pattern alterations in regards to performance over various types of transitions.

While tread groove pattern may be the cause that increases traction it could also be the amount of surface area of the tread that is coming in contact with the floor during the transition that is increasing traction. This surface area contact still would be altered by changing tread patterns and characteristics. While tread grooves are necessary both from a durability standpoint, but also to minimize risks of slipping on contaminated surfaces, by determining the amount of surface area in contact with the floor during a transition it could explain the differences experienced between tread patterns.

By collecting and recording velocities and accelerations of participants during various transitions further explanation of the differences in slips between transitions could be discovered.

Lastly, having more participants with varying anthropometries complete the various transitions on the force platform a better idea of the frictional requirements of shoes could be further discovered and discussed for multiple body types that could exist among the different positions on a basketball team.

CHAPTER 6: Conclusions

This study has relevance and importance as it well documents the slipping of athletes on hardwood surfaces with commercially available shoes under normal, non-contaminated court conditions. While other studies have looked at the slipping of shoes on various materials it is often done using a mechanical tester under contaminated floor conditions. This study shows that the problem of slipping while training, practicing, or playing in a game on a basketball court with basketball shoes exists.

This study has found that between the 2015 Nike Hyperdunk basketball shoes and the Under Armour Lockdown basketball shoes there was a significant difference in the amount of slipping that occurred over a variety of transitions. Particularly in transitions with a lateral type plant step the Under Armour shoes had lower instances of slips. This could be from differences in the shoes, but the most likely factor that could explain these differences is the variation in tread patterns.

This study also found that different types of transitions based on movement and direction changes have varying risks for slipping. While the shuffle drill of this study showed the most difference between shoes, the half court transition showed the highest instance of slips occurring. Of the transitions that showed the most slip the fact that the full court and half court transitions, and the full court and shuffle transitions, were shown to be statistically different shows that there is some difference in the amount of slips experienced based on the type of transition and the distance leading up to that transition. This could give some insight into which transitions types basketball shoes should be tested on to ensure they have the appropriate or desired traction players may be looking for.

This study also supports the idea that the current values considered for the coefficients of friction of basketball shoes may be too low. The force plate tests of this study indicate that coefficient of friction values during transition type movements could even reach a value of 1.34. There may be a need for more realistic testing of basketball shoes when determining if the coefficient of friction will prevent slip in dynamic transitions.

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APPENDIX A: Preliminary Survey Questions

1. How many pairs of basketball shoes do you own?
2. If you own more than one, are they all the same kind?
3. If you own more than one pair of basketball shoes, do you separate shoes for different situations?
4. Is there or would there be a reason for choosing different shoes in different situations?
5. How many pairs of basketball shoes do you buy at a time?
6. How long do you expect your shoes to last?
7. How much are you willing to spend on a pair of basketball shoes?
8. What do you look for when purchasing basketball shoes?
9. What tread patterns if any, do you find to be desirable in a shoe?
10. Do you like when your shoes squeak?
11. Can you recall times when you or your foot has slipped while playing basketball? Please describe the situation.
12. Have you ever experienced an injury from you or your foot slipping? If yes, please describe the extent of the injury.
13. Does the level of traction you experience or expect to have change the way you play basketball?
14. If there was a basketball shoe shown to give you an edge in traction would you want that shoe?

APPENDIX B: Drill Completion Post Experimental Interview Questions

1. Which tread pattern do you feel gave you the most traction?
2. Did you have any expectations of the shoes before you ran through the drills?
    a. If yes, what were they?
    b. If yes, did this have any effect on the way you ran through the drills?
3. Does the level of traction you have affect the way you normally run drills?
    a. If yes, how?
4. When you normally run during practice, do you expect your shoes to slide a little bit?
5. When you were running the drills did you feel as though any of the shoes provided you with more or less traction than any of the other shoes?
6. If there was a basketball shoe that was shown to give you an edge in traction, would you want that shoe?
7. Do you feel that fatigue affected the amount of traction you received from any of the shoes?
8. Do you feel that fatigue affected the way you ran through any of the drills at any point?
9. When purchasing basketball shoes do you consider the tread pattern of the shoe?
    a. If yes, what do you look for? What makes a tread pattern desirable to you?
10. When purchasing basketball shoes do you consider traction as a factor in determining your choice.
    a. If yes, is there a way you attempt to test the traction before you purchase the shoes?
11. Do you like when you have basketball shoes that squeak?
    a. Does this affect your use or purchase of basketball shoes?

