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PERFORMANCE OF ATHLETIC CLEATED SHOES IN THE SPORT OF ULTIMATE FRISBEE

By

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Bachelors of Science, Industrial Engineering, University of Louisville, May 2010

A Thesis

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University of Louisville

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As Partial Fulfillment of the Requirements

for the Professional Degree

MASTER OF ENGINEERING

Department of Industrial Engineering

December, 2012

PERFORMANCE OF ATHLETIC CLEATED SHOES IN THE SPORT OF ULTIMATE FRISBEE

Submitted by:_____

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(Date)

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_____

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ABSTRACT

Athletic cleated shoe failures are commonplace to competitive-level ultimate frisbee players. Currently, there are no athletic cleated shoes designed for the sport of ultimate frisbee; players generally choose between football or soccer cleated shoes in the hopes of finding a match between footwear designs for a different sport and the needs of their own sport. A focus group and subsequent survey were conducted and administered, respectively, to better understand the types of failures that occur, as well as the causes of these failures. Approximately 78% of failures experienced in ultimate frisbee are caused by the player executing a cut, or quick change of direction. This motion leads to failures along both the outside and the inside of the toe box, which account for roughly 88% of reported failures. With these failures in mind, further observation of the sport as well as a detailed biomechanic laboratory experiment have been proposed to determine the need for an athletic cleated shoe specifically designed for the sport of ultimate frisbee.

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I. INTRODUCTION

A frisbee player is sprinting along the sidelines, using long strides to pull ahead of the defender at their hip - both are in a mad dash for the frisbee disc sailing overhead. As the disc descends to just a few feet above the turf, the player in front plants their feet firmly, pushes down into the ground to set up a forward lung in an effort to grab the disc, when suddenly their right cleated shoe rips apart at the seams. Their toes spill over the edge of the outsole; their balance lost, they crash to the ground just as the frisbee, too, falls untouched to the earth.

Chances are, anyone who has played ultimate frisbee at a competitive level has had at least one encounter with a cleated shoe failure of this kind. Whether the seams rip apart, the fabric of the upper tears open to expose the foot, or any other of the myriad modes of failure, these instances are a common occurrence within the sport. Because of these failures, players would be hard-pressed to travel to a tournament without seeing duct tape called upon at half-time to repair a cleated shoe failure, or to not know a teammate or two who bring an extra pair of cleated shoes “just in case.”

Despite a wide range of athletic cleated shoes available to the public for field sports such as American football, soccer, and lacrosse, there is no cleated shoe option that addresses the sport of ultimate frisbee. Frisbee players are left to pick and choose from other sports’ offerings, their choices based mostly upon previous experience and recommendations from friends. This lack of specific design for the sport of ultimate

frisbee is causing players to choose cleated shoes which were designed with a separate target population in mind.

Football and soccer cleated shoes are the most prevalent in use by ultimate players, which may be explained by similarities between the three sports' required movements and actions. These shared actions – namely accelerating, changing direction quickly (cutting), decelerating, and jumping – lead to forces upon footwear that can be very similar, creating designs in footwear that are also comparable.

However, as each sport is different, they require different actions in varying frequencies, thus changing the need for strength and durability in footwear for each sport. The body types of football players vary, but on average are larger than those found in other sports. These players will likely see all of the previously mentioned actions, however they will have a high amount of downtime between their repetitions as the ball is not always "live." This size of player and method of action will require high strength in certain parts of footwear, but may not require long durability. A soccer player, on the other hand, is generally smaller and will execute these actions for longer periods of time, but may also get substantial downtime when the ball is not in his or her part of the field. This smaller size of player and longer duration of action emphasizes the durability of footwear more so than the strength. An ultimate frisbee player has no standard size, however, and will execute these actions with much greater frequency due to a lack of pauses between possessions and the constant involvement of all team members on every play of both offense and defense. This non-standard player size and

the increased frequency and duration of actions means that the sport of ultimate frisbee requires a cleated shoe that has both strength and durability throughout the shoe.

With the variances in duration and frequency of the actions mentioned above come variances in requirements of footwear to deal with the forces created by these actions. Simply by visual examination, it is easy to identify the difference between soccer and football cleated shoes, as shown below.

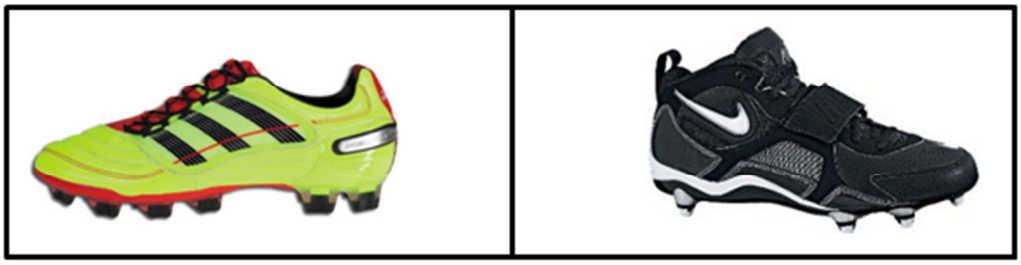

Figure 1.1 - Soccer cleated shoe (left) compared to football cleated shoe (right). Source: www.google.com

As you can see, compared to it's soccer counterpart the football cleated shoe appears to be made of more durable construction with large surfaces, straps, and increased stitching. With the differences in required action leading to such different designs for soccer and football cleated shoes, would it not be sensible to assume that equal attention should be paid to the difference in necessary design for ultimate frisbee cleated shoes?

This study, Performance of Athletic Cleated Shoes in Ultimate Frisbee, aims to determine:

- How are cleated shoes failing in ultimate frisbee? and

- What causes these failures?

Furthermore, the goal of this research is to gather data that will be used to design a biomechanical laboratory test to address the final question: Is a new design warranted by these failures?

II. LITERATURE REVIEW

When examining the field of research in athletic footwear, it becomes apparent that past and present studies are mainly focused on the effect of footwear upon the body (Nigg, et. all, 2005), and that the design and manufacturing of footwear is more focused on the form of the shoe than on its fit (Khaled, at. all, 2003). Neither of these two areas addresses the concern of footwear's failure to maintain structural composure during physical loading. In order to gain an understanding of how one might measure a cleated shoe's ability to withstand these physical forces, it is necessary to understand the construction of athletic cleated shoes.

A. Cleated Shoe Design

There are two main portions of an athletic cleated shoe: the upper and the lower. The upper is generally made from leather, synthetic, or knit material that wraps around the sides and top of the foot and is designated by (1) in Figure 1 (McPoil, 2000). The lower, on the other hand, is comprised of both the midsole (2) and the outsole (3). The main purpose of the midsole is to act as a cushion for the foot, attenuating shock by way of its construction of foam-like polymers such as Ethylene Vinyl Acetate (EVA) and

Polyurethane (PU) (McPoil, 2000). The outsole, on the other hand, is of solid construction, and is the bottom-most part of the cleated shoe. The outsole is designed for interaction with the playing surface, and houses the cleats for field sports such as American football, soccer, and ultimate frisbee.

Figure 1.2 - Illustration of the shoe upper (1), midsole (2), and outsole (3) of a football cleated shoe. Source: www.ebay.com

All three of these components are attached to what is known as the “last”, which is the foot-shaped shell that creates the overall size and shape of the shoe. Using the “Strobel” method is the most common method to perform this attachment (McPoil, 2000). This method utilizes a piece of felt-like material to first attach the upper to the last, then the midsole and outsole are either glued or stitched into place underneath the last.

B. Seam Strength

Although no research was found investigating the failure of athletic footwear to maintain structural integrity during physical loading, research in the related field of joint and seam strength of footwear was discovered. This research indicated that the joint between the footwear upper and sole was the most critical joint as it receives the heaviest loading (AE Bond, 1995). To determine the strength of both stitched and adhesively bonded joints, SATRA peel testing is used (AE Bond, 1995 and Intertek, 2010). This method of testing involves placing the materials in opposing clamps, then slowly increasing the tensile load of the pull between these two clamps. The load at failure is considered the bond strength.

Due to the increased loads put upon them, athletic footwear has a 25% higher required seam strength (stitching) than casual shoes at 10 N/mm compared to 8 N/mm based upon the SATRA peel test (Intertek, 2010). These elevated requirements in seam strength for athletic footwear indicate that specific design is necessary when demanding the capability to withstand the physical forces seen in sports. Otherwise casual footwear, athletic footwear, and formal footwear would all be one and the same, with no variances in their required characteristics. However, these elevated requirements for athletic footwear do not explain the differences between footwear designed for specific sports, and the requirements that come with each sport. This level of detail would be greatly informative for those wishing to determine if footwear design was truly representative of the biomechanical forces experienced in each sport.

C. Ultimate Frisbee Popularity

The lack of research in the area of athletic cleated shoe's ability to maintain structural composure during physical loading highlights the need for this study, specifically when targeting the sport of ultimate frisbee. According to USA Ultimate - the governing body for ultimate frisbee in the United States - popularity has been steadily increasing since the turn of the century. Between the years of 2004 and 2011, membership in USA Ultimate nearly doubled, adding over 15,000 players in the 8 year span. This rise in popularity is due mainly to the increase of adolescent and young-adult members. Of the total membership, "College" and "Youth" members make up the majority as a combined 72% (USA Ultimate). Over the past 8 years, membership in both of these sections has grown by 206%.

