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Comparison of three base stealing techniques in Division I collegiate baseball players

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COMPARISON OF THREE BASE STEALING TECHNIQUES IN DIVISION I COLLEGIATE BASEBALL PLAYERS

An Abstract of a Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Sean Boss

University of Northern Iowa

July, 2016

ABSTRACT

The problem that baseball coaches face is which base stealing technique is most effective. The purpose of this study is to compare three base stealing techniques (crossover step (CS), jab step (JS), and drop step (DS)) on initial sprint kinematics and steal time in Division I baseball players. This paper will address the stretch shortening cycle (SSC) and its effects, the false step technique, sprinting technique, and acceleration. This research will provide coaches with the knowledge and educate them on which technique provides greater sprint speeds. The method for research was experimental, repeated measures design to determine the effects of three different base stealing techniques on sprint capabilities. The results showed no significant difference between the three techniques (F(4,32)=2.3, p=0.083). A secondary analysis showed that a smaller magnitude of heel displacement during the drop step resulted in faster sprint times when compared to a larger heel drop through 5-m (F(4,100)=16.5, p=0.001). In conclusion, when teaching the DS, a smaller heel displacement resulted in faster sprint times when compared to a larger heel displacement.

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This Study by: Sean Boss

Entitled: Comparison of Three Base Stealing Techniques in Division I Collegiate Baseball Players

has been approved as meeting the thesis requirement for the

Degree of Master of Arts

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CHAPTER I

INTRODUCTION

Base running in baseball is an aspect of the game that draws a lot of attention (Fox, 2006). The ability of the base runner to steal a base provides many advantages for the offensive side of baseball. Safe arrival at the stolen base requires the ability of the base runner to cover the distance between bases in a short amount of time, reaching the base before the catcher throws them out (Brunfeldt, Dapena, & Ficklin, 2015). With on base percentage and run production decreasing, stolen base attempts are increasing (Moore, 2012).

A successful stolen base advances the runner and removes a force play at second base (Ficklin, Lund, & Reilly-Boccia, 2014). With the removal of the force play at second, the defense is unable to turn a double play and is required to throw the batted ball across the infield. The most important advantage that is provided by the advancement of bases without making an out is that it provides the offense with three opportunities to drive the runner in with a hit, successively increasing the run expectancy (Ficklin et al., 2014).

Run expectancy is the average number of runs a team produces during any situation (Ficklin et al., 2014). Increasing the run expectancy is the potential reward for the attempt of stealing a base. For example, a team can expect to score 0.56 runs in an inning with zero outs and zero runners on base. If the lead-off man reaches first base, this value increases to 0.95. With a successful attempt of stealing second, this value will increase again to 1.19 (Lederer, 2006).

If the baserunner at first base is thrown out at second base while attempting to steal, the run expectancy decreases from 0.95 (runner at first base with zero outs) down to 0.30 (zero runners on base and one out). This results in a loss of 0.65 because of the failed attempt (Lederer, 2006). The potential risk (0.65 decrease) outweighs the potential reward (0.24 increase) by nearly three times. In other words, a team needs three successful stolen bases for every one failed attempt to break even. Being caught stealing is a double-edged sword. A runner who is thrown out not only produces an out, but also removes himself from the base paths and potential scoring position (Lederer, 2006).

From MLB statistics from 2000-2005, the average run value for all stolen base attempts was -0.041662, with a success rate of 67% reaching just under the rate to break even (Fox, 2006). Keeping the marginal out, the risk of an out produced by a stolen base attempt, should be kept low (Moore, 2012). Although attempting to steal a base gives many tactical advantages in terms of run expectancy, the success rate of this attempt needs to be taken into account.

Along with the sabermetric analyses of a stolen base, the proper technique and footwork is also a crucial element. Very little is known about the proper technique of stealing a base. Two common techniques that are utilized are the CS, where the left leg crosses in front of the right leg with right leg generating the force, and the JS, where the right foot takes a small step towards the base before the left foot crosses the right with the left leg generating the force (Wasserman, 2015). A new technique is being introduced called the DS.

The DS is a negative/false step where the right foot drops toward the left foot, so that the right foot is now directly underneath the right hip. This position creates an efficient shin angle at that ankle joint that is mechanically advantageous to accelerate the body. The DS allows the hips to open, creating the proper direction of movement towards the advancing base (Wasserman, 2015). A similar movement of the first step in collegiate linebackers was analyzed in a recent study comparing the first step and rhythm/DS on sprint speed. The results found that the rhythm/DS technique resulted in a greater acceleration when compared to the first step technique (Cusick, Ficklin, & Lund, 2014).

