A BIOMECHANICAL ANALYSIS OF THE BACKHAND DISC GOLF DRIVE FOR DISTANCE

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CHAPTER I

INTRODUCTION

For years researchers have studied the patterns of movement related to complex sports skills to break down these skills into components so that biomechanists can analyze the fundamental principals of the actions contained within. Understanding these actions allows researchers to deconstruct and analyze these actions to limit and correct any deficiencies found. While breaking down these movements into their components, actions can be grouped together and referred to as phases, such as the windup, cocking, and acceleration phases of the baseball pitch. These phases allow instructors or coaches to teach the complex movement in parts and allow participants to learn the movements with less chance of injury or learning incorrect technique. In sports such as baseball, track and field, swimming, football, and many others these phases are a critical part of learning the proper sequence of events while teaching the body the correct biomechanical position for optimal performance. In many of these sports these phases seem to have been around almost as long as the sports themselves, when in all actuality these movement patterns and sequences came from many years of professional observation by coaches and biomechanists watching the successful attempts of veteran players.

This process of observation can now be made more efficient due to the use of new analyzing techniques, namely video analysis. Video analysis can be used to record and analyze the same successful attempt without the participant having to perform these complex skills multiple times. Using video analysis, multiple attempts or multiple participants can be observed simultaneously and even on the same screen at varying speeds to truly judge the similarities or differences that lie within each action.

Furthermore, when these videos are overlaid, they can be synchronized so that researchers will not only be able to see differences in movement patterns, but also the different angular velocities allowing them to more accurately attribute the "success" of an attempt to movement patterns or to the speed at which these movements are performed.

Statement of the Problem

In sports that are popular, a biomechanical analysis of the movements often exists both for learning the movement and for modifying the technique. Biomechanical analyses originate from observation by biomechanists, strength and conditioning coaches, and athletic trainers who watch players that are deemed "successful" at some aspect of the game. Qualities such as running speed, throwing accuracy, or in the case of disc golf, distance thrown, are analyzed and actions or phases of actions that make these players "successful" at these aspects of the game are identified. Phases can then be used to teach novice players efficient technique and to modify actions of experienced players wanting to increase their "successfulness". Phases are generally named for the action being performed during the phase, these names allow for a common language to use when discussing phases of a complex skill. Currently, there is a lack of research in the sport of disc golf which has led to the development of a slang language to discuss the throwing motion related to this sport. Once these phases are identified and named, the language of disc golf will be established so that disc golfers and sports performance professionals can effectively communicate to not only enhance the performance of the thrower, but to also modify the training regimen to prevent injury, modify equipment to better suite players, and modify courses to accommodate appropriate skill levels of players. Establishment of a common language is one of the aspects of disc golf that is of the utmost importance.

Purpose

The purpose of this investigation is to gather video of disc golf drives for distance and analyze the data to extract and name phases of the drive, establishing a common language that researchers, sport performance professionals, and the disc golf community can use to communicate.

Significance of Study

The research into the dynamic sport of disc golf is relatively nonexistent therefore; the significance of this study is great. With the phases of the drive for distance identified and named, the communication for the improvement of disc golf technique can begin. Biomechanists, strength and conditioning professionals, athletic trainers, and disc golf athletes will be able to more readily communicate and with greater detail than previously existed when discussing the disc golf throwing motion. Ease of communication could lead to improvements in training technique, throwing mechanics, injury prevention, equipment modification, and much more. The cornerstone to all of this possible improvement is the establishment of a biomechanical analysis and a common language with which to discuss and describe both the individual and groups of actions that combine to makeup the disc golf backhand drive.

Hypothesis

H_o: The disc golf drive for distance will be a continuous movement and no discernable steps will be identified between throwers of similar success levels.

H_1: The disc golf drive for distance will have a finite number of steps that are able to be distinguished between throwers of similar success levels.

Delimitations

This study was delimited to:

1. All throwers were Advanced Division amateur disc golfers.
2. All subjects were males.
3. All subjects were competing in the distance field event of the Oklahoma State Championships.
4. All distances were measured from the same position by a range finder.

Limitations

These limitations were recognized during the course of the study:

1. The convenience sample of Oklahoma State Championship participants was not representative of all disc golfers.
2. Wind direction and speed were unknown for each thrower.
3. Type of disc and type of shot were unknown for each thrower.
4. The speed of movement exceeded the maximum speed that could be filmed clearly with the camera utilized for data capture.
5. Descriptive measurements for the throwers were unknown.

Assumptions

The following assumptions were made during the course of this study:

1. Throwers gave full effort when throwing for maximum distance.
2. Throwers were injury free at beginning of distance competition.