12. What other characteristics do you look for when purchasing basketball shoes?

13. Have you ever experienced any injury due to you or your foot slipping?

14. How many pairs of basketball shoes do you own?

15. Are they all the same kind?

16. Do you separate shoes between games and practice?

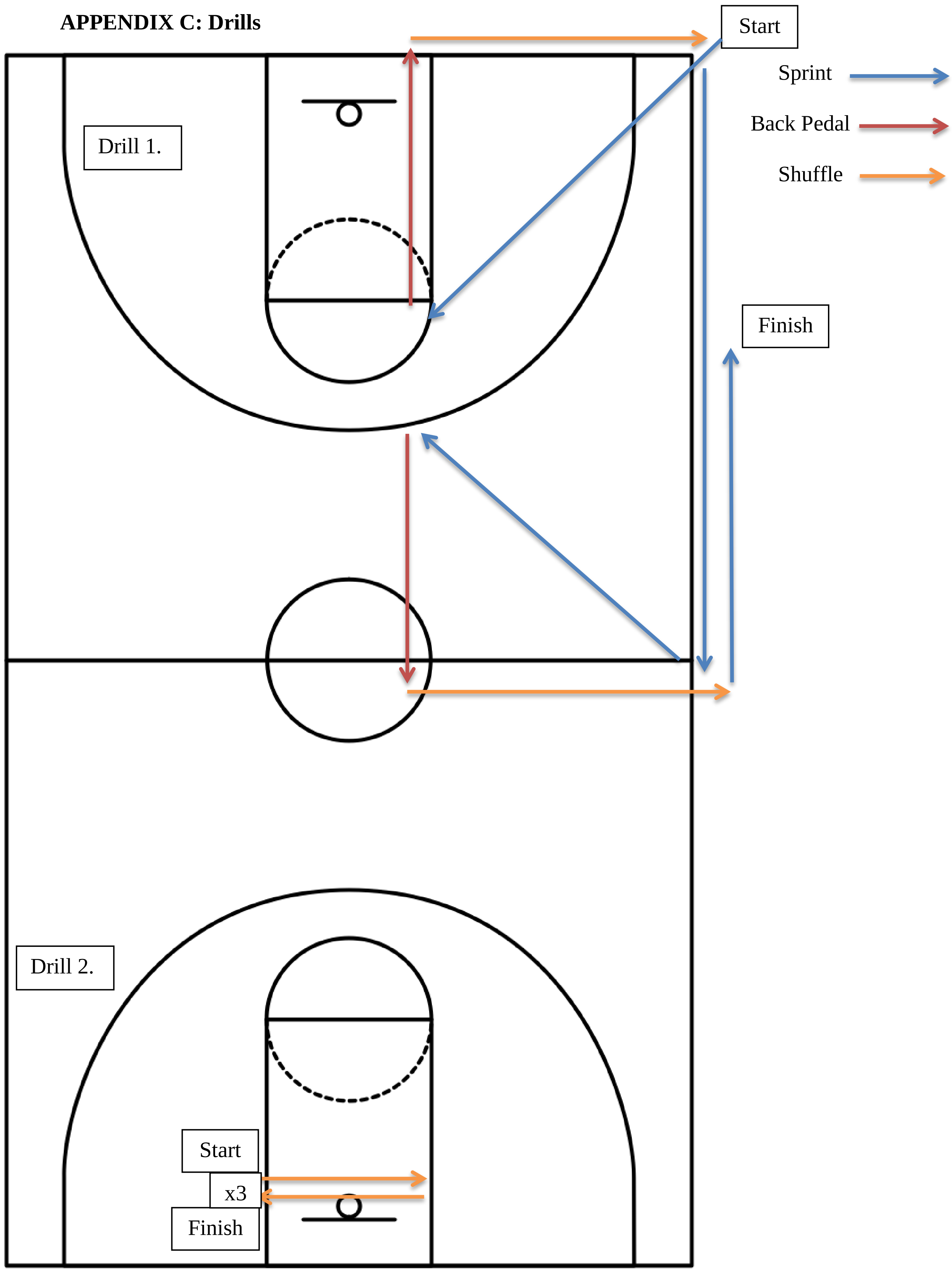
17. Is there a reason for choosing different shoes in different situations?