The mechanisms of why this technique should work comes from a biomechanical standpoint. The shift of weight from the DS displaces the center of mass (COM) in the path of the ground reaction force (GRF; Cusick et al., 2014). Maximizing the forward component of the GRF is beneficial in maximizing acceleration, which requires adaptations in technique from the lesser angle between the ground and GRF vector. One way this may be accomplished is by leaning forward, or in this case, taking a step backwards. Additionally, this technique allows the runner to utilize the benefits of the stretch shortening cycle (SSC) from the repositioning of the lead leg, improving the ability to generate force during the first step (Cusick et al., 2014).

Despite the evidence that this DS technique resulted in greater acceleration in collegiate football linebackers and the biomechanical mechanisms showing the benefits of this technique, baseball coaches continue to eliminate the DS. Very little research has conclusively determined the greater technique.

Statement of the Problem, its Significance, and the Purpose of the Study

The problem that coaches face is that they are uninformed of which base stealing technique is the best. In the past, the CS technique has been utilized because of the notion that there is no “negative” motions. These coaches are unware that this negative motion may put the runner in a more biomechanically efficient position to generate force and accelerate. This research will provide coaches with the knowledge and educate them on which technique provides greater sprint speeds. Therefore, the purpose of this study is to compare three base stealing techniques on initial sprint kinematics and steal time in Division I baseball players.

Null Hypothesis

There is no difference between the three base stealing techniques on sprint kinematics and steal time.

Delimitations

The subjects that will be participating in this study are Division I baseball players. The variables that will be included in this study are acceleration, velocity, ground reaction force, and center of mass. The equipment used are high speed cameras and digitizing with MaxTraq in the biomechanics laboratory. The results of this study will utilized to generalize the tactic of base stealing in baseball.

Limitations

A limitation of this study is the experience of one base stealing technique compared to the other two. Some athletes may prefer one technique over the other two and utilize it on a daily basis, limiting the experience of the others. Another possible limitation is the range of skill in base stealing within the subjects. Although all athletes have experience with base stealing, some athletes may have been utilized in base stealing, providing them with greater experience.

Definition of Terms

- Acceleration: The rate of change of velocity per unit of time
- Velocity: The speed of something in a given direction
- Ground reaction force (GRF): The force exerted by the ground on a body in contact with it
- Center of mass (COM): The point representing the mean position of the matter in a body or system
- Stretch shortening cycle (SSC): An active stretch (eccentric contraction) of a muscle followed by an immediate shortening (concentric contraction) of that same muscle

Assumptions

1. The subjects participating in this study gave maximal effort during each trial
2. Each base stealing technique was performed properly by each subject
3. The data collection techniques are valid and reliable

CHAPTER II

REVIEW OF RELATED LITERATURE

In order to understand the benefits of the false step technique utilized in base stealing, the mechanisms that enhance the movement need to be addressed. The following review of literature will contain the role of the stretch shortening cycle (SSC) in athletic movements, the effects of the false step, and the sprint cycle. The mechanisms of each of these topics will be addressed to compare the three base stealing techniques on initial sprint kinematics and steal time in Division I baseball players.

Stretch Shortening Cycle

The stretch shortening cycle (SCC) describes a natural muscular function in which a pre-activated muscle-tendon complex is lengthened during the eccentric phase of the movement followed by a muscle-tendon shortening during the concentric phase (Gollhofer, Leukel, & Taube, 2012). The muscle-tendon mechanism is engaged during quick, explosive movements such as sprinting, jumping, and agility. Movements that are essential in sport (Markovic, & Salaj, 2011). The SSC has gained a lot of attention in sports performance because of the important role it obtains in the components of sport, power and agility (Finni, Ishikawa, Komi, & Kuitunen, 2005).

The major advantage of the SSC is considered to be partial storage and release of kinetic energy leading to enhanced power output and greater movement economy (Gollhofer et al., 2012). The effect of the SSC on the enhancement of positive work can be of the order of 1.5-2.3 times the work capabilities when starting from maximal isometric action (Komi & Nicol, 2011). It has been shown that the energy stored by the

SEC in the downward phase provides 32% of the total muscle energy in the push-off phase (Bohm, Bruggemann, Cole, & Ruder, 2006).

Since this phenomenon is so important to performance, many researchers have conducted numerous studies to explain the effects of this mechanism and how it relates to performance. The important function from the SSC are to minimize unnecessary delays in the force-time relationship by matching the pre-activated levels of force to the required level to meet the expected eccentric loading and to make the final concentric action either more powerful or to generate force more metabolically efficient (Komi & Nicol, 2011). The SSC operates through a combination of mechanisms relating to muscle mechanics.

One SSC mechanism contributing to the increase in maximal power production is the storage and release of elastic energy from the elastic components of the muscle-tendon unit. The SSC allows for energy storage capabilities of the elastic components (SEC) and stimulation of the stretch reflex to employ a maximal increase in muscle recruitment. With the increase in muscle recruitment caused by the SCC, this phenomenon leads to a more explosive concentric action enhancing sports performance (Jeffreys & Turner, 2010).