Definition of Terms

1. **Anhyzer** - a throw that turns in the same direction as the throwing arm, so that for a right-handed player throwing backhand, the disc will turn to the right

2. **Backhand** - the standard disc golf throw in which the thrower's arm comes across the body with the back of the hand being used to lead the throw
3. **Disc** -a flat piece of plastic designed to fly for varying distances; also known as a "Frisbee", for the trademark product of the Wham-O Corporation
4. **Drive** - the first throw from the tee box usually performed with a driver
5. **Driver** – a disc designed with a smaller, sharper edge to fly further for use on the drive
6. **Foul line** – a player must throw from behind this line to be considered fair, crossing this line would result in a foul and the throw would not count for competition
7. **Hyzer** – a throw that turns in the opposite direction of the throwing arm, so that for a right-handed player throwing backhand the disc will turn to the left
8. **Phase** – a step in a complex sports movement that is essential to the completion of said sports movement
9. **Simulcam** – A feature of the Dartfish software that allows the user to view and analyze two athletes' performances, blended in a single background
10. **Stromotion** – A feature of the Dartfish software that allows the user to compound video images into a frame-by-frame panoramic set of images
11. **Tee Box** – the area a thrower is restricted to when making the drive

CHAPTER II

REVIEW OF LITERATURE

Disc Golf

Disc golf is a relatively young sport the history of which, although stated rather informally, has not been well documented to date. Disc golf began rather crudely by students throwing pie pans for entertainment. Games were eventually invented by throwing the discs at random targets such as trees, trash cans, light poles, and so on. The use of plastics revolutionized the game when inventor Fred Morrison used the substance to create the first plastic flying disc, the Pipco Flying Saucer (Palmeri and Lambert, 2003). In the early 1950s Bill Robs improved the flying saucer with the invention of the Pluto Platter, which in the late 1950s was marketed by Wham-O under the name of the Wham-O Frisbee. In the early 1960s the Copar Company of Chicago put a disc on the market called the Sky Saucer which includes a rule book for a game called sky golf. In 1964 Wham-O countered by creating the Official Pro Model that was designed for sport (Palmeri and Lambert, 2003). From 1964 to 1969, a man named George Sappenfield organized several Frisbee golf events in California, using a variety of targets for the completion of the "holes" similar to traditional golf ("History of", n.d.). 1969 was also the year of the first official disc golf tournament held in Pasadena, California, at Brookside Park using ribbons tied around natural objects to create targets for "holes" (World Flying Disc Federation, n.d.). In 1971, the first Frisbee Club was created in

Rochester, New York, where Frisbee golf has been played on a regular basis (Palmeri and Lambert, 2003). In 1974 the American Flying Disc Open was played using small wooden boxes as targets, marking the first time a standard target was used on all holes of a course (World Flying Disc Federation, n.d.). The year 1975 witnessed the establishment of the Professional Disc Golf Association (PDGA) and the development of the first permanent disc golf course located in Oak Grove Park in Pasadena, California, by Ed Headrick. Headrick was also the inventor of the first Disc Pole Hole, a chain-style disc catcher that consisted of ten chains hung in a parabolic shape over an upward opening basket. For this invention Headrick was awarded a United States Patent that was issued in 1975 (Headrick, n.d.). In the year 1977, the first PDGA tournaments were held in Mobile, Alabama, and northern New Jersey (Palmeri and Lambert, 2003). The PDGA was turned over to the players for the organization of tournaments and standardizing of the rules for play in 1982. In 1983 Dave Dunipace invented and patented the triangle-rimmed disc, which brings the advantage of distance with accuracy to the game of disc golf (Palmeri and Lambert, 2003). In 1993 the PDGA began to chronicle the history of disc golf and the PDGA Hall of Fame was established by Lavonne Wolfe. Disc golf truly reached a milestone in worldwide popularity when it became a featured event in the 2001 World Games in Akita, Japan. To this day disc golf continues to grow in popularity with more courses, more tournaments, more players, and more fun for everyone (Siniscalchi, 2005).

Biomechanics

Biomechanics as a field of study has been around for many years; however the name biomechanics did not become popular until the 1960s. Late in the 19^{th} century and early in the 20^{th} century the word kinesiology gained popularity for the description of the study of human movement (McGinnis, 2005). As early as 1895 Marey wrote *Le Mouvement*, this publication contained descriptions of a "biomechanics" laboratory that utilized a variety of devices to measure forces and motions of both humans and animals (McGinnis, 2005). Biomechanics is technically too broad of a field for the study of human movement specifically related to sport and performance, so the field of sport biomechanics was created. Sport biomechanics could be said to have received its start in 1912 with the publication of an article titled "One hundred and twenty-two feet per second" by F.C. Lane that investigated the speed of a pitched baseball by Walter Johnson (Lane, 1912). This work in the mechanics of movement continued into the 1920s and 30s with research being conducted in events such as swimming, track and field (Cureton, 1939). With the onset of WWII, sport biomechanics research was reprioritized and research more directly related with the war efforts received more attention. However, a decade after the war, in 1955, a book was published focusing on the mechanics of movement rather than the anatomical aspects of human movement (Bunn, 1955). During the 1960s the term biomechanics started to gain popularity and so did the interest in the field of human movement (Hamill & Knutzen, 1995). The research in the field of sport biomechanics has grown rapidly in the past few decades coinciding with the accessibility and popularity of the computer. The personal computer has allowed for the rapid advancement in the details now known about certain movements, such as the baseball pitch, walking gait, and track and field events, by processing the huge amount of data from multiple sources simultaneously creating a more accurate picture of what exactly is happening during these movements. The use of video analysis is linked to biomechanics for several reasons including the advantage of viewing a high-speed movement at variable speeds, being able to view the same attempt more than once, and determining how long a certain aspect of the movement takes. Video analysis and biomechanics have combined to produce extensive data on shoulder kinematics as it is related to the overhand baseball pitch (Jobe, Tibone, Perry, & Moynes, 1983) (Jobe, Moynes, Tibone, & Perry, 1984). Other movements to include wheelchair propulsion, diving, and weight lifting have been broken down into phases with the use of video analysis and biomechanics (Hamill & Knutzen, 1995). All of these sports and activities now enjoy the benefit of having a model from which to teach novice players and with which to make assessments on the efficiency of the movements involved.