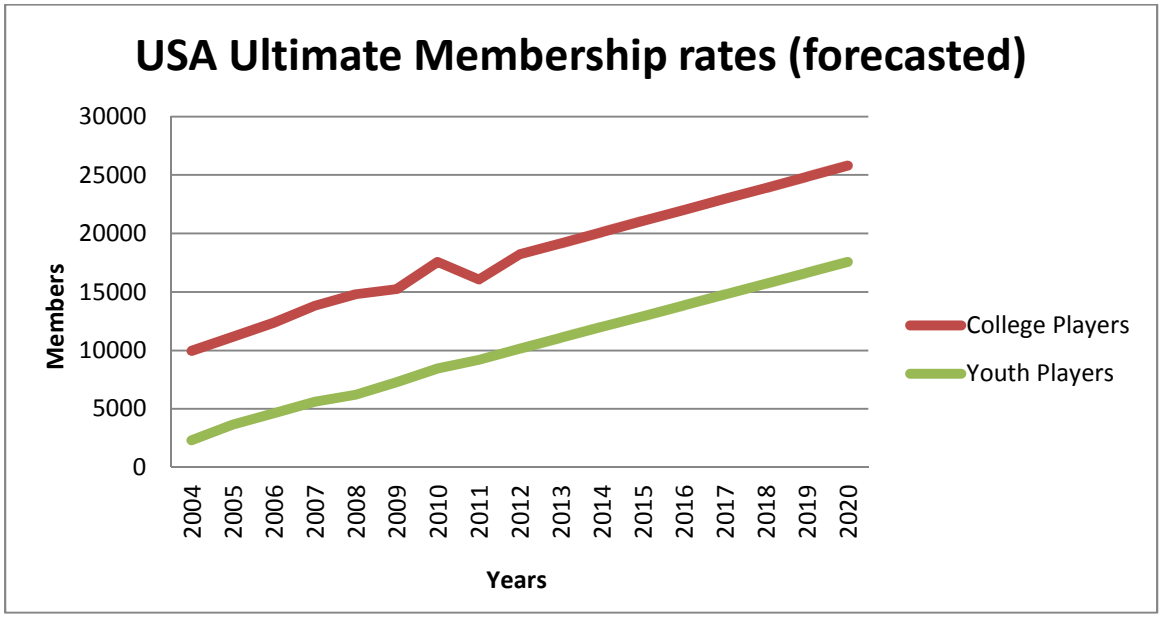

Figure 1.3 - Annual membership in USA Ultimate nearly doubled between 2004 and 2011. Forecasting shows a continued growth with populations surpassing 40,000 college and youth players by 2020.

Despite a decrease in college players in 2011, this upward trend looks to continue in the coming years. Forecasting suggests that populations of youth and college players will surpass 40,000 combined within the end of this decade.

One possible explanation for the decrease in membership rates in 2011 could actually indicate a positive move for the sport: the creation of the first professional frisbee league. In April of 2012, the sport of ultimate frisbee witnessed its first professional game. The American Ultimate Disc League (AUDL) brings frisbee to the national spotlight, and highlights the popularity of this sport which is played around the world. Tryouts for the initial eight teams began in the spring of 2011, and may have pulled USA Ultimate members away from renewing their college-level memberships so that they could focus on becoming professional athletes. With the addition of seven new AUDL teams for the 2013 season, an even larger population of frisbee players will be performing at the highest level and will need the footwear necessary to allow this competition to occur (www.theaudl.com).

In addition to the highest competition level, there has been continued growth in the youth level in recent years. One reason for this may be that frisbee requires no special space or fixtures in order to play it. As long as you have people, a disc, and an open area to play, you can start a game. For this reason, frisbee can be started by anyone, almost anywhere, and has the potential to spread in a manner similar to the way soccer has.

With an increasing player population year after year, combined with the expanding professional league, there is now a greater need for research into the performance of cleats in the sport of ultimate frisbee.

III. METHODS

This research was conducted in two parts, and utilized a mixed-methods approach. Part One was created to answer the questions, “How do cleated shoes fail in ultimate frisbee?” and “What causes these failures?” by use of a qualitative study. This study involved the development of a focus group to determine the three most common cleated shoe failures witnessed by ultimate frisbee players, as well as the three most common actions that caused those failures. These failures and actions were then used in further qualitative study for Part Two: development, distribution, and analysis of a survey that asked a larger population of ultimate frisbee players to choose the most common of these three failures and actions. Then, by utilizing quantitative analysis, it was determined whether or not there was a greater occurrence of one pair of action and resulting failure, which lead to the final stage: designing a laboratory test to replicate the cleated shoe failure and measure the biomechanical forces enacted upon the shoe during the most common failure. This experiment would be designed to test if current cleated shoe construction can withstand the biomechanical forces present in ultimate frisbee, and provide results to help determine the answer to the final question, “Is a new design warranted by these failures?”

A. Qualitative Study

To best understand the types of cleated shoe failures that occur in ultimate frisbee, the most practical method was to ask the frisbee players how their cleated shoes fail. It is assumed that the players themselves are experts in this matter, since they are the most familiar with cleated shoe use in their sport.

An effective method in gaining information from the players directly would be the use of surveys. However, since existing research on failure modes was non-existent, it would have been difficult to construct a survey asking players which failures were most likely. Either the principal investigators (PIs) would need to create a list of failures on their own, or they would have to provide a survey with an open-ended question. These both proved to be impractical first steps: for one, a list created by only the PIs would be lacking in terms of depth and experienced knowledge. Also, the way by which different players could describe the same witnessed failure in an open-ended question is boundless; therefore, the investigators could mistakenly label the same failure as two separate incidences if interpreted incorrectly, and vice versa. In order to ensure that the list of failures was created by experienced persons, and that the description of failures could be understood by all parties, a focus group was formed to help build the survey that would follow. This focus group identified the perceived most common areas of failure in cleated shoes as well as the actions that caused said failures. These failures and actions were then used to construct a survey that was distributed among a larger group of frisbee players.

1. Focus Group Design.

The focus group was designed with one moderator as well as two additional observers who were charged with taking note of the non-verbal communication occurring between the focus group participants. To ensure that data collected in the focus group and subsequent survey could be used to generate an executable laboratory study; guidelines were developed to narrow the variables affecting cleated shoe wear and causes for failure.

Subjects for the focus group were recruited from the local Louisville Ultimate Frisbee Association. Since membership in this association is required to play organized events, recruiting members ensured that subjects were experienced and currently playing the sport at a competitive level. This experience and competition level provided a greater likelihood of insightful viewpoints on cleated shoe failures as well as experienced-based anecdotes and examples.

Eight male volunteers were chosen to take part in the study. A quantity of eight subjects was chosen to keep the focus group at a manageable size yet obtain a large data set. In order to keep variables in the future lab study limited, only male subjects were chosen.

Subjects between the ages of 19 and 35 were chosen in order to target physically active adults. Thirty-five was selected as the age ceiling because strength and mobility are shown to gradually decline in males between the ages of 20 and 55

(Sampson et. all, 2000). Targeting roughly the middle of this age group as the age ceiling was thought to help maintain a subject population that would still be playing at a competitive level.

The subjects were required to have at least 3 years of experience playing the sport in the past 5 consecutive years to ensure recent and adequate playing time to be knowledgeable of cleated shoe failures. Male subjects were proven to be healthy by having no pre-existing lower body injuries which would limit their athletic ability, nor could they wear any foot orthotics. Omitting these players from the study was seen as a way to reduce variables in the forthcoming laboratory test.

Attention LUFA ultimate players: There will be a focus group held on the University of Louisville's Belknap Campus to investigate cleat performance. Free food will be provided. All healthy male players aged 19-35 are invited to volunteer. Expected duration of this focus group will be just under 2 hours (115 minutes), and will meet only once.

This group is being organized by Dr. G.T. Holman, PhD, who can be reached at Talley.holman@louisville.edu or (502) 852-7997. Please contact Andrew Johnson, B.S., at agjohn03@louisville.edu for more information.

Figure 1.4 - Announcement for the focus group that was sent to the Louisville Ultimate Frisbee Association (LUFA)

The focus group duration was 115 minutes, with a 15-minute break between two 30-minute segments containing two questions each. Only one focus group was held, which was recorded using an audio recorder. After the focus group, the audio recording was anonymously transcribed, referring to each subject by a color for their name. Colors were chosen that each had unique sounding names to decrease the chance of the moderator's confusion between subjects during audio transcription. As an example, black and blue were not both selected because they started with the same two-letter

combination which could be confusing. The names set aside for subjects were; Mr.'s Orange, Red, Black, Green, Yellow, White, Tan and Purple. After the transcription, the audio recording was destroyed to protect subject confidentiality.

After the group had yielded a list of failures and the actions by which they occurred, the subjects were asked to rank both failures and actions in order of least common occurrence to most common occurrence using the Rank-Order method. Using these ranks given by the group, the three most common failures and actions were selected to be used in the subsequent survey. The questions and transcription of this focus group can be found in Appendix II.

2. Survey Design.

As with the design of the focus group, guidelines had to be created for the acceptable survey subjects. Due to the nature of a survey, these guidelines were formed as demographic and exclusionary questions that would narrow down acceptable results. The survey can be found in appendix III.

The survey was formulated to present the previously identified top three failures and actions that cause them to the wider frisbee-playing public and ask for the players' opinions on the most common of each. The same Rank-Order method was used to present these options.

B. Data Collection and Analysis

To ensure proper data collection during both the qualitative and quantitative portions of this study, a multifaceted approach was used. During the focus group, a specific population was targeted for sampling. For the survey, however, both cluster and random sampling were utilized to gain information.

1. Focus Group Data Collection

Focus groups, as explained by Krueger and Casey, are “carefully planned discussions… on a defined area of interest” (Krueger and Casey, 2009). In order to run the discussion effectively, specific populations of subjects who share common knowledge on the area of interest are sought. Therefore, guidelines were created to specify the target population, and a request for volunteers matching this population was sent to the local frisbee association, as stated above in *Focus Group Design*.