When the muscle complex is stretched, elastic energy is stored in the SEC, consisting of tendons, and contributes toward force production if a concentric contraction occurs immediately after (Dickens, 2012). Tendons are considered to be the key site for the storage of energy within the SEC because of their ability to store energy, recoil, and release energy. The tendon recoil is responsible for both the increase in power output and conservation of energy during movement (Jeffreys & Turner, 2010).

The energy stored in the SEC during the eccentric phase either increases the force production during the concentric movement. The stored energy increases the force production during the concentric phase beyond the ability of an isolated concentric muscle action. Stored elastic energy contribute to the reflex recruitment of additional motor units, the increase in rate coding, and enhancement in potentiation before contraction (Hennessy, & Kilty, 2001). The greater the release of elastic energy, the greater reduction in cross-bridge formation and force production needed (Jeffreys & Turner, 2010). The SEC can generate a large amount of force and optimizes rate of force development (RFD), but has been shown to not be possible during slower movements (Dickens, 2012).

The efficiency of the SSC depends on the ability to transfer energy from the eccentrically stretched muscle-tendon complex to the concentric push-off phase. Muscular stiffness regulation is considered to be an essential factor for a successful transfer of energy. The reflex contributions induced by the stretch during the eccentric phase enhance muscular stiffness, leading to an increase in performance during the concentric phase. The reflex may also prevent muscle yielding in certain conditions where the muscle is not pre-activated (Gollhofer et al., 2012).

Another SSC mechanism is from the work of the muscle spindles. The muscle spindles are proprioceptors within the muscle that detects changes in relative length of the muscle. During a sudden lengthening of the muscle, the muscle spindles release an impulse to the spinal cord. The size of the impulse depends on the magnitude of the stretch. If the impulse is large enough, an automatic protective response causes the muscle fibers to contract (Dickens, 2012). The firing frequencies are proportionate to the velocity of change of length of the muscle in relation to the amplitude (Gollhofer et al., 2012).

The rate of the stretch is essential during this movement. A greater muscle recruitment and activity during the SSC concentric phase results from a higher stretch rate. Moreover, the forceful and rapid lengthening of the muscle-tendon unit during the eccentric phase of the movement causes a mechanical deformation of the muscle spindles that activate a reflexive action. This stretch reflex increases the stimulation of the muscle and results in an increased contraction force during the concentric phase and contributes to an enhancement of power output. The extent to the enhancement in power from the SSC depends on the rate of the stretch and the magnitude of the impulse detected (Cormie, McGuigan, & Newton, 2010).

The muscle spindles may be responsible for the potentiation after a prestretch of the muscle due to its initial reflex recruitment of additional motor units and rate of firing of the recruited units. This mechanism contributes to the development of an active state at a high level, which allows the muscle to generate higher force production during the concentric phase (Jeffreys & Turner, 2010).

The muscle length has an impact involved in the increasing force output after SSC. The force enhancement is related to the longer length of the muscle before the concentric phase. This places the muscle in a more advantageous position on the length-tension relationship to produce force. Due to the effects of the SEC, the muscle fibers are at optimal length at contraction and are able to produce greater force. Due to this isometric action, the lowering of force output with increasing velocities is avoided and enables the muscle fibers to far exceed the force output of concentric contractions (Jeffreys & Turner, 2010).

False Step

An athlete's ability to initiate and change direction rapidly is influential to sprinting and sport performance (Dysterheft, Lewinski, Pettitt, & Seefeldt, 2013). When moving from one point to another, quickness is often the deciding factor (Brown, Coburn, Johnson, Judelson, Khamoui, Tran, & Uribe, 2010). Therefore, coaches should be placing most of their efforts on the mechanics of acceleration and first step quickness to maximize the efficiency of training (Cronin & Frost, 2011). In many sport activities and movements, it is required of the athlete to accelerate from a stationary position to maximal speed (Kraan, Snijders, Storm, & Veen, 2000). From the stationary position, two main take off techniques are involved, the forward step and the false step (LeDune, Nesser, Finch, & Zakrajsek, 2012).

The forward step requires the athlete to step forward into a sprint from a standing position. The false step allows the athlete to take a step backwards, or in the negative direction, before stepping forward with the opposite foot (LeDune et al., 2012). With the step backwards, the athlete's base of support displaces behind the center of gravity before stepping in the desired direction (Cusick et al., 2014).

The initial movement from a stationary position, the center of mass must be displaced outside the base of support. This is achieved by one of two ways: by a rotation of the body at the ankle joint, shifting the center of mass, or displacing the base of support by changing a foot position by stepping backwards or to a side (Cronin, Frost, & Levin, 2008). Researchers have identified two important factors of maximizing acceleration: forward position of the body's COM and the use of the SSC (Brown et al., 2010).