Video Analysis

Due to the novelty of advanced video analysis software coupled with the newfound popularity of disc golf, there exists no related research studies. However, in competitive athletics, video analysis has been used in many facets of sport coaching. Recently, coaches have become more sophisticated and have begun to utilize the advanced video analysis computer software. Researchers have also identified this trend and have produced valuable research relating to biomechanics and coaching. Video analysis has produced remarkable data in football studies related to rates and types of injuries sustained during competition (Arnason, et al, 2004; Andersen et al, 2004; Gorden, et al 2003). Video analysis has also been used to research mechanisms of injuries in team handball and taekwondo giving researchers the advantage of viewing the injuries at slower speeds to assess the true mechanism of injury (Otsen, et. al. 2004) (Koh, et al, 2004). Gymnastics was observed to assess the judging criteria and how it affected the participating athletes. The research produced invaluable results on injury related to landing (McNitt-Gray, 1991). As a result judging criteria was changed to allow athletes to employ better landing strategies such as bending of the knees and flexing of the torso to lessen the impact of landing and therefore decreasing the stresses placed on athletes.

Summary

The short existence of video analysis and the novelty of disc golf combined to make research on the subject of video analysis of disc golf difficult. The unavailability of pertinent research creates a void between researchers and the disc golf community on the basis of language. This lack of a common language between researchers and the disc golf community makes it difficult to discuss the important aspects of a disc golf throw and makes it even more difficult when trying to teach a novice player how to throw properly. With the use of video analysis in conjunction with biomechanical analysis it is possible to analyze a disc golf drive for distance and group movements into phases, name those phases according to what is happening, and present a pattern of movement that will be able to be applied throughout the disc golf community.

CHAPTER III

METHODOLOGY

When performing a complicated sports skill for the first time, it is beneficial for the participant to have an idea of what the movement is supposed to look like when successfully performed. The participant will most likely, not be able to perform the skill in this manner, but the ability to imitate will aid the participant in the first few attempts at the skill. It would be difficult for an individual learning this sports skill without having any names for the phases in the movement. The process would be extremely difficult and frustrating for both the athlete and the coach. This example further illustrates the need for a common language with which to discuss the disc golf throw and the details of the movements that lie within. The subjects, instrumentation, experimental design, and procedure are described within this chapter.

Subjects

The Disc Golf community is composed of 11,302 current Professional Disc Golf Association members (PDGA, 2006). Of these members, 92% are males and 8% are females, 26% of which are pros, 67% are amateurs, and 7% are juniors (PDGA 2006). The sample for this study is a sample of convenience since useful video and measurements are difficult to obtain. This is due to the newness of disc golf and the even more recent disc golf video, of which only a limited amount can be used for the study because of measurement issues. The video considered viable contained fifteen males in the advanced men's division. All subjects were participating in the Oklahoma Open Disc Golf Tournament and were registered in the field events and more specifically the distance competition. Only gender could be determined from the video; all other measurements regarding subjects will be determined using the Simulcam feature of the Dartfish software (Dartfish; Fribourg, Switzerland).

Subjects were not recruited specifically for this research. A test video was recorded and analyzed to assess the capabilities of the camera and the software. The conclusion was that the camera was not of high enough quality to obtain accurate and reliable results. Therefore, the decision was made to try and locate viable video from a professional source; reasoning behind the decision included higher quality of camera equipment and experience of the camera operator to obtain useable footage. Alan Hansen Begg, CEO of discgolfTV.com LLC, was contacted and he provided six tapes of video that had been previously recorded for review. Upon review, the tape of the Oklahoma Open distance competition was chosen because the camera was stationary for all the throwers allowing the video's to be overlaid and viewed simultaneously. Also audio could be heard in the video allowing researchers to obtain distance measurements from the spotter in the video as he was announcing the distances thrown in yards aloud for recording and crowd information purposes.

Instrumentation

A Panasonic 3CCCD Ultra-Compact Digital Palmcorder (Panasonic Corporation of North America; Secaucus, NJ) mounted on a Sunpak Platinum Plus 59" Tripod

(ToCAD America Inc.; Rockaway, NJ) was used to capture the disc golf video, which was recorded by Alan Hansen Begg, CEO of discgolfTV.com LLC. The DartTrainer Pro Suite Version 4.0 Advanced Video Analysis Software (Dartfish; Fribourg, Switzerland) was used to capture and analyze the video data. The video was received in the form of a tape and then was transferred to a Dell Dimension 8400 (Dell Inc.; Round Rock, TX) computer by a digital video cable.