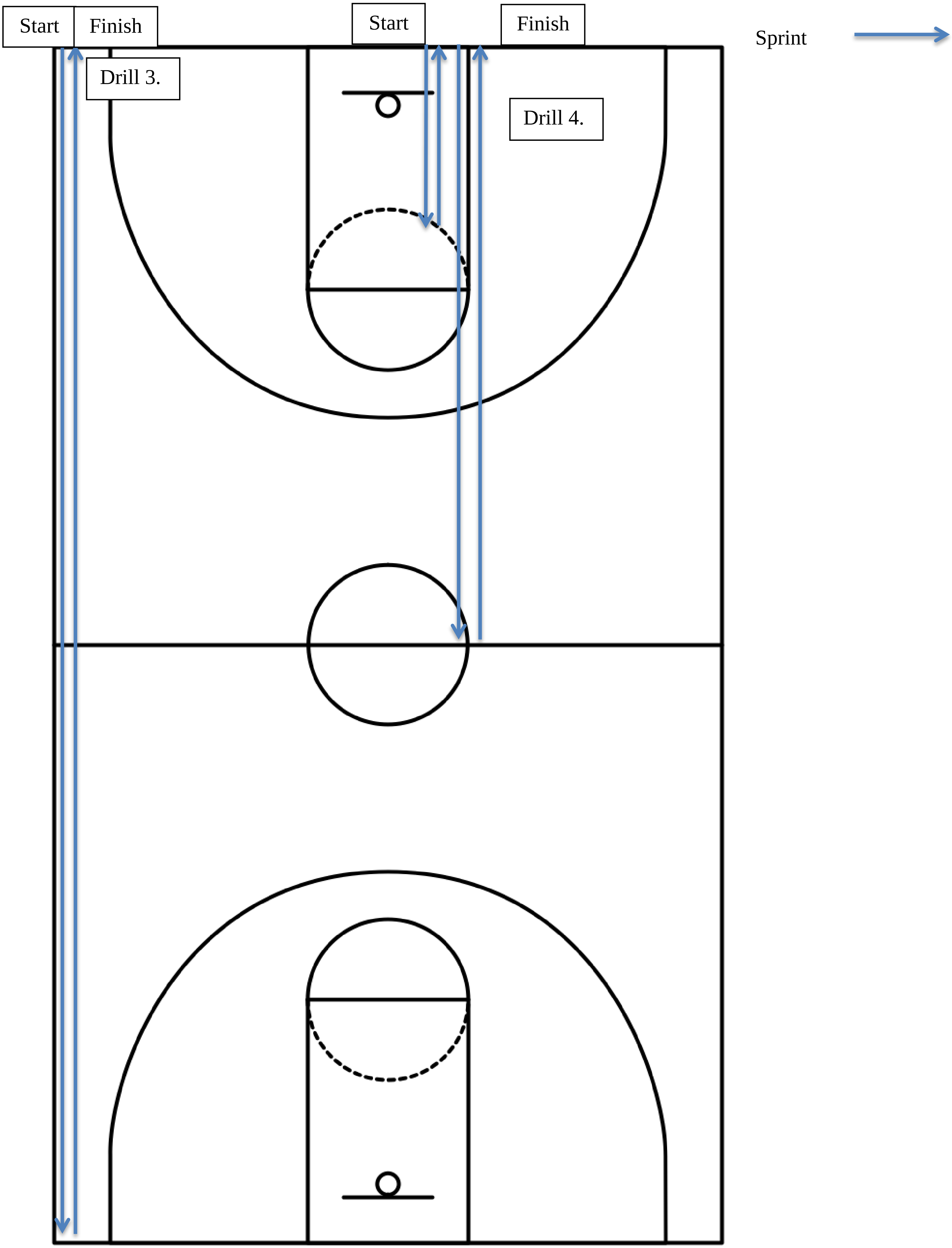
18. How much are you willing to spend on a pair of basketball shoes?