2. Survey Data Collection

Since surveys oppose focus groups in the method of subject selection, opposing data collection techniques were carried out. Cluster sampling was first used, and after identifying the cluster the sampling method transitioned to random selection.

a. Cluster Sampling. In order to identify a population that could feasibly be studied within the scope of a thesis, cluster sampling was used to narrow down the world-wide population of players. The Great-Lakes region was highlighted as the local cluster of primary data collection (region identified by USA Ultimate). This cluster contains the three cities of Louisville, KY; Nashville, TN; and Versailles, OH. Each of these cities represents a similarly sized subject group due to the presence of club-level tournaments in each. These tournaments attract a large population of highly skilled players for the weekend(s) they are conducted.

b. Random Selection. To ensure a heterogeneous subject population, random selection was used within the cluster identified above. In all cities, frisbee players were approached at tournaments with disregard to age, gender, height, weight, or visible handicaps. They were asked if they would like to participate in a survey regarding the performance of athletic cleated shoes in frisbee, and if they answered yes they were handed a physical copy of the survey along with a pen to fill out said survey.

3. Qualitative to Quantitative Analysis

a. Translation of Data. In order to render results from the survey into quantitative data, the answers were first translated from an alphabetical scale to a numerical scale. This scale followed the pattern A=1, B=2, C=3, etc. This made calculation of means, standard deviations, and alpha statistics much easier.

However, certain questions had answer scales that did not easily lend themselves to this translation, such as rank-order and forced-choice with the ability to mark several choices. When dealing with rank-order questions, the answer selected as most important was chosen as the subject's answer, and all subsequent ranks were ignored. Therefore, if choice C were selected as most important, the numerical translation was 3. In cases where multiple choices were selected, the mean of the numerical values was calculated. A selection of both A and B, then, would have a numerical value of 1.5.

Question 9 was the exception to these rules. This question asked respondents which position on the field they play most often, and allowed for multiple selections. Since certain positions require the same repeated motions, the selection of these positions was translated as the same numerical value. Specifically, selections of the "Handle" and "Cutter/Popper" position were treated as the same value (1) due to their similarity in physical motions: both require very frequent changes in direction, or cuts. The "Wing" position alone was given a value of 2 as it did not share similarities with

other positions. Selections of the “Mid” and “Deep” positions were also translated to the same value (3) due to their lack of a specific frequent motion. Selection of “All Positions Equally” was translated as the mean of all values, 2.

b. Omission and Removal. As noted above, not all questions fit into the alphabetical to numerical translation. One such question, number 15, was formatted with a numerical answer required. This question dealt with the length of time (in months) that a respondent had owned their current pair of cleated shoes. Due to the vastly larger range of answers possible than the standard 1 through 6 for the other survey questions, this question was not used to determine the overall Cronbach’s alpha statistic. Questions 5-7 were also omitted because the presence of answers was case-dependent. These questions dealt with injury issues, and due to the fact that these questions applied to less than 50% of respondents, it was deemed that not enough data points existed to include these questions.

There was also a case made for the removal of one survey. This survey contained an answer to question 9 that was a statistical outlier. The value recorded for this answer was approximately three times greater than the next-largest value, and was over 14 times the average of all other values (240 compared to 84 and 16, respectively). Due to this incomparably large value, it was speculated that the respondent may not have understood the wording of the question. This potential lack of understanding, and

the increased possibility of incorrect answers throughout the survey's entirety, resulted in the respondent's data being removed.

Before final calculation of the most common cleated shoe failures and the actions that caused them, the data was reviewed and responses from all respondents, who had failed the exclusionary questions, were removed from the data. The exclusionary questions, numbers 5-7, dealt directly with injuries and braces which would change the way the individual moves on the field. A change in one's movement while playing the sport of frisbee would create an additional variable for how their cleated shoes are affected. In order to discount any failures that may have occurred due to the added pressures of ankle/knee braces, or unnatural movements caused by injury compensation in the individual, those who answered "Yes" to question 4 were removed from the data set.

c. Quantitative Analysis. In order to determine validity of the data gathered by the survey, the Cronbach's alpha and Pearson's correlation statistics were calculated using Minitab, a Microsoft program, for individual pairings of survey questions previously identified as validating questions. For this survey, validation questions were questions 1 and 8, which refer to the respondents age and their years of experience, since a natural correlation between age and experience was expected. The Cronbach's alpha was also used to determine the overall validity of data gathered from each question in the survey. Again, the omissions and removals stated above apply to this calculation.

To determine the most common failures witnessed by ultimate frisbee players, and the actions associated with them, the percentage of selection for each choice was calculated. The same method was used to determine the most common cleated shoe types used by frisbee players

IV. Results

The Cronbach's alpha and Pearson's correlation for the validating questions resulted in positive correlations.

Validating Questions Analysis	
Pearson's Correlation	0.67
Cronbach's Alpha	0.80

Figure 1.5 – Result of Pearson's and Cronbach's Alpha calculations for questions 1 and 8.

An overall Cronbach's alpha for the survey in its entirety also showed a positive correlation.

Survey Test Results	
Cronbach's Alpha	0.70

Figure 1.6 – Result of the Conbrach's Alpha calculation for the survey.

The preferred cleated shoe types were reported as:

- Soccer cleated shoes = 20 selections
- Football cleated shoes = 14 selections
- Other cleated shoes = 4 selections
- Lacrosse cleated shoes = 3 selections

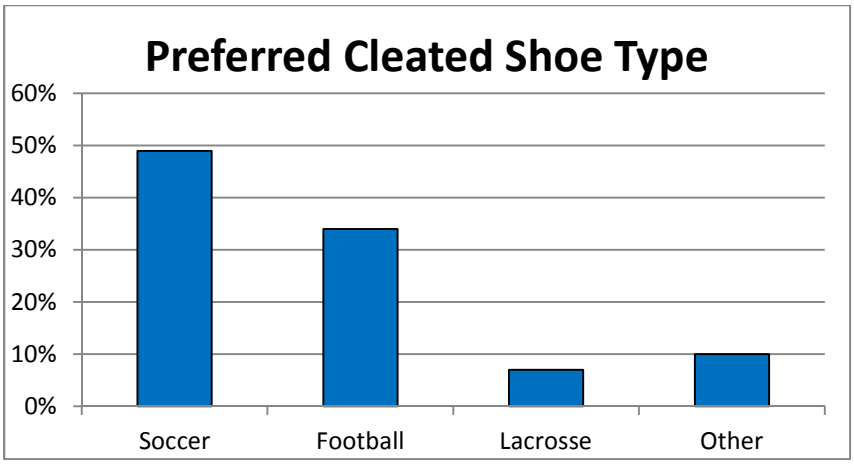

Figure 1.7 – Preferred cleated shoe types, by sport.

Most common failures were reported as:

- Failures along the outside of the toe box = 17 selections
- Failures along the inside of the toe box = 18 selections
- Failures along the front of the toe box = 5 selections

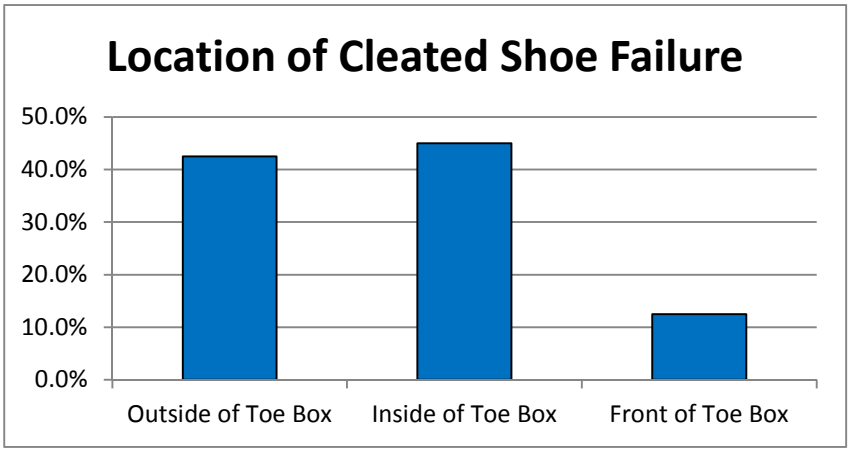

Figure 1.8 – Location of cleated shoe failure while playing ultimate frisbee.

Most common causes of failure were reported as:

- Cutting = 32 selections
- Stopping = 8 selections
- Jumping = 1 selections

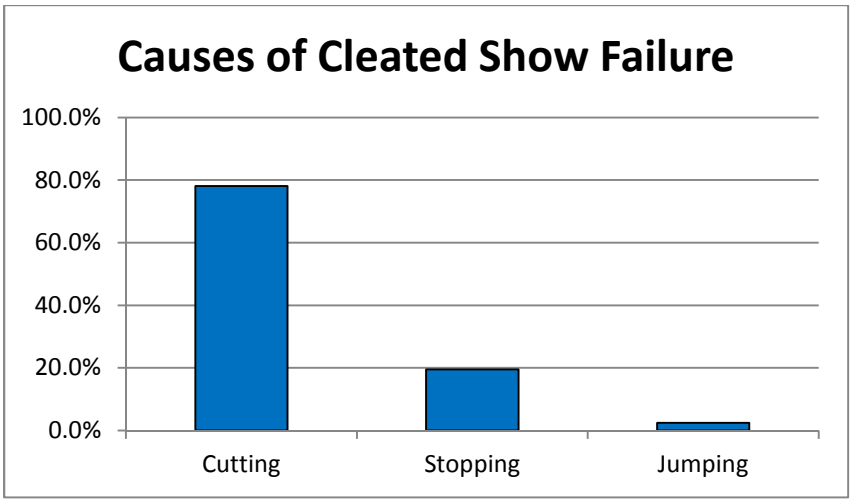

Figure 1.9 – Actions that cause cleated shoe failure while playing ultimate frisbee.

VI. DISCUSSION

A. Interpreting Data

1. Alpha and Correlation Statistics

The Pearson's correlation value (0.7), indicated a strong correlation between question responses, falling within the 0.5-1.0 range (Cohen, 1988). A Cronbach's alpha value of 0.8 falls within the tighter consistency range of 0.8-0.9 denoted as good consistency for this statistic (George, 2003).