Experimental Design

The design that will be used in this study will be mixed methods. When the data is collected, the designation of subjects to each group will be based on the "successfulness" of the drive collected from the subject. Successfulness of a drive is directly related to the distance thrown, in a distance competition the further the disc is thrown the more successful the drive is considered. For this reason the categorization of subjects will be quantitative. However, the analysis of each throw will be qualitative because there is very limited theory existing on the correct technique of this dynamic sports movement. Most kinesiological analyses are considered qualitative because they involve observing a movement and providing a breakdown of the skills and identification of the muscular contributions to the movement (Hamill & Knutzen, 1995). For these reasons mixed methodology will be the most effective way to collect and analyze appropriate data.

Procedure

Video data was collected by one fixed camera positioned to the left of the tee box area on a tri-pod. A five-foot wide area was marked with discs on the ground to designate the foul line or front of the tee box. However, a true tee box was not used because the subjects were not restricted on the amount of space they could use to generate each attempt. The distance of the throw was measured by a laser range finder. Once the data was captured, the video was categorized according to length of the throw, so that the longer the throw, the more successful the attempt.

Video was analyzed by slowing the speed of each video and observing the movements of the joints while considering the musculature involved with the movement of each joint. Once all videos were viewed, video was taken two at a time and analyzed using the Simulcam feature of the Dartfish software. The Simulcam feature allows researchers to view two videos at the same time blended onto the same background. Markers are set in the background and the two videos are aligned so that any difference or similarity can be attributed directly to the movement of each thrower. With commonalities starting to emerge each video was marked where these actions were similar to other videos analyzed. After marking all the videos with the common actions, these actions were grouped into discrete phases and these phases were named according to the joint movements that lie within. With all the joint movements accounted for, the musculature associated with that movement was recorded and will be presented in the following sections.

CHAPTER IV

FINDINGS

Results

The sport of Disc Golf is a relatively young sport that is lacking the necessary attention from the Biomechanics and Strength and Conditioning communities for it to prosper such as other sports like baseball, football, and traditional golf. By utilizing the Dartfish software's capability to analyze video data, the time required to properly deduce a common set of actions necessary to perform a disc golf backhand drive for distance properly can be reduced considerably. Researchers can now view what they deem to be successful attempts to identify the discrete movements that are critical to the outcome of the athletic skill.

Video analysis of the fifteen males has shown that there are eight distinct phases of the disc golf drive for distance. Groups of actions make up each phase, which was given a name according to the movements performed. The eight phases consisted of four lower body phases and four upper body phases. The phases in order of occurrence in the throw are Approach, Preload, Transition, Load, Cross Over, Pull, Plant, and Release. Since all of the throwers in the study were right handed the explanation of the phases in the throw are for a right handed thrower.

Approach is a lower body phase that starts when the left foot makes contact with the ground and ends when the left foot loses contact with the ground. This phase begins the throw and starts the momentum of the thrower moving toward the direction of the throw.

Preload is the second phase and is the first upper body phase. It is a small range of motion that starts the throwers upper body in the counterclockwise rotation. This movement does not really accelerate the disc in either direction rather it sets up the upper body to rotate further in the counterclockwise direction.

Transition is phase three the second lower body phase. It is named transition because the motion in this phase transitions the thrower to a posture of accelerating toward the direction of the throw with the back of the thrower leading the way. The right foot is turned so the heel is toward the direction of the throw aiding the upper body in its counterclockwise rotation.

Load is the phase in which the majority of the counterclockwise rotation takes place. In this phase the upper body takes aid from the lower body and accelerates the disc away from the direction of the throw. This phase is called Load because it loads the upper body to begin the acceleration of the disc towards the direction of flight.

Cross Over is just that, the left leg is adducted across the midline of the body. Crossing over of the lower body is the continuation of the counterclockwise rotational forces the movement up to this point has created. During this phase the right leg is extended to the rear in preparation for the Plant. At the end of this phase the thrower has created the maximum distance to accelerate the disc forward.

The Pull phase is the acceleration of the disc toward the direction of flight. This is accomplished by rotating clockwise as fast as possible. This rotation is where the disc gains speed and is pulled along the line it will eventually be released on.

The Plant phase is the last lower body phase and is the stopping of the forward momentum and transferring all the rotational and forward forces to the disc. This phase is started with the right foot making contact with the ground and is ended with the rotation in a clockwise manner on that foot.

The Release phase is the last phase of the throw. The release is the point at which the disc has lost contact with the thrower and is under its own power. After the release the momentum of the thrower is carried out in the follow through, the deceleration of the thrower.

These eight phases are made up of many individual actions that can be grouped together to explain the movement in this complex skill. Approach, Preload, Transition, Load, Cross Over, Pull, Plant, and Release will now be the terms used to describe the phases of the disc golf drive for distance. With these terms the disc golf community and the sports performance community can more easily communicate for the benefit of all.

Discussion

The disc golf backhand for distance is a throw that utilizes the entire body in a rapid series of movements that must be controlled and coordinated to produce the desired result, maximum distance. The throw starts out smoothly and accelerates to a point of, in some cases, an audible snap as the disc is ripped from the thrower's hand by the rotational forces generated. The pure distance drive is different from that used in a golf round, in that some of the steps will be more exaggerated and all will be done at maximum effort as opposed to the controlled manner in which a drive is thrown by a golfer who is throwing to have at least some accuracy. The drives are very similar and the steps remain the same; however, the pure distance drive is much more dynamic.