19. How many pairs of shoes do you buy at a time?

20. How long do you expect your shoes to last?

APPENDIX C: Drills




Start
Finish
Drill 3.
Start
Finish
Drill 4.
Sprint

APPENDIX D: Current Market Shoe Tread Analysis

Diagonal treads of any kind	35/37 = 95%
Herringbone pattern in any direction	22/37 = 59%
Zig Zag/ Wave like pattern across the shoe	23/37 = 62%
Break lines across the shoe in the front half	19/37 = 51%
Break lines in heel region	20/37 = 54%
Treads near outer edge of shoe are along the shoe	16/37 = 43%
Lack of treads or an indentation on arch	21/37 = 57%
Lack of treads or an indentation in center of heel	14/37 = 38%
Different pattern/shape on ball of foot	10/37 = 27%
Use of concentric shapes	9/37 = 24%
Same pattern of tread over whole outsole	6/37 = 16%
Possibility of cupping	3/37 = 8%
Use of Diamond Shape	5/37 = 14%
Use of Hexagons	4/37 = 11%

A large number of the shoes documented include some kind of diagonal treads, usually consisting of some type of herringbone pattern, a zig zag pattern, a wave like pattern, etc. Many of the shoes had lines going across the front half of the shoe, with break lines also going across the front half of the shoe. Most of the shoes changed the type of pattern or the orientation of the pattern over the course of the whole outsole. Many shoes seemed as though they did not value having treads on the center of the heel, or over the arch region. This can be explained as these do not seem to be high points of contact. A good number of shoes had treads along the shoe direction near the outside edge of the sole.

Many of these common trends are supported by previous studies. Having break lines could allow for flexibility and for the shoe to bend, but they could also be an attempt to allow a channel for contaminants to move out from under the shoe. The lines across the front half of the shoe are in support of having tread grooves perpendicular to a major desired movement direction of forward and backward. The lines along the shoe on the outside would then also be beneficial for lateral movements as the treads again would be perpendicular to the desired movement direction. This would all be beneficial if there is any sort of contaminant that could end up on the playing surface by increasing the chance for greater coefficient of friction under those circumstances.

2015 Nike hyperdunks:

- Herringbone pattern on majority of shoe sole
- Concentric Circles from the inner ball of the foot.
- Open circle at heel.
- Small break lines at the front half of the shoe.
- No tread on arch.

2015 Nike Kobe elite X:

- Large X at heel center
- Figure on inner ball of foot with lines across shoe
- Narrow arch with a lack of tread on arch
- X pattern making small squares on rest of tread
- No breaks for bending or channels

2015 Nike KD 8:

- Diamond pattern at ball of foot
- Lines along arch
- Herringbone pattern
- Large thick breaks across shoe in front half of shoe
- Large thick break along shoe direction at inside part of the heel
- All shoe tread designs are made of small rectangles.

Nike Lebron XIII:

- 5 hexagons in front half of shoe
- 1 large hexagon on heel
- Hexagon on ball of foot and heel is split in half with treads across and along shoe
- Hexagon on big toe has treads across shoe
- Hexagon on other toes angles out and back.
- Rest of shoe made up of small triangles including arch.
- No break lines

Nike Kyrie 1:

- Herringbone pattern
    - Long zig zags treads on the rest of the shoe, curving and following the slight curve from toe to arch to heel.
- Circle at center of arch
- Break line through the heel starting forward inside near arch going back across heel.

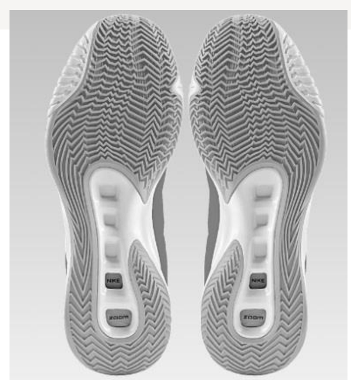
Nike Lebron XII:

- 5 hexagons on front half of shoe.
    - Each has a web like pattern (small triangles)
- Large breaks between hexagons
- Hexagon centered on the heel
- The rest of the tread is broken into polygons, many of which are triangles.

Nike Jordan Rising High:

- Concentric Diamond pattern on front half of shoe.
- Indent on arch
- Single diamonds on heel
- Small line breaks across front of shoe.