Having both test statistics fall in positive ranges indicates that the validation questions had correlated answers. Specifically, as a player's age increases their years of experience also increase. These results not only confirm our initial belief that age and experience would be correlated, but are also consistent with the data found in USA Ultimate membership rates that show the majority of new frisbee players are youth- and college-aged. Frisbee players are shown to enter the sport at an early age, and continue playing through the years.

While the survey's Cronbach's alpha value (0.7) was lower than the 0.8 required for good consistency, it is within the range of acceptable consistency, and is seen as a validation of overall survey data.

2. Cleated Shoe Failures and Causes

With total selections separated by only a single entry, there was no statistical significance between the two main causes for cleated shoe failure. However, with a combined 87.5% of total selections, the two failures of tears along the outside and inside of the toe box are by far the most prevalent in the sport of ultimate frisbee.

Garnering 78% of total selections, cutting was determined to be the leading cause of the aforementioned failures. This result lends credence to the selected most-common failures, as during cutting an increased physical load is placed upon the sides of the cleated shoe, increasing its chance for failure.

B. Reforming Questions

With the results gained from this analysis, it becomes necessary to narrow the field of study to determine more information regarding cleated shoe failure. Specifically, new questions need to be answered. They are:

How often do ultimate frisbee players cut? With the leading cause for cleated shoe failure determined to be cutting, the overall frequency of this motion during a game of ultimate frisbee is a necessary piece of information. This data will help shed light on the frequency of physical loading applied to cleated shoes worn by frisbee players.

Are cleated shoes designed to withstand the loading associated with repeated cutting? Taking the frequency discovered by the previous question, it would need to be determined if the current design of athletic cleated shoes could withstand that level of repeated physical loading. If this answer is no, then the evidence would point to the need for a new design in athletic cleated shoes to address this specific aspect of ultimate frisbee.

C. Recommendations

Considering all of the data and the discussion above, much still needs to be done to determine if the athletic cleated shoes currently available can properly handle the physical stresses inflicted upon cleated shoes by the sport of ultimate frisbee.

1. Observations

In order to create a baseline for the frequency of cutting executed during a game of ultimate frisbee, direct observation is recommended. By sending out a team of observers to tournament and league play, multiple games and/or players in each game can be watched at once. Observers would be recommended to pick a player before the game starts, and record demographic information as well as that player's position on the

field. Throughout the game, the observer would tally each cut made by that player. Overall playing time would also be tracked, so that a frequency of cuts per unit of time could be created. Through repetition of this method, a new data set would be compiled, and the average cut frequency per position per unit of time could be calculated.

2. Biomechanics Laboratory Experiment

To answer the second question generated above, “Are cleated shoes designed to withstand the impact of repeated cutting?” a lab experiment is proposed to test the current cleated shoes used for ultimate frisbee.

This experiment will identify the physical loading upon athletic cleated shoes during cutting, and will test the ability of cleated shoes to maintain structural integrity during such loading. The following procedures and methods will be used to create this experiment.

- A selection of the most commonly used cleated shoes (as determined by the survey in this thesis) will be put through SATRA peel testing. This test will determine each cleated shoe’s seam strength, which will be used for later comparisons.

- The elasticity of each cleated shoe's materials will be determined either by: a) contacting the manufacturer, b) Using the Young's modulus for the material, or c) running an elasticity test in the laboratory.
- A fatigue test will be conducted to determine the acceptable loading levels and the failure-causing loads for each cleated shoe. This test will apply a load to the cleated shoe material in a cyclical manner until failure of the material, or until a specified number of cycles (determined by the observed cutting rate of frisbee players) have been completed to consider the load acceptable. This test will be repeated with a sequence of loads until both the highest acceptable load and failure-causing load are determined.
- A motion-capture study will be the final portion of this experiment. Visual markers will be placed upon the selection of cleated shoes in the noted areas of failure (outside and inside portions of the toe box), both above and below the seam between the upper and the sole. Subjects will be asked to wear the cleated shoes while performing multiple cuts on a section of astroturf in the lab. The location of markers will be recorded before the subject places their foot in the cleated shoe. This will set the standard location with no stresses upon the cleated shoe material. The subject will then put on the cleated shoe, and the markers will be recorded by a motion capture system while the subject executes a cut. This will capture the deformations within the cleated shoe caused by cutting. These deformations, along with the elasticity of the materials found previously, will be used to determine the total stress being placed upon the

cleated shoe material while cutting. These stresses will then be compared to the stresses found in the previous SATRA and fatigue tests.

- Underneath the section of astroturf will be a force plate to track displacement and force applied during the cutting motion. This will provide data on the normal force reaction during cutting, which will allow better understanding of all forces applied to the cleated shoe.
- The motion capture system will utilize telescoping lenses. These lenses are preferable due to their ability to retain high resolution on a small capture area, while being placed further away. The benefit of a larger distance between capture area and lens is the lower likelihood of distortion caused by the curvature along the rim of the lens. This distortion is usually caused by lenses placed closely to the capture area, so that motion captured travels to the outside edges of the lens. Measurements based upon the resulting video may not be as reliable in these instances.
- With the combined findings of the SATRA test, fatigue test, force plate, and motion capture study, finite elemental analysis will be used to draw a conclusion regarding the ability of the current selection of athletic cleated shoes to withstand the physical forces applied to them during the sport of ultimate frisbee. The use of FEA will help to determine if the failure is caused by the stress of loading or by the material properties. If it is found that – for either reason – cleated shoes cannot withstand these forces, then a new cleated shoe design is necessary to properly address the needs of this sport.

D. Discussion and Conclusions

Currently, there are no athletic cleated shoes designed for the sport of ultimate frisbee. Players generally choose between football or soccer cleated shoes in the hopes of finding a match between footwear designs for a different sport and the needs for footwear in their own sport. Although frisbee players cannot agree on which cleated shoe best fits their sport, they can agree on some things; specifically, what types of failures they experience, and the causes of these failures. Overall, the action of a quick change in direction, or cutting, accounts for 78% of failures in cleated shoes while playing frisbee. The most frequent failures this action causes are tears along the outside and the inside of the toe box, which make up 88% of failures.

Ultimate frisbee is a sport that has experienced considerable growth over the past 8 years. Numbers of youth and college players, who make up over 70% of current members of USA Ultimate, have more than doubled in that time span to over 25,000 players in 2011. With continual growth in these demographics, membership rates are projected to increase and exceed 43,000 by 2020. In addition to this growth of young players, ultimate frisbee has now become a professional sport. With the expansion of more professional teams in 2013, there will be an unheralded number of frisbee players competing at the highest level. Ultimate frisbee is proven to be a sport that is adopted at a young age and played through an individual's years. With a growing number of young players every year, and these players continued competition sometimes even through to

the professional level, the market for athletic cleated shoes specifically designed for ultimate frisbee is expanding annually. Based upon these findings, it is now time to take the next step to determine if the current design of athletic cleated shoes can withstand the forces of repeated cutting in ultimate frisbee.

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APPENDIX I

GRAPHS RELEVANT TO STUDY

	2004	2005	2006	2007	2008	2009	2010	2011
Staff	182	182	188	182	179	182	213	212
Lifetime	231	331	342	360	376	397	407	442
Adult	6572	6764	7112	7413	7723	7707	7465	8268
College	9951	11157	12374	13813	14815	15237	17568	16058
Youth	2298	3646	4617	5628	6218	7274	8467	9193
Coach/Player	0	0	0	0	0	615	661	455
Coach	0	0	0	0	0	118	165	193
Friend & Family	0	0	0	0	0	56	55	73
TOTAL	19234	22080	24633	27396	29311	31588	35001	34894
	10%	14%	11%	11%	7%	7%	10%	0%

Figure 2.1 - Number of members for USA Ultimate (governing body for the sport in USA)

APPENDIX II

FOCUS GROUP QUESTIONS ANDTRANSCRIPTION

A. Questions

1. What was your last pair of cleated shoes to fail/break?
    a. Ask for type of cleated shoes (sport type; include sport position)
    b. Ask for duration of use
    c. Ask for material type
    - Expected Answers: Their most recent pair. Soccer cleated shoes, failed after 6 months, fabric was a combination of leather and man-made materials.
2. How did this pair fail/break?
    a. Ask for type of failure
    b. Ask for area of shoe in which failure occurred
    - Expected Answers: A tear along the outside seam of the shoe (next to 5th metatarsal).
    - This question will lead directly to the list of failures on the survey.
3. How quickly did the failure/break occur?
    a. Ask If instantly; during which action?
    - Expected Answers: The failure occurred suddenly, over the course of one day. A small tear appeared early during a game, and the shoe broke by the end of the game.
    - This question will lead directly to the list of actions that cause failures on the survey.
4. Have you experienced this failure/break before?
    - Expect Answers: Yes, my previous pair of cleated shoes had failed in a similar way.

B. Transcription

Subject: We should refer to you as…

Moderator: You can refer to me by my name, that's fine.

Subject: Master and commander?

Moderator: Master and commander, that's fine – you can refer to me by my name. Luckily I am running the study, so my name will be attached to it anyway, but yours won't be, for uh…

Subject: Can we call you Mr. Johnson?