The analyses of the data have shown each throw has eight common steps, four are lower body movements and four are upper body movements. The steps are Approach, Preload, Transition, Load, Crossover, Pull, Plant, and Release, which are alternating upper body and lower body movements that begin with the lower body. The steps in a disc golf throw are not completely sequential nor are they completely simultaneous; rather they are a blend of the two. Some of the movements such as Preload and Approach have aspects that are occurring at the same time, yet they do not begin or end at the same time. Furthermore, all throwers do not necessarily begin these movements at the same point of the phase that is in progress. Using clock positioning as a reference, the front of the tee box would be identified as twelve o'clock while the back of the tee box would be characterized as the six o'clock position (Figure 1).

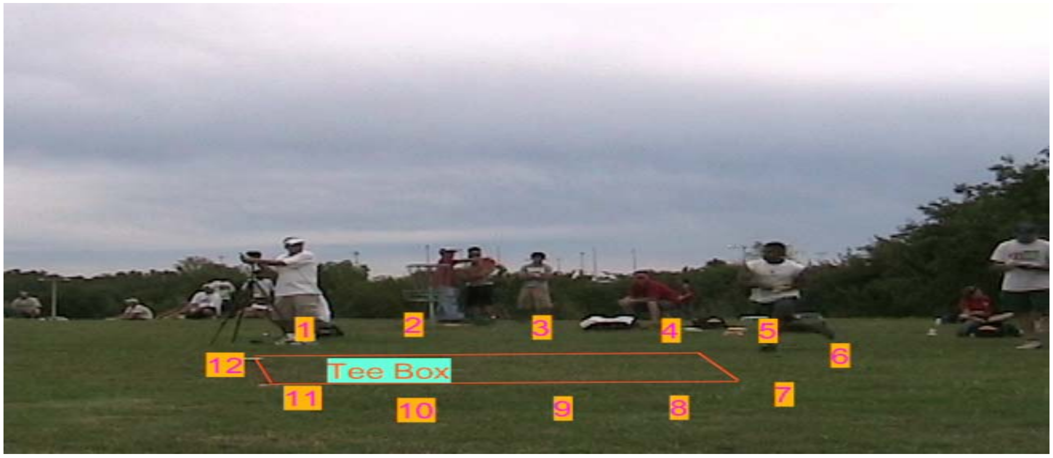

Figure 1 Clock reference around tee box

This reference point will remain fixed, so that if one were to lay the numbers on the ground surrounding the tee box, the thrower would move from the six o'clock position toward the twelve o'clock position with a slight deviation toward the nine o'clock position during the Transition step to allow for the Crossover to remain inline with the rest of the throw (Figure 2).

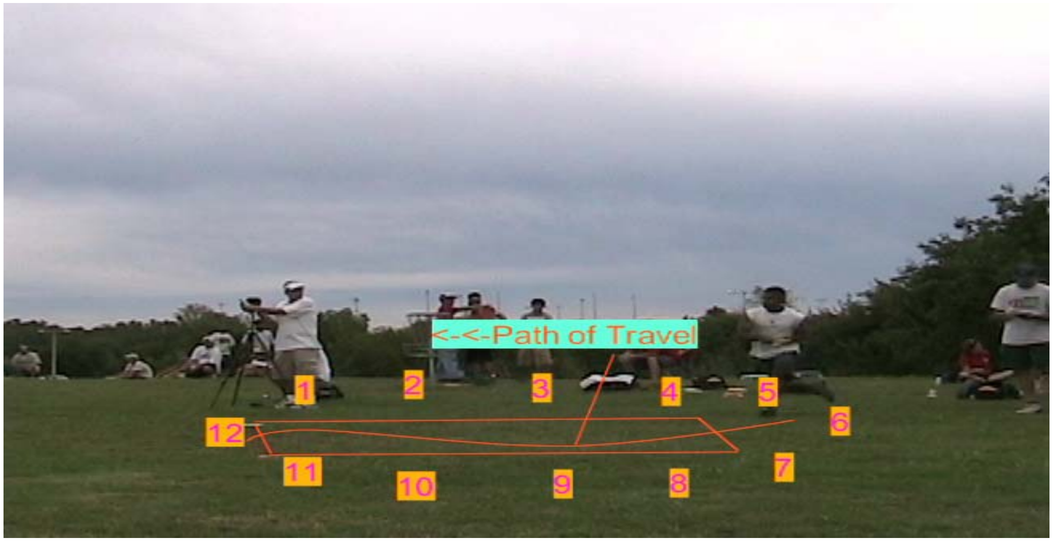

Figure 2 Path of Travel

The progression of the throw will begin with the first step named Approach. Up to this point, the throwers may have done various things to build momentum or rhythm to begin the throw; which is unique to almost every thrower like a pre-throw routine. The first step that is discernibly different from these pre-throw steps and uniform throughout all throwers is termed Approach. In this step the thrower turns the left foot close to parallel to the front of the tee box, or in this case the foul line. This turning of the foot positions the thrower's lower body in a manner that allows the thrower to complete the throw with the body facing the left side of the tee box, nine o'clock, and moving forward to the front of the tee box, twelve o'clock. When the thrower's left foot strikes, the toe box is first to contact the ground and begins to absorb the weight of the thrower (Figure 3).