Nike Zoom HyperRev:



- Large indent from arch through the center of the heel
- Treads are mostly jagged lines across the shoe.
- Treads curve to be along the shoe on the outside of the arch

Nike Zoom Hyper quickness:

- Same as previous

Nike Jordan CP3.VII AE:

- Herringbone pattern
    - Zig Zag pattern on outer rim and in ovals located on the ball of the foot.
- All other sections have an "S" shape along the length
- Jordan Symbol in center of the heel.

Nike Jordan Men's Super.Fly 4:

- No treads on arch.
- Indent on arch for Jordan symbol
- Outside edge has treads in a wave like pattern along the length of the shoe
- The toe region excluding the big toe has the same wave pattern
- Herringbone Pattern
    - All other regions have zig zag pattern across the shoe.
- Break lines in middle along shoe at heel
- Break lines in front half of shoe separating what seems to be major points of contact.

Nike Hyperfuse 2011:

- Herringbone pattern
    - Zig zag pattern across the front half of the foot.
- Medium size line breaks in front half across shoe
- Swoosh from arch into heel area
- Heel treads longer diagonal lines
- Center of heel break lines meet
- Treads along the length of shoe on outside edge.
- Lack of treads on arch

Adidas D Lillard shoes:

- Herringbone pattern with rounder corners
    - Shorter zig zag pattern on the front half of shoe
- Lines across heel
- Indent from arch through center of heel.
- Break lines following shoe outline

Adidas D rose 6 boost:

- Point at front center of shoe.
- All treads angle back and away from center line
- Adidas logo at center of heel

Adidas D Rose 773 IV:

- Herringbone pattern
    - Zig zag pattern broken into squares. The points and change of directions are present in the squares.
- Logo in the center of the arch
- 3 lines along center of heel (Adidas) made of diamond pattern

Adidas Isolation 2:

- Herringbone pattern
    - Long zig zag pattern across width of the shoe
- Adidas logo in center of heel
- Grooves on outer edge follow shoe outline
- Indent from arch back to the heel
- Narrow arch with lack of treads
- Small break lines across the front half of the shoe
- Small break line along the shoe in the middle of the front half.

Reebok Shaq Attaq IV:

- Herringbone pattern
    - Zig Zag Pattern
- Large breaks in front half of shoe for bending
- No tread on arch
- Indent in center of heel

UA Micro G Clutchfit Drive 2:

- Herringbone pattern that alternates direction
    - Zig Zag patterns alternating point direction between line breaks.
- Zig Zag treads over the entire sole including logo

UA Clutchfit Lightning:

- Break line in the middle of the front half of the shoe along the shoe.
- Break lines across the front have of the shoe
- Very toe of the shoe has a zig zag pattern across the shoe
- Herringbone pattern alternating direction
  - The outside half of the shoe has a zig zag pattern along the length of the shoe
  - The inside half (ball of foot side) of the front of the shoe has a zig zag pattern across the shoe.
- Center of the heel has a large logo made of diamond pattern with lines across the shoe
- The heel region has a zig zag pattern across the shoe

UA Lockdown:

- Large break line down the middle of the shoe along the length all the way to the heel
- 2 large break lines across the front half of the shoe.
- Tread pattern is made up of a bow tie like shape.

Another UA Clutchfit Lightning:

- Herringbone pattern with a lot of breaks and gaps in treads
  - Comprised mostly of diagonal lines, or a zig zag pattern.
- Large breaks in tread mostly in the middle of the shoe along the shoe.
- Break lines that separate a region near the outside section of the arch region

UA Curry 2:

- Break lines across shoe in the front half of the shoe
- Break line across mid heel of the shoe
- No treads on the arch through the middle of the entire heel.
- Concentric zig zag pattern, almost like concentric stars.
- Zig Zag direction is along the shoe near the inside and outside of the shoe
- Zig Zag direction is across the shoe near the middle of the shoe.

Nike KD Trey 5 III:

- Herringbone Pattern
  - Zig Zag Pattern all same direction.
- Thick break lines along front half of the shoe.
- Kd logo along arch checker board pattern around logo
- Break lines meet at center of heel with surrounding treads in variety of directions.