Moderator: Mr. Johnson would be very nice, thank you very much. Um, so as I mentioned, I'll pass this to you and you can pass it to each other when you'd like to speak. If you have an idea or an answer that you want to put down before you get the chance to speak it, there's a pen and paper in front of you guys to jot notes on. Um, the recorder is here in the middle of the table, so for those of you far away from it – if you could make sure you speak loudly and clearly, and if you guys can make sure you annunciate and try and stay away from the use of slang just so it's easier to understand once the meeting has been transcribed. Also, I'll go ahead and describe most of these questions that I'm going to be asking you revolve around failures and breaks. Failure and break of a cleated shoe, basically is defined as either a tear or wearing down of a cleated shoe that makes it not usable. So whether that's seams busting open, cleated shoes ripping off, or two parts of the shoe separating; if it stops your cleated shoe from being able to be used, then it's either a failure or a break. Anything else, please just try to describe it as best you can; a rip, a tear, a chunk missing or something like that; try to describe other detriments to your cleated shoe as best you can. So outside of that, that's basically all of the ground rules. I'll go ahead and start asking you all some questions. Feel free to keep eating as you'd like, but once you have an answer, or input, just let me know, raise your hand, I'll toss you a little – uh, squeezy toy – and field your response. So the first question I'll be asking is:

First Question: "What was your last pair of cleated shoes to fail or break?" Can anybody remember?

Mr. Orange: I had a pair of addidas copas, which are a soccer cleated shoe, and they failed.

Moderator: Adida copas?

Mr. Orange: Adidas Copa.

Moderator: And you said those were soccer cleated shoes.

Mr. Orange: Correct.

Moderator. Ok, wonderful. Do you, uh.. do you know what kind of fabric those are made of?

Mr. Orange: They should be a… leather.

Moderator: Alright. How long did you have those far?

Mr. Orange: I had them for… two years.

Moderator: Alright, and when you're finished with uh, with your um, comments, you can feel free to pass it along to anyone else. Yes, Mr. Red.

Mr. Red: I had two pairs of cleated shoes fail within, on the same weekend. Uh, one was a pair of Adidas, I don't remember the type. They were, um, they were receiver cleated shoes, wide receiver cleated shoes.

Moderator: Ok, so they were football cleated shoes?

Mr. Red: Yea, and the other ones were Nike receiver cleated shoes. Uh, they were fairly similar. The Nike, like, it's whatever like their premiere wide receiver cleated shoes are.

Moderator: Ok. Do you know how long you had those before they failed?

Mr. Red: Both of them were under 6 months. And they failed in the same spot.

Moderator: Alright, and do you know what sort of material those were made out of; if they were mainly leather or a man-made material?

Mr. Red: Uh, I'm not sure what the top was. I don't think they were like, real leather. Uh, but the bottom, I think both the bottoms were plastic. It was a softer material on top, and then like a plastic foot base that hold in cleated shoes.

Moderator: Alright, thank you. Alright Mr. Brown.

Mr. Brown: I had a pair of – oh I've got it here – um, sorry, I've got it written down, Diadora LXK, uh thosea soccer cleated shoe. And before that I had Adidas Predators fail in the same way.

Moderator: Really?

Mr. Brown: Mhmm.

Moderator: Were those soccer cleated shoes as well?

Mr. Brown: Yes.

Moderator: Ok. About how long did you have the three different pairs before they failed?

Mr. Brown: Um, about a year each.

Moderator: Ok. And do you know what type of material those were made out of?

Mr. Brown: Leather.

Moderator: They were leather? Ok. Alright. Mr. Black?

Mr. Black: I had one pair fail, and it was an Adidas brand soccer cleated shoe, I don't remember exactly which one.

Moderator: Do you know roughly the duration of time you had them for?

Mr. Black: About a year.

Moderator: About one year?

Mr. Black. Yea.

Moderator: And you know the material it's made out of?

Mr. Black: It was the same plastic material that Mr. Red had on his shoes.

Moderator: Ok. Alright, I've got the KEVA - Oh, sorry, do you have something else to add, Mr. Red?

Mr. Red: The Nike's were Nike Air Zoom pros.

Moderator: They were Zoom pros?

Mr. Red: Yea. And the low cut, not the high top.

Moderator: Nike Air Zoom pro. Ok. Thank you, I forgot to mention: I have two helpers today. They're not going to be asking you any questions. They're just here to basically observe, to see if, you know, general reactions to questions and everything. Really don't mind them, they're not going to be judging you or interfering or asking questions or anything, so you can pretend like they're not here. Um, ok so moving on to the next question:

Second question: "How did your last pair of cleated shoes fail or break?" Mr. Red?

Mr. Red: Both of them failed on the outside, um, just below the toe box.

Moderator: Ok which side? Along the first metatarsal or the fifth?

Mr. Red: Fifth. One was on the right shoe, one was on the left shoe.

Moderator: Alright, and what sort of failure: was that a rip along the seams, was that a separation of the top and bottom?

Mr. Red: Uh, both actually. It ripped along the seams and then it ripped so much that eventually then it came undone. So it was like a rip and then the separation between the material and the plastic underneath.

Moderator: Ok. For those of you unfamiliar: the first metatarsal is your big toe, and the fifth is your pinky toe; so basically asking what side of the toe box the cleated shoe had failed. Alright Mr Black.

Mr. Black: On those Adidas that I had, they broke on both feet on the right side the seam near the heel, uh, completely opened up.

Moderator: Do you remember which side of your heel?

Mr. Black: The inner left.

Moderator: Ok on the right foot it was the inner left.

Mr. Black: Yes, the left. And then on the left side, the entire front of the shoe the seam busted. I had like a gaping mouth action on my shoe.

Moderator: So was that in the very front, in front of your…

Mr. Black: Ya the entire, ya the whole like the seams busted at both toes, and it eventually came around and met.

Moderator: Ok was that at where the upper meets the plastic bottom?

Mr. Black: Mhmm. Right near the seam.

Moderator: Alright Mr. Brown.

Mr. Brown: Uh with the Diadoras I had, I had both started to rip at a seam by the… did you say the first metatarsal?

Moderator: Where, on your big toe?

Mr. Brown: Ya. Uh, except behind, when you're closer to the ball of the foot. Um, and it was a seam in the leather, it was actually between two leather panels.

Moderator: Ok, so that was on the upper entirely, between two of the leather panels?

Mr. Brown: Yes, and that was on both shoes.

Moderator: In basically the same spot?

Mr. Brown: Yep, now and with the three Adidas the same thing happened, except it was between the upper and the insole.

Moderator: And was it in a similar place?

Mr. Brown: Mhmm.

Moderator: Ok.

Mr. Brown: Same spot only lower in the cleated shoe.

Moderator: Ok. Yes, Mr. Orange

Mr. Orange: Uh the Copas separated at the 5th…

Moderator: Ok along your pinky toe?

Mr. Orange: Mhmm. And then actually the previous cleated shoe that I owned, that failed, was a Nike Speed TDs. I ended up getting a new pair recently.

Moderator: And the Nike Speed TDs are receiver cleated shoes as well?

Mr. Orange: Yes.

Moderator: Ok, so both your soccer cleated shoes and football cleated shoes failed on that 5th metatarsal?

Mr. Orange: The Speed TDs failed at the 1st.

Moderator: Ok. And, for the soccer cleated shoes, your addidas, along the 5th metatarsal, was that a rip at the seams? Or was that between the lower and the upper?

Mr. Orange: Separation of material, so it was between the leather and the hard plastic is what gave way. As was the same with the Speed TDs.

Moderator: Ok. And I'm sorry, remined me again: That was a failure of the football at the 1st metatarsal?

Mr. Orange: Yes. Close to the ball of the foot that I think Mr. Brown was explaining.

Moderator: Alright, wonderful. Does anyone else have anything to add? Ok, thank you very much. So we're making some pretty good pace. It's only 5:27, would you guys like to take a break or just keep going with the questions, there's only two left.

Group: Let's keep doing this! Let's keep going.

Moderator: Ok wonderful. So third question: we're remaining on your last pair of cleated shoes to break or fail. This question involves how long it took to occur. Not how long you owned the cleated shoe for, but once you noticed the start of the failure or break, how long it took to go from noticing it beginning to an unusable cleated shoe. Alright Mr. Red?

Mr. Red: Uh, the first ones –because they were in the same weekend – just blew out immediately. Like I didn't notice anything, they just blew out. Then that made me look at the other ones, and see that there was some wear and a little fraying. And then those burst the next day.

Moderator: The next day? So how many games did you get in on the first day? Was it at a tournament? Were you playing 4 or 5 games?

Mr. Red: Yea, so the first one died in the final game of a tournament. And then the next one went out the second game of league the next day.

Moderator: Ok, so you got… was it at the end of the game? Beginning of the game?

Mr. Red: Beginning.

Moderator: Beginning of the game. So you basically got one plus a little bit of an extra game. We'll just call that 1 game before blow out (failure).

Mr. Red: And like I said I only really noticed it because I looked, because the other ones did it.

Mr. Orange: The Speed TDs, I didn't use them until they failed. Once they started to show they were going to go, I went ahead and got the new pair and broke those in so I never had them blow out. One they started separating, I didn't want to be in a game and all of a sudden my cleated shoe goes.

Moderator: Ok, so from when you noticed the start of that tear, to when you stopped using it – was it the same time? Did you notice after a game and never use it again?

Mr. Orange: I noticed it, I let it keep going a little bit until my new ones came in.

Moderator: Do you know about how long that was? Maybe how many games you played?

Mr. Orange: How many games? We could say, probably give it a full weekend of tournament play, so we'd say like 8 games?

Moderator: So 8 games until you stopped using?

Mr. Orange: Ya. Cuz it got to the point where it's, the start of the next game is gonna blow 'em out.

Moderator: Ok. Mr. Brown.

Mr. Brown: Ya, so I had them for almost a season before I noticed them starting to rip. So that would be – with pickup and everything – maybe 20 games? And then probably went another, you know, put them down during the winter, came back for the next spring season and probably played another 10 or so games on them before I thought they were unuseable.

Moderator: And did you stop using them because they got to the point you thought they would fail on your next use, or did they blow out?

Mr. Brown: They didn't blow out, but I thought that they would fail.

Moderator: Ok. Thank you. Mr. Black.