Figure 3 Left leg absorbs weight of thrower

After contact with the ground the lower extremity contracts eccentrically into slight flexion and then begins abduction propelling the thrower in a sideways manner toward the front of the tee box, twelve o'clock. The eccentric contraction begins with the gastrocnemius, soleus, quadriceps (rectus femoris, vastus medialis, vastus intermedius, and vastus lateralius) gluteals (gluteus maximums, gluteus medius, and gluteus minimus) and tensor fasciae latae absorbing the weight of the thrower. The abduction begins with concentric contraction of the hip abductor group (piriformis, superior gemellus, inferior gemellus, obturator externus, and obturator internus) coupled with the gluteals and tensor fascia latae as the lower extremity moves to abduction (Figure 4).

Figure 4 Left lower extremity abducted

At the end of this phase the quadriceps extend the lower leg and the gastrocnemius and the soleus plantar flex the foot. This phase of the throw is complete when the left foot has lost contact with the ground and is no longer providing forward movement.

The second phase is called Preload and is the first throwing movement of the upper body. This step begins before the Approach phase is complete and before Transition begins. Preload is the movement of the shoulders to a set position in preparation for the actual Load phase. This movement is required to help the thrower begin the counterclockwise rotation of the upper body as the right leg is directed toward the nine o'clock position. At this point in the throw, the subjects head is pointed forward, meaning that the head is restricting the amount of rotation that is possible to achieve. The action of turning the shoulders comes from a concentric contraction of the external and internal obliques of the non-throwing side.

When the right foot makes contact with the ground, the third phase, Transition, begins. During this lower body phase the subject was observed to end the Preload phase and begin the Load phase, both of which are upper body movements. The right foot makes contact with the ground toe box first, having the right leg already in abduction and internal rotation, proximal to the previously planted left foot (Figure 5).

Figure 5 Beginning of Transition Phase

The motion of the right leg as it is being moved into position for contact with the ground is generated by the concentric contraction of the hip flexors (illicaus, psoas major, and pectineus). Internal rotation is generated by the hip adductor group (adductor longus, adductor brevis, and adductor magnus). The body of the thrower is still moving toward the twelve o'clock position, but the thrower begins the counterclockwise rotation that will eventually take the upper body around, 100° - 170°, so that the thrower's back is facing the throwing area. When the movement of the thrower has brought the center of gravity over the right foot, the right leg is in slight hip and knee flexion, due to the eccentric contraction of the gastrocnemius, soleus, quadriceps, and the gluteals with the toe pointing toward six o’clock and the heel pointing toward twelve o’clock. The right leg continues this movement with an extension of the lower extremity, contracting the quadriceps, and hip flexors propelling the thrower into the air with his back to the throwing area. This moment in which the thrower has lost all contact with the ground is typically when the Load phase begins.

Phase four of the backhand disc golf drive is the Load phase, an upper body movement that positions the thrower in maximum horizontal adduction. One could compare this phase to the loading of a spring, so that if one arm of the spring is fixed in position, the further one brings the opposite arm of the spring around, the more force the spring will react with when the arm is accelerated. Essentially, the thrower is loading his/her own spring, as the lower body continues through Crossover and into the Plant phase, the lower extremities are starting to twist clockwise while the upper body is twisting counterclockwise. Movement for the upper extremities begins with the throwing arm moving into shoulder flexion due to contraction of the deltoid. The scapula is abducted by the serratus anterior, and pectoralis minor and the elbow is extended with a concentric contraction of triceps brachii and anconeus. Simultaneously, the thrower is rotating the torso counterclockwise by contracting internal and external obliques of the non-throwing side. This Load phase can be restricted by the movement, or more accurately the lack of movement of the head. If the thrower does not remove their eyes from the target area briefly, the head will restrict the possible movement of the shoulders and in turn the arm. Turning the head so that the eyes are 120° – 190° from the target often translates into more distance to accelerate the disc when the pull begins. To illustrate, refer to the difference in the right hand position in Figure 6 and Figure 7.

Figure 6 Beginning of Load Phase

Figure 7 End of Load Phase

Phase five or the Crossover is characterized by the left leg passing behind the right leg, crossing the legs of the thrower briefly. During the Crossover, the Load phase will end and the Pull phase will begin. The Crossover begins with the left toe box making contact with the ground, the left leg is in adduction across the midline of the body, behind the right leg with the toe pointing to approximately seven or eight o'clock, and the knee is in slight flexion (Figure 8).

Figure 8 Beginning of Cross Over Phase

The movement of the throwing motion carries the thrower's center of gravity over the left leg, and the left hip moves eccentrically into flexion utilizing the gluteals, quadriceps, and gastrocnemius acting as a shock absorber. Once the center of gravity is over the left leg it begins concentric contraction of the hip abductors, gluteals, quadriceps, and hip external rotators (piriformis, obturator internus, obturator externus, superior gemellus, and inferior gemellus) to abduct and externally rotate the left leg. Simultaneously the right leg moves into extension and external rotation by contracting the gluteals, hamstrings (biceps femoris, semitendinosus, and semimembranosus) and external rotators in preparation for the Plant (Figure 9).