Nike KD VII Elite:

- Large center oval at the arch lacking treads
- Jagged almost wave like pattern on the heel
- Many lines are on a diagonal
- Almost concentric "v" like pattern on the front half of the shoe

Nike Zoom without a doubt:

- Concentric hexagons from the ball of the foot.
- Large Nike logo from arch to the center of the heel lacking tread
- Zig Zag pattern on the outside front, toe region except for big toe.
- Herringbone pattern
  - Zig Zag pattern on the back half of the heel
- Lopsided, oblong hexagons (almost oval) covering the rest of the sole.
- Thin break lines y pattern on heel
- Thin break lines splitting the patterns in the toe region.

Nike Lebron Soldier IX:

- No tread on arch
- Crown symbol on center of heel
- Herringbone pattern along shoe length
  - Zig zag tread pattern on outside quarter of the front half of the shoe nearer the arch
- All other treads are hexagons made of small triangles.

Nike Prime Hype II:

- No tread on arch
- Heel has an indented oval (almost tear drop shape) in the center with concentric treads around it
- Break lines of the heel are basically an asterisk.
- Concentric circles starting at the ball of the foot, the big toe, and the outside pad of the foot next to the ball of the foot.
- All other treads are extensions of the concentric circles
- Break lines across the shoe in the front half of the shoe are more forward than the concentric circles.

Nike Air Max Audacity:

- Underlying herringbone pattern (difficult to tell)
    - Appearance of a zig zag pattern with an overlay of non-uniform ovals.
- The ovals form a nike swoosh in the center of the shoe with diagonals intersecting it.

(2014) Nike Hyper Dunks:

- Concentric diamond pattern on ball of foot and big toe region
- Outside ball of foot region has triangular type concentric shape
- Outside toe region has slight zig zag pattern along the length of the shoe
- Narrow arch with lack of tread because of logo
- Heel region consists of treads that follow the outline of shoe.

<u>Nike Jordan Air Deluxe:</u>

- Jordan Symbol in the center of the heel
- Treads following leg direction of Jordan symbol
- 3 pointed star shape in center of the front half of the shoe.
- Treads in front of star symbol follow direction of the points of the star
- Treads below the star go along the shoe
- Another 3 pointed star in the center of the arch region.

<u>AND 1 Tai Chi:</u>

- Thick tread lacking grooves outlines the front half of the shoe.
- Logo in the center of the arch
- Some break lines across the front half of the shoe
- Herringbone pattern
    - All areas with tread patterns consist of zig zag or wave like pattern across the shoe.

<u>AND 1 Xccelerate 2:</u>

- Logo in the center of the arch.
- Rounded herringbone pattern
    - Majority of the treads are a wave pattern across the shoe
- Herringbone pattern
    - The back outside portion and front inside portion of the treads are a sharper zig zag pattern.

Adidas Crazy 8:

- Little tread over the arch region
- Herringbone pattern
    - All treads in the front half region and in the heel region have a zig zag pattern across the shoe.
- Triangular areas from the outer edges of the shoe break up the consistent shape of the fore foot tread area.

Adidas Dual Threat:

- Rounded herringbone pattern
    - Front half of shoe made up of wave like pattern going across the shoe.
- Front half of the shoe is broken up by think break lines going across the shoe.
- Almost the entire perimeter of the shoe has small treads that follow the outline of the shoe.
- Logo in the heel to arch region.
- Heel has break lines across the shoe and diagonal and wave like treads

Nike Kyrie 2:

- Logo in center of heel
- Treads along shoe over arch region
- Heel made of diagonal treads changing direction in the middle of the shoe
- Front half of the shoe consists of concentric ovals surrounded by varying directional treads
- Toe of shoe has treads across shoe
- Break lines through the ovals
- Mostly lines across the shoe or slight diagonal away from center of ovals in the front half of the shoe.
- A few treads along the shoe on the outer edge of the front half.

Adidas J Wall 2.0:

- Rounded herringbone pattern
    - Wave like pattern in the front half of the shoe broken up by several break lines across the shoe and one along and in the middle of the shoe.
- W logo is made of rectangles, brick like pattern, John “Wall”
- Wave like pattern on heel overlaid by 3 strips along the shoe with treads across the shoe

Adidas Crazy light Boost:

- Herringbone pattern
    - Slight diagonal lines across the shoe in the front half of the shoe.

- Three break lines along the shoe in the front half
- Outer edge of the shoe is mostly lines across the shoe with some slight angles
- Logo in center of arch
- Indent in center of heel.