Mr. Black: My addidas that I had, I got them at the beginning of my first club season and I played all of club season on it. Granted I didn't play a whole lot whereas Mr. Orange played a whole lot more than I

did. I didn't break them down as much but then I kept them for Fall league, for the Winter time I put them away and brought them back out for spring and it was spring league that they began to come apart, and like any other ultimate player – I didn't have a spare one in use – I duct taped them and they only lasted a few more weeks past that, maybe 2 or 3 weeks tops.

Moderator: So what caused you to start duct taping them? Did you notice the rip occurring and start taping them then?

Mr. Black: I noticed the rip occurring, and you know it happened in the first game of spring league and I wanted to keep playing so I taped them together.

Moderator: So from the rip – you were in a spring league game?

Mr. Black: Yes.

Moderator: Did you continue the rest of the day before taping them?

Mr. Black: Yes. Or no, when I saw the rip I finished the game on it and then in between games I got tape from someone and taped them together.

Moderator: So it was pretty immediate?

Mr. Black: Ya.

Moderator: So you noticed it, and you taped it together. And how long did it last?

Mr. Black: 2, maybe 3 weeks after that, so 6 to 10 games. With league and pickup here and there.

Moderator: Ok, so 6 to 10 we'll call it 8 on average. Did it blow out? Did they become completely unuseable?

Mr. Black: No they became unuseable. They had the mouth effect on the left and it was definitely time for a new pair. If I would have let them go, if I kept taping them, obviously it wouyldn't have had the same effect as a proper cleated shoe.

Moderator: Alright. Does anyone have anything to add? No? Ok. Wonderful. Do you guys.. next question, Do you remember what was happening for the blowouts, or for when you first noticed it, do you remember what happened? If you were cutting, or jumping, or anything like that. Do you all have, maybe if it wasn't your last pair, any pair that has broken in the act of movement, do you remember what that was? Mr. Red.

Mr. Red: Uh the one that broke in the tournament, I was cutting, I faked deep, I planted on my left foot, and when I came back in I didn't feel it go but all of a sudden my toes were touching grass. And then the other pair the next day was I was playing defense and the person made a cut and I planted off my right foot and it went; I noticed that one right away. It almost made me roll my ankle.

Moderator: So the first time was a fake deep, so technically I guess a hard cut.

Mr. Red: They're both quick changes of direction.

Moderator: Alright. Anyone else? Mr. Orange.

Mr. Orange: I think the Copas, from a bad habit that I have from playing soccer, I would drag my right foot for moving the ball, so I think that transitioned over to ultimate when I first started playing that's why I was wearing the Copa's because that's what I was used to from soccer. I actually remember thinking about it a while back and I think that could have been a catalyst for me losing it on that right side of the right foot.

Moderator: Ok. And so that's more of uh, you noticed the fact that you were dragging your foot a lot when you were moving when you were advancing, and you think that might have contributed to it?

Mr. Orange: Ya, when I go to fake and change the other way; in soccer you're dragging a ball, so in ultimate I was dragging my foot… which is very inefficient cutting.

Moderator: Ok. Does anyone have other cleated shoes? Ya, Mr. Black.

Mr. Black: My role in ultimate is to be a middle cutter, at least it has been for the last year or so. I rely solely on making hard in-cuts hard out-cuts, immediate changes of direction. How I blew the toes on the left foot was a fake in and a hard plant, a change of direction going the other way, and the seam broke... I can't remember on the 1st or the 5th. That's how it started, one of the sides broke as I was cutting the other way. As far as the right heel, I can't think of a way of how I broke that.

Moderator: Ok. Alright. Mr. Brown, anything to add?

Mr. Brown: Um, none of mine blew out, but on all of the pairs of cleated shoes, I could feel them. On hard cuts every once in a whole I could feel them ripping a little bit more, a little bit more. I never got a blow out, but it's the same deal; a hard cut, change of direction.

Moderator: Ok. Alright, does anyone have… ya?

Mr. Red: As I said, like, the reason I feel like mine are always on the outside is whenever I make cuts, I know I get on the outside of my foot. So it feels like my foot always sort of slides over, like if the top part as any give, it feels like it floats over the top of the edge of the shoe. And if I cut it too hard, if I don't stop in time, I can really feel my entire foot going over. So if I am actually cutting solidly, that's what leads it to end up breaking.

Moderator: So you can basically just feel the entire upper role over the plastic bottom and feel your foot go with it.

Mr. Red: Ya, I feel like I spend a lot of time on the out, like the, the cleated shoes on that side.

Moderator: Alright. Anyone else? Ok. Thank you. So, final question:

Have you all experienced this failure or break before in your cleated shoes? I know some of you had mentioned you had a few cleated shoes to break that way. What would you say if you've had multiple cleated shoes fail, you noticed the most of? Which one did you see reoccurring the most, or you think is the main cause for action of failure for your cleated shoes? As in where it breaks the most, or where they fail the most? Mr. Red?

Mr. Red: Well like I was saying, being on the outside of my cleated shoes I think, I currently have two different pairs of the same cleated shoe but the bottoms of them are slightly different, like the setup of the cleated shoes. The one that has more cleated shoes on the outside is currently, like looks fine. And the other one has, you can see where it's starting to tear apart. And I brought those if you wanted to take a look at them.

Moderator: Ya, if you wouldn't mind that would be good. So you think basically that it's that area of the cleated shoe?

Mr. Red: Ya, and the fact that one of them has 4 or 5 along the edge and the other has 2, the one that has 4 is holding up a lot better than the other.

Moderator: Ok and they're both on the same outside…

Mr. Red: On the right foot along the 5th metatarsal.

Moderator: Ok. Alright, Mr. Orange.

Mr. Orange: The Speed TD's I think is just a wear and tear kind of deal, I don't think that it is necessarily anything that I was doing wrong; whereas the coppas I believe that I was, that it was my fault for them to not, be of propure use anymore because of my use of them. The Speed TD's I think it was just maybe the glue or something like that.

Moderator: Ok. But as far as having past cleated shoes fail on you, have you noticed any recurring themes?

Mr. Orange: Well I've only owned two pairs of the Speed TD's, I went back to them because they end up being great for the sport and they did hold up for a year maybe longer and I just made the choice of switching. But the second pair that I own now I've had for last season and I'm still using them this season and they have not showed anything of wear and tear.

Moderator: Are those the only two that you've owned while you've played ultimate Frisbee?

Mr. Orange: The Speed…

Moderator: Of any cleated shoe, any type of cleated shoe.

Mr. Orange: Ya, just those two. I tried a pair of I went for a bargain on the lacroisse cleated shoes, the under armor lacross cleated shoes, it was a waste of $30, they are terrible. So I went back to the Speed TD's after those. I tried those out for a while.

Morderator: Ok, thank you. Mr. Brown.

Mr. Brown: Um, when I had the three pair of Adidas fail in the same way I started to look for cleated shoes that were reinforced between the upper and lower. So that's why I got the Diadoras. They didn't rip there, they ripped between two leather panels just above the same spot where the Adidas had. So then I tried football cleated shoes, the Nike Speed TD's, because they're a little wider – I have kind of wide feet – there are a lot of soccer cleated shoes that I can't wear. Right behind my toes is pretty wide. And those worked out for me, I haven't had them fail the same way again.

Moderator: Ok. Have you noticed any sort of wear and tear in that same area where the two previous cleated shoes have failed?

Mr. Brown: I haven't noticed any wear and tear. Instead of having a bunch of smaller panels stitche together it has a wider panel in that area, I was hoping since there's not as many seams it would be stronger. So far so good.

Moderator: Alright, so the two previous that had failed on you were both soccer cleated shoes and both failed along the inside, say the ball of your foot. Generally in the same area: one inbetween two panels and one between the upper and lower.

Mr. Brown: Right.

Moderator: Ok. So that's the most common area of failure that you've noticed in cleated shoes?

Mr. Brown: Mhmm.

Moderator: Alright Mr. Black.

Mr. Black: The Adidas soccers that I had and the cleated shoes prior to that, I haven't really broken away from Adidas until recently when I got the nike Speed TDs. But the adidas soccer cleated shoes the same problems occur mine every time, is it breaks along the 1st and the 5th. One foot or the other I always have, it's the same break. I don't know, I guess it's because I cut really hard on that foot or whatever, last year I gave up on those Adidas. Like Mr. Orange, and a lot of other people, have got the Speed TDs, I heard they're good so I got a pair and they've lasted almost a year now and still there's no breaks. They're a little worn from using them, but there's no breaks, nothing on them that looks like they're going to tgive any time soon.

Moderator: Ok, and you said for previous failures they start, the tears are along the seams of both sides of your foot? Both near your big toe and pinky toe?

Mr. Black: Ya. It starts on one side and the other side happens shortly after that.

Moderator: And that's pretty consistent on the cleated shoes you've had previous to the Nike TDs?

Mr. Black: Ya. Pretty much every pair of cleated shoes I've had for the past 5 years; since playing competitively at least.

Moderator: Ok. And all of those, or the majority of those, were where the upper and lower meet? Or were they along the seams?

Mr. Black: Along the seams. It starts along the seams, say the 1st (metatarsal), it would start there. And then shortly after that I would get one along the 5th. They would rip along the fabric. Once it breaks it just only takes time to make it's way up.

Moderator: Ok. Mr. Orange.

Mr. Orange: I just remembered a pair of cleated shoes I had between the Copas and getting the Speed TDs. I can't remember the name brand of them.

Moderator: Do you remember what type of sport they were for?

Mr. Orange: Soccer. I stuck in the soccer realm. Uh, they did the same thing the Copas did, only a lot sooner. They started tearing along the same side as the Copas…

Moderator: Along the outside of your foot along the pinky toe?

Mr. Orange: Yea, near the pinky toe. And they happened a lot sooner, within the same season that I bought them.

Moderator: So that was possibly just having them for 4 or 5 months maybe? Half of the year?