Figure 9 End of Cross Over Phase

During this crossing of the center of gravity over the midline of the thrower’s body, the disc has stopped moving backwards or counterclockwise, thus ending the Load phase, and has started moving forward due to the movement created up to this point to begin the Pull phase. At this point in the throw the pelvis is still rotated counterclockwise with the right hip pointing to about the nine or ten o’clock position. The right leg is extended and slightly externally rotated, the left hip and knee are in slight flexion, and the torso is slightly flexed at the waist with the right shoulder positioned over the left knee. The right arm is held horizontally adducted proximal to the chest, and the eyes are directed to the rear to allow for the maximum range of motion in the Load phase (Figure 9).

The Plant phase of the throw begins in the middle of the Pull phase so these two explanations will be combined. Until this point all the motions of the thrower have taken the disc away from the intended direction of flight, which has allowed the thrower to position his/her body in the optimal position to accelerate the disc forward.

Phase six is called the Pull and is initiated by the forces of the clockwise twisting action of the thrower. During the Load phase, the thrower is rotating counterclockwise with the upper body and the lower body is rotating clockwise moving through the Crossover phase. As discussed previously, the center of gravity crosses over the midline of the thrower’s body causing the disc to start accelerating forward. To continue the forward acceleration, the thrower plants the right foot, starting the Plant phase, and rotates externally starting with the foot rotating on the heel or the toe, depending on the thrower, and moving to the knee and pelvis, leading to the rotation of the upper body. This motion utilizes the peroneus longus, peroneus brevis, hamstrings, gluteals, external rotators of the hip, obliques, latissimus dorsi, rhomboids, supraspinatus, infraspinatus, deltoid, triceps brachii and even the hand extensors (extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris) . All of these contractions are concentric to build torque and generate enough force to throw these discs in excess of six hundred feet.

The eighth and final phase is Release. The name release may be misleading because it is not a letting go of the disc; rather the disc is actually accelerated to a point that the weight and speed of the disc combine to overcome the pressure of the grip applied by the thrower (Figure 10). The release point is determined by many things still unknown to researchers due to the recording limitations of camera equipment and the excessive speed at which this movement occurs.

Figure 10 Release Point

However, the throw does not end at release. Upon completion of this action there is the "follow through", a secondary, but very important part of the Release phase of the throw. The "follow through" allows the thrower to transfer the maximum amount of energy to the disc because there is no slowing of the movement prior to the disc leaving the hand. The follow through also allows the thrower to decelerate the body without placing tremendous strain on the weak points in the kinetic chain, such as the knees or shoulder. The deceleration is usually supported by the non-throwing arm and lower extremity swinging around and being held out from the body to both help slow the thrower down and maintain balance as the throwing motion ends with an excess of rotational velocity (Figure 11).

Figure 11 Follow through after release

The slowing starts with the concentric contraction of the deltoid, gluteals, and abductors of the hip, coupled with an eccentric contraction of the obliques on the non-throwing side. The throwing side is contracting eccentrically the pectoralis major and minor, deltoid, and biceps brachii, while holding an isometric contraction on the muscles of the lower extremity allowing the thrower to rotate on the heel or the toe.

CHAPTER V

CONCLUSION

In conclusion, this research has provided a foundation of knowledge for the continuation of research in the field of Disc Golf Kinesthetics. By defining the eight phases of the disc golf backhand drive for distance: Approach, Preload, Transition, Load, Crossover, Pull, Plant, and Release. There will now be a viable new language with which to discuss the pattern of movements known as the backhand disc golf drive for distance. Further research needs to be conducted on the variety of techniques that are utilized to throw a disc, such as the “backhand drive for accuracy”, the “approach”, the putt, the “forehand”, the “roller”, the “grenade”, the “thumber”, the “tomahawk”, and other pertinent throws. With advanced video analysis techniques, new and innovative software, updated higher speed and definition cameras the research could produce more accurate and reliable results.

One of the largest limitations to this research was the speed at which the camera was able to capture video. In many cases the thrower was moving too fast for the camera, resulting is blurred footage and translating into some speculation on certain aspects of the throw like the Release, for instance. In the future with the use of higher speed cameras, the research will continue to develop the efficiency with which a disc can be thrown and the areas of speculation such as arm velocity, release point, and the determination of disc characteristics such as angle of release, and speed at release.

Recommendations

1. It is recommended that the camera used for capture of data be capable of performing at high rates of frames per second as a means to capture movements that are very fast without being blurred to further enhance the analysis.
2. It is recommended that professional level disc golfers be utilized for the capture of data as their level of experience and expertise of performing the disc golf throw are most likely higher than other players of lesser skill divisions.
3. It is recommended that the researcher obtain descriptive measurements of the athletes to be analyzed such as arm span, height, and distance on the throwing arm from jugular notch of sternum to the tip of the middle finger with the arm horizontally abducted.
4. It is recommended that the researcher document the type of throw and the model and weight of the disc used in each attempt as all success cannot be attributed to the thrower directly; some of the success or failure of a throw is due to disc selection. Much like the success or failure of a ball-golf shot depends on the club selected.
5. It is recommended that other throws used in a typical disc golf round be analyzed to extract the key positions so that all throws can be trained for and performed proficiently.
6. It is recommended that a solid or an incrementally painted black and white stripped background be used for contrast to the disc and athlete movement during analysis.

REFERENCES

Andersen T.E., Floerenes, T.W., Arnason, A., Bahr, R.(2004). Video analysis of the mechanisms for ankle injuries in football. *American Journal of Sports Medicine*, 32, 69-79.

Armstrong, B.D., Cordova, M.L.(2001). Delayed-Onset muscle soreness does not alter the kinematics and kinetics of the squat-lifting technique. *Journal of Sport Rehabilitation*, 10, 184-195.

Arnason, A., Tenga, A., Engebretsen, L., Bahr, R.(2004). A prospective video-based analysis of injury situations in elite male football: football incident analysis. *American Journal of Sports Medicine*, 32, 1459-1465.

Behnke, R.S.(2001). Kinetic anatomy. Illinois, Human Kinetics.

Bunn, J.(1955). Scientific principles of coaching. New Jersey: Prentice-Hall.

Cureton, T.K., Jr.(1939). Elementary principles and techniques of cinematographic analysis. Research Quarterly, 10(2):3-24.

Goosey, V.L., Campbell, I.G.(1998). Symmetry of the elbow kinematics during racing wheelchair propulsion. *Ergonomics*, 41, 1810-1820.

Goosey, V.L., Fowler, N.E., Campbell, I.G.(1997). A kinematic analysis of wheelchair propulsion in senior male, senior female and junior athletes. *Adapted Physical Activity Quarterly*, 14,156-165.

Gorden, J.A., Straub, S. J., Swanik, C. B., Swanik, K.A.(2003). Effects of football collars on cervical hyperextension and lateral flexion. *Journal of Athletic Training*, 38, 209-215.

Hamill, J., Knutzen, K.M.(1995). Biomechanical basis of human movement. Pennsylvania: Williams and Wilkins.

Headrick, E. (n.d.) An Abbreviated History of Disc Golf. Retrieved from Disc Golf Association's web site: http://www.discgolfassoc.com/history.html

History of Disc Golf. (n.d.) Retrieved June 13, 2005, from http://members.tripod.com/odgc-sc/dghistory.htm

Hiley, M.J., Yeadon, M.R.(2003). Optimum technique for generating angular momentum in accelerated backward giant circles prior to a dismount. *Journal of Applied Biomechanics*, 19, 119-130.

Jobe, F.W., Tibone, J.E., Perry, J., Moynes, D.R.(1983). An EMG analysis of the shoulder in throwing and pitching: a preliminary report. Am. J. Sports Med., 11: 3-5.

Jobe, F.W., Moynes, D.R., Tibone, J.E., Perry, J., (1984). An EMG analysis of the shoulder in throwing and pitching: a second report. Am. J. Sports Med., 13: 216-222.

Koh, J.O., Jane Watkinson, E., Yoon, Y.(2004). Video analysis of head blows leading to concussion in competition taekwondo. *Brain Injury*, 18, 1287-1296.

Lane, F.C.(1912). One hundred and twenty-two feet a second. The Baseball Magazine, 10(2):22-25, 104, 106, 110.

McGinnis, P.M.(2005). Biomechanics of sport and exercise 2nd ed. Illinois: Human Kinetics.

McNitty-Gray, J.(1991). Kinematics and impulse characteristics of drop landings from three heights. International Journal of Sport Biomechanics, 7:201-224

Otsen, O., Myklebust, G., Engebretsen, L., Bahr, R.(2004). Injury mechanisms for anterior cruciate ligament injuries in team handball a systematic video analysis. *American Journal of Sports Medicine*, 32, 1002-1012.

Palmeri, J., Lambert, S.(2003). The history of disc golf. Retrieved June 12, 2005, from University of Wisconsin-Parkside's Disc Golf Web site: http://www.uwp.edu/departments/union/discgolf/history.html

Prentice, W.E.(2006). Arnheim's principles of athletic training: a competency based approach 12th ed. New York: McGraw Hill.

Siniscalchi, J.(2005). Disc golf can bring personal and community benefits to rural America. *Parks and Recreation*, 43-47.

Tortora, G.J.(2005). Principles of human anatomy 10th ed. New Jersey: John Wiley and Sons, Inc.

World Flying Disc Federation (n.d.). History of Disc Golf. Retrieved June 15, 2005, from World Flying Disc Federation’s web site: http://www.wfdf.org/index.php?page=history/discgolf.htm

VITA

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Scope and Method of Study: The purpose of this investigation was to gather video of disc golf drives for distance and analyze the data to extract and name phases of the drive, establishing a common language that researchers, sport performance professionals, and the disc golf community can use to communicate. The drives of 15 male disc golfers in the advanced division were analyzed using video analysis software.

Findings and Conclusions: Video analysis of the fifteen males has shown that there are eight distinct phases of the disc golf drive for distance. Groups of actions make up each phase, which was given a name according to the movements performed. The eight phases consisted of four lower body phases and four upper body phases. The phases in order of occurrence in the throw are Approach, Preload, Transition, Load, Cross Over, Pull, Plant, and Release. This research provides a viable new language to discuss the pattern of movements known as the backhand disc golf drive for distance with more detail and accuracy than previously existed.

ADVISER'S APPROVAL: Tona Hetzler