Mr. Orange: A little bit longer than half of the year.

Moderator: Ok, we'll say 7-8 months. And was that similar to the adidas soccer cleated shoes in that it was a split between the upper and the lower? Or was that along the seams?

Mr. Orange: It was actually the fabric itself right above where they attach the two different materials (the upper and the lower). And they should have been leather as well.

Morderator: And did that rip ever become large enough to require you to stop using them?

Mr. Orange: Ya it got to the point where my pinky toe was coming out. I say my pinky toe, it was like my foot was coming out of that side… whether it was one or two, opening up.

Moderator: Ok. So that really has been your most common occurrence of failure, and that happened in two different soccer cleated shoes?

Mr. Orange: Yes.

Moderator: Mr Red.

Mr. Red: The Adidas' I had were Adi Zeros. Again, they were low-cut, because I think there's a high-cut.

Moderator: And the Nike air zoom pros were a low-cut as well?

Mr. Red: Yea. And I've never had a cleated shoe last me 6 months if I'm using it by itself. And even then, sometimes they don't make it.

Moderator: Ok. Does anyone else have anything to add? So basically, just to wrap it up; if anyone has any extra comments or things that you had thought of during the questions, information that had to do with failures or anything else, you can share them now. Ya, Mr. Orange.

Mr. Orange: All of my, all of my issues with cleated shoes have been on the right foot. Except for the last pair of Speed TDs was on the left foot, where it seemed like it was just a wear and tear. So all the other cleated shoes seemed to be on the right foot.

Moderator: Would you say that is your predominant cutting foot?

Mr. Orange: Yes.

Moderator: Are you right handed?

Mr. Orange: Yes.

Moderator: Do you find yourself right foot dominant?

Mr. Orange: I jump off my left.

Moderator: In both basketball and in, Frisbee?

Mr. Orange: The force side in ultimate is flick, so I generally plant on the right to go left. Around here we don't force much backhand.

(laughter among the group)

Moderator: Ok, anyone else? Alright. So I'll just go over what we talked about; wrap it up a little bit by reveiwing the failures that everyone thought was most common; we'll go through them, and try to decide on which ones we think we have seen the most or have heard people complain about the most; people that we play with, or people that we talk to about cleated shoes; as far as suggestion on what to go with.

It seems that Mr. Red gets the majority of his failures along the pinky toe of the predominant cutting foot; right on the outside of the cleated shoe. So I'm going to go ahead and right these downs so we can

rank which ones we thionk we've heard the most or have happened to us the most. So we'll call this a failure along the 5th metatarsal. It was a rip at the seam, the upper and lower had actually separated; so we'll call this "Rip along the 5th metatarsal."

Mr. Black most often gets tears along the seam of both the 1st and 5th metatarsal. That reflects in Mr. Red's observation, but also adds another one: a "Rip or tear along the 1st metatarsal."

Mr. Brown noticed that the ball of his foot, near the 1st metatarsal, at or directly above the upper and lower boundary. So again that would be a rip at the 1st metatarsal.

And Mr. Orange noticed a rip along the 5th metatarsal wide enough to show his toes; so that'll be another one for rip along the 5th. So of these two, a rip along the 5st metatarsal and a rip along the 1st metatarsal, do you all have any more that you want to add to that? That you've noticed a lot of. Can you think of anything that we might be missing?

Mr. Red: I was going to say that I think the 5th blows out first, but there's usually some wear and tear on the 1st as well for me. But for me the 5th has always just been wanting to… destroy.

Moderator: Ok. Anyone else? Maybe other failures that you've heard about, that you've seen or people have told you about.

Mr. **Red**: I've also seen the toe box go.

Moderator: The front of the toe box?

Mr. Red: Ya, like by the first toe.

Moderator: In front of the first toe?

Mr. Red: Ya. In front. From like people dragging toes and stuff like that.

Moderator: So we'll say in front of toe box at 1st metatarsal. Or just in general?

Mr. Red: Well, further down than the metatarsal.

Moderator: Right, right so the first phalangee. So just the front of the toe box?

Mr. Red: Ya, and it's definitely the front, not the top, it's the front. I'm pretty it's from like dragging toe on throws and stuff. Travelling.

Group: Travelling! Yaaa.

Moderator: Mr. Orange.

Mr. Orange: Whenever I've taped anyones shoes for them, it's always seems to be that it's on the toe side. I can't remember a time when I've ever had to tape someone's heel of their cleated shoe.

Moderator: Ok, so you always notice it at the front of the shoe, near the toe box.

Mr. Orange: Ya, whether it's the first toe or the last toe. I've always taped the front of their shoe before they've gone in for a game.

Moderator: Ok. So all the failures you've noticed, to your recollection, have been at the toe box.

Mr. Orange: Yup.

Moderator: Ok. Mr. Black.

Mr. Black: The same with Mr. Orange: the most common that I have ever seen is wrapping the front near the toes, but there have been occasions where I have seen people needed tape near their heels. It's almost a rarity, but I have seen it. I guess it takes more wear and tear on the heels than the toes, but we push off our toes more than anything else. Definitely agree, the toes near the 1st and the 5th are always the first things to go every time, that I've noticed, and it's the first thing we tape every time. But there are instances where we tape the heels, they're just every rare.

Moderator: Thank you, Mr. Brown.

Mr. Brown: *** Comment stricken due to its lack of relevance to the conversation ***

Moderator: Mr. Red.

Mr. Red: When people, especially people who jump a lot, there's no sign of failure per say, but along the ball and the arch it can get way too bendy and people feel like they can't jump anymore. There's no, like the normal part of the shoe that's there to support the arch and everything like that sort of goes, so when they get up on their toes it folds. So I've seen that before, I've had a pair that felt like that before, but I stopped using them. There's no real sign of it, other than that you can fold the shoe up – which some people like – but it does take away stuff. And those are usually soccer cleated shoes, not football.

Moderator: And that's a degradation of the plastic along the lower portion of the toe box, or along the ball of the foot?

Mr. Red: It's like in the arch, on the sole itself. Not on the edges, just goes in the middle and it's really bendy. No support to lift. And like I said it's only soccer shoes that I've seen do that.

Moderator: So we'll call that "Degredation of the arch" ?

Mr. Red: Ya, Arch/Sole.

Moderator: Ok. Alright. So out of the four options we have up here, we'll go ahead and get [people's opinion on which one happens to them the most or they have seen the most of. So for the first two that were mentioned, we have a rip along the 5th metatarsal, which is of the fabric itself and then eventually leading to a separation of the upper and lower. A rip along the 1st metatarsal, which is the same failure

but on the opposite side of the toe box; and again, 5th metatarsal refers to the side along the pinky toe and 1st metatarsal refers to the side along the big toe. The front of the toe box, in front of your toes along the big toe, along the first phalangee. And as Mr. Red just mention, degradation of the arch/sole where it becomes too pliant to forcibly jump off of. So as far as these, if you'd just like to rank them, whoever would like to speak can just go ahead and say which one they think happens the most and rank them: 1 being the most frequent and 4 being the least. Mr. Orange if you'd like to start.

Mr. Orange: With the options you have listed, the one that's listed second?

Moderator: The rip along the 1st metatarsal, along the big toe.

Mr. Orange: Ok, so for me, what I've noticed, it is in the order than you do have it established right now. What I've noticed is it starts on the pinky side, then the big toe side, then the three and four.

Moderator: Ok. Thank you. Mr. Red.

Mr. Red: I would rank them in order from 1-4: The 5th metatarsal, the 1st metatarsal, then the jump, then the toe.

Moderator: Ok, thank you. Mr. Brown.

Mr. Brown: For other people I've noticed: 5th metatarsal, then 1st, then toe box, then degradation of the arch. But for me, personally, it's always the 1st metatarsal then the 5th.

Moderator: Ok. Well we'll go with personal experience, because it's the best you have in mind that you've experienced the most personally. Thank you. And Mr. Black.

Mr. Black: For me it's the way you have it: the 5th metatarsal rips most frequently, then the 1st metatarsal, then the toe box, then the degradation.

Moderator: Ok. Alright, wonderful. Well – Mr. Orange, sorry.

Mr. Orange: I had a teammate blow his cleated shoe out this past game that we had, where he was making a forward cut, stopped, and I believe his toe busted out through the front of his cleated shoe.

Moderator: Really. So the front of the toe box?

Mr. Orange: Yea. So I actually witness that one. It was wild. He was cutting in for me, too.

Moderator: Does that recollection change your vote on the front of the toe box being number 3?

Mr. Orange: Uh, no. But it also provides another explanation for why someone's toe might go out first.

Moderator: Right, exactly. Wonderful. Alright, does anyone have anything else to add? No? Wonderful. Alright, well that's going to conclude the focus group, you all can feel free to hang around. Feel free to

continue to eat or drink, I have some consent forms for the rest of you to fill out that came in a little late. So if you could read through these and sign at the end that would be appreciated. Thank you very much!

APPENDIX III

CLEATED SHOE PERFORMANCE SURVEY

INSTRUCTIONS: This set of questions asks about your experience with athletic cleated shoes (the entire shoe) while playing ultimate frisbee. Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.
For questions 1 through 17, please circle one option that best represents your answer, unless instructed otherwise.

1. **Age**
    a. 19-24
    b. 25-30
    c. 31-36
    d. 37+

2. **Gender**
    a. Male
    b. Female
    c. Transgender (Male to Female)
    d. Transgender (Female to Male)
    e. Gender queer (don't identify with binary gender roles)

3. **Did you participate in the Cleated shoe Performance focus group held on June 7th, 2012?**
    a. Yes
    b. No

4. **Have you had a lower body or leg injury that has changed the way you move, run or affected your performance on the field?**
    a. Yes
    b. No

5. **If you answered yes to question 4, how long ago did this injury occur?**
    a. 0-1 month
    b. 2-6 months
    c. 7-12 months
    d. 1-2 years
    e. More than 2 years

6. **If you answered yes to question 4, do you wear a brace to correct, support or assist during physical activity?**
    a. Yes
    b. No
7. **If you answered yes to question 6, how long have you worn this brace?**
    a. 0-1 month
    b. 2-6 months
    c. 7-12 months
    d. 1-2 years
    e. More than 2 years

8. **How many years of experience do you have playing organized ultimate Frisbee?** ***(Organized refers to playing in a league, on a school or a club team; pick-up games do not count)***
    a. 0-2 years
    b. 3-6 years
    c. 7-10 years
    d. 10+ years

9. **What position do you play most often? <u>Mark all that apply if playtime is equal.</u>**
    a. Handle
    b. Cutter/Popper
    c. Wing
    d. Mid
    e. Deep
    f. All positions equally

Based upon the cleated shoe types shown below, please answer questions 10 and 11.

Football

Lacrosse

Soccer

10. Which cleated shoe type are you currently using for ultimate frisbee?

a. Football
b. Lacrosse
c. Soccer
d. Other; Please describe: _____

11. Which is your preferred cleated shoe type for ultimate frisbee?

a. Football
b. Lacrosse
c. Soccer
d. Other; Please describe: _____

12. Which type of material (construction) is your current cleated shoe's upper made from?
(Upper refers to the area of the shoe that surrounds the top of the foot)

a. Leather
b. Synthetic hard material
c. Synthetic soft material
d. Rubber
e. Other

13. Which is your preferred material for cleated shoe uppers?

a. Leather
b. Synthetic hard material
c. Synthetic soft material
d. Rubber
e. Other

14. Based upon your preferred material selected in the previous question, please RANK the importance of the following characteristics from most important (1) to least important (4).

___: a) Looks / aesthetics
___: b) Durability
___: c) Breathability
___: d) Flexibility
___: e) Other:_____

15. How long have you had your current pair of cleated shoes?

_____ months

16. Based upon cleated shoes you've owned, what is the most common issue dealing with fit?

a. Snug fit, but not too tight
b. Tight around the toes
c. Tight around the sides of the foot
d. Loose fitting
e. Other: _____

17. Which is your preferred fit for cleated shoes?

a. Snug fit, but not too tight
b. Tight around the toes
c. Tight around the sides of the foot
d. Slightly large for your feet
e. Loose fitting
f. Other
Please describe: _____

18. Please RANK the following types of cleated shoe failures in order from most common (1) to least common (3), based upon your preferred cleated shoe type selected in question 11

___: a) Tear in the material along the outside of the toe box (along the pinky toe)

___: b) Tear in the material along the inside of the toe box (along the big toe)

___: c) Tear in the material along the front of the toe box (in front of the toes)

19. Please RANK the following actions that cause any cleated shoe failure in order from most common (1) to least common (3)

(Cleated shoe failure refers to tears, rips, holes, broken seams; any defect in the material of the cleated shoe upper)

___: A quick change of direction (cutting)

___: A quick deceleration (stopping)

___: Jumping or leaping

20. What physical movement do you use most often when trying to get open for a disk?

a. Cut (a quick change of direction)
b. Acceleration
c. Deceleration
d. Jumping
e. Other

APPENDIX IV

SURVEY RESULTS

A. Survey questions 1 through 10

Survey ID	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10
CS1	1	1	2	2				2	1	1
CS2	1	1	2	2				1	3	3
CS3	1	1	2	1	2	1	2	2	2	1
CS4	1	1	2	2				2	1	3
CS5	2	1	2	2				3	1	1
CS6	1	1	2	2				2	1	3
CS7	2	1	2	1	2	1	2	3	1	3
CS8	1	1	2	1	5	2		2	2	1
CS9	1	1	2	2				2	2	3
CS10	2	1	2	2				2	3	1
DS1	2	2	2	2				2	1	3
DS2	1	1	2	1	2	1	4	2	1	1
DS3	1	1	2	2				2	1.5	1
DS4	1	1	2	1				2	2	1
DS5	1	1	2	1	5	1	5	1	1	1
DS6	2	1	2	2				1		4
DS7	2	1	2	1	2	1	2	2	2	3
DS8	1	1	2	2				1	2	3
DS9	4	1	2	1	5	2		4	1	3
DS10	2	2	2	2				3	2	3
RX1	3	1	2	1	5	2		2	1	3
RX2	3	1	2	1	5	1	4	4	2	2
RX3	3	1	2	1	5	2		2	3	3
RX4	1	1	2	1	5	2		2	2	3

RX5	1	1	2	1	1	2		2	1.5	3
RX6	2	2	2	1	3	1	3	1	3	3
RX7	3	1	2	2				4	1	3
RX9	2	1	2	1	5	2		4	2	3
RX10	2	1	2	1	4	2		2	2	1
LF1	4	1	2	1	5	1	5	4	2	2
LF2	1	1	2	2				1	2	4
LF3	1	2	2	2		2		2	2	3
LF4	2	2	2	1	5	2		1	2	3
LF5	2	1	2	1	3	2		2	1	3
LF6	1	1	2	2				2	2	3
LF7	1	1	2	1	4	2		1	1	3
LF8	2	1	2	2				3	1	1
LF9	2	1	2	2				1		2
LF10	3	2	2	1	4	1	4	3	3	3
2Z1	1	1	2	1	5	2		1	1	3
2Z2	1	1	2	1	3	2		2	1	1

Figure 2.2 - Survey question 1-10

B. Survey questions 11 through 20

Survey ID	Q 11	Q 12	Q 13	Q 14	Q 15	Q 16	Q 17	Q 18	Q 19	Q 20
CS1	1	3	3	1	3	4	1	2	1	1
CS2	3	3	3	2	2	1	1	2	1	1
CS3	1	3	3	2	1	5	3	2	1	1
CS4	1	3	3	4	2	3	1	1	1	1
CS5	1	3	3	2	12	2	1	2	2	1
CS6	3	3	1	2	7	1	1	1	1	1
CS7	4	3	3	1	1	2	1	1	1	1
CS8	1	3	3	4	24	1	1	1	2	2
CS9	3	3	3	2	0	2	3	1	1	1
CS10	1	3	3	5	7	2	1	2	2	1

DS1	3	2	1	4	2	1	1	1	1	1
DS2	1	3	3	4	12	2	1	1	2	1
DS3	1	3	3	4	2	3	6	2	1	1
DS4	1	3	3	4	1	1	1	2	1	1
DS5	1	3	3	3	1	2	3	2	1	1
DS6	4	1	5	2	14	5	1	2	1	4
DS7	3	1	1	2	18	3	1	2	1	2
DS8	3	3	3	2	1	2	1	3	2	1
DS9	3	1	5	4	12	5	1	3	1	1
DS10	3	3	3	2	24	3	1	1	1	1
RX1	4	3	5	5	30	2	1	2	1	1
RX2	2	3	3	4	8	2	1	1	1	1
RX3	3	1		4	84	3	1		1	1
RX4	3	1.5	3	2	7	3	1	2	1	1.5
RX5	3	3	3	4	21	5	1	1	3	1
RX6	3	3		2	60	2	1	1	1	1
RX7	3	3	3	2	4	2	1	3	1	1
RX9	1	3	3	5	14	3	1	2	2	1
RX10	1	3	3	5	4	2	2.5	1	1	1
LF1	2	3	3	5	18	5	1	3	1	1
LF2	4	1	1	2	0	4	1	1	1	4
LF3	3	1	1	2	10	2	3	2	1	1
LF4	3	1	1	4	0	2	1	2	1	2
LF5	3	1	1	5	24	5	1	2	2	1
LF6	3	1	1	1	48	1	1	2	1	1
LF7	3	1	1	2	12	3	1	2	2	2
LF8	1	2	2	2	6	3	1	1	1	1
LF9	2	3	3	2		3	1	1	1	1
LF10	3	3	3	5	8	2	1	1	1	1
2Z1	3	3	1	2	18	3	1	1	1	1
2Z2	1	3	3	5	7	3	1	3	1	1

Figure 2.3 - Survey question 11-20

C. Minitab and Excel Calculations

1. MiniTab Calculation of Pearson's and Cronbach's Alpha for validating questions

```
Correlation Matrix

Pearson correlation of Q1 and Q8 = 0.673


Item and Total Statistics

          Total
Variable  Count    Mean   StDev
Q1           42  1.7857  0.9249
Q8           42  2.1667  0.9606
Total        42  3.9524  1.7243


Cronbach's Alpha = 0.8039
```

Figure 2.4 – Minitab output of Pearson's and Cronbach's Alpha

2. Cronbach's alpha calculation for the survey

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_{Yi}^2}{\sigma_X^2}\right) \qquad (1)$$

Where: K = 16

$\sum_{i=1}^{K}\sigma_{Yi}^2$ = 11.86

σ_x^2 = 34.37

VITA

Andrew Johnson was born on January 16th, 1987 in the city of Hartford, Connecticut. He grew up in the small town of Simsbury, Connecticut, where he graduated from Simsbury High School in 2005. Andrew was accepted into the Speed National Scholars' Program and enrolled at the University of Louisville's JB Speed School of Engineering in the Fall of 2005. Although he enrolled as a Mechanical Engineer, Andrew decided to switch majors to Industrial Engineering after speaking at length with Dr. John Usher about the former Department Chair's IE career.

Over the course of his college career, Andrew was a co-op for Samtec and General Electric. After obtaining his B.S. in IE, Andrew also worked as an Industrial Engineer for UPS Supply Chain Solutions on a part- and full-time basis for just shy of 2 years. Andrew also held the positions of Vice President as well as President of the Human Factors and Ergonomics Society, U of L Chapter. Upon completion of his Master's Degree, Andrew will continue to work in the field of Ergonomics while applying for PhD positions in Ergonomics and Biomechanics.