From a parallel stance, an athlete chooses to initial movement by a repositioning of their center of mass by leaning, or moving their feet (Cronin et al., 2008). Both techniques are commonly utilized by coaches and are implemented in various sports activities. The argument for the forward step is that it eliminates the backwards step, thus saving time generating forward momentum. Although, the false step utilizes the effects of the SSC and the elastic properties of the tendon and the reflex movement (LeDune et al., 2012).

According to previous research, it has been stated that the false step outperformed the forward step in terms of production of force at the initial step. The false step has been shown to also generate faster sprint times from an upright position when compared to other techniques (LeDune et al., 2012). The research also showed that using a false step technique, sprint time was reduced by 100 ms when the distance to be covered was as short as 3 meters (Cronin et al., 2008).

In an additional study comparing the force and power at push-off between a staggered stance, parallel stance, and the false step, the researchers concluded that using a backwards step to accelerate is advantageous. It was also stated that the athletes participating in the study inherently adopted the backwards stepping strategy when asked to sprint from a stationary position (Cronin & Frost, 2011).

From previous research, the false step has shown to be the superior technique if the distance to be covered is less than ten meters (Brughelli, Cronin, Frost, Green, & Levin, 2007). When the false step was compared to a forward step over a 5-meter sprint the difference was significant, with the false step resulting in substantially faster times. Stepping backwards to initiate forward movement can improve sprint performance due to the increase in force and power production at push-off. Using the forward step caused the subjects to remain in contact with the ground for a longer period of time, and it took the subjects longer to reach their peak force. In addition, the time period from peak force to takeoff was also greater (Cronin & Frost, 2011).

Many mechanisms partake in the enhancement from the false step technique and improve the performance of the movement. Certain biomechanical properties are present during the false step that allow for greater acceleration and sprint velocities that are important to recognize. It is important for coaches and sports performance coaches to understand these effects when concentration on the technique of the first step used when initiating movement (Cusick et al., 2014).

Utilization of the SSC by the false step is crucial and increases the force production capabilities, therefore, decreasing sprint times. When the athlete steps back, there is an eccentric action of the muscle, lengthening the calf muscle. This activates the muscle spindles sending a signal to the spinal cord, sending a reflex signal back to the muscle serving to the increase in force production during the concentric muscle action (Brown et al., 2010). The SSC has been shown to increase the force production capabilities by preloading the muscle with elastic energy (Dysterheft et al., 2013). This ballistic movement created by the false step is then supported by greater acceleration values.

To accelerate forward from a standing position without a loss of balance, the athlete must keep the body COM in the path of the GRF (ground reaction force). Maximizing the forward component of GRF is beneficial in maximizing acceleration, but also requires an adaptation of technique to account for the lesser angle. This can be accomplished by moving the ground point of application of the GRF, or stepping backward. This has been applied by the use of starting blocks in the sport of track and field (Cusick et al., 2014).

Higher values of GRF that are applied in a shorter amount of time seem to facilitate greater impulses. A study done on field sport athletes demonstrated that those who were capable of producing greater GRF, especially the vertical component, exhibited less contact time with the ground and bigger stride length, which resulted in faster times during the first five meters of a sprint that was initiated from a split stance position (Callaghan, Jeffriess, Lockie, Murphy, & Schultz, 2013). It has been shown that faster sprint times, within the first 10 meters of a sprint run, are achieved with greater horizontal impulses (Kawamori, Newton, & Nosaka, (2013).

Horizontal forces and impulses are extremely important for acceleration and sprint starts. During block starts in track and field, greatest horizontal forces were a result by maximizing the horizontal component of the GRF. Utilizing the false step resulted similar values due to the repositioning of the COM and extra forward lean. Taking a false step increases the horizontal component of the total GRF produced during a sprint start.

The study compared the values generated during the sprint starts in track from the blocks. Utilization of the start blocks maximized the horizontal forces produced during their takeoff by allowing them to lower their COM and assume a forward lean in an attempt to achieve greater accelerations (Cusick et al., 2014).

An additional study that compared the effects of forward and false step on total sprint time also concluded that the false step is far more superior. The authors suggested that false step is a better training technique as it displaces the COM anteriorly while at the same time utilizing the SSC, concluding that the false step resulted in greater horizontal power and bigger impulse (Brown et al., 2010).

The countermovement of the false step is intended to create an explosive movement to propel the body forward at a high rate (Brown et al., 2010). Although taking a false step prior to accelerating forward seems counterproductive, the shorter time to peak force and higher force production are more important (Kraan et al., 2000). The utilization of the SSC increases the impulse during the initial push which decreases total sprint time. The false step technique allowed the runner to utilize the SSC for improving the ability to generate initial force production during the first step (Cusick et al., 2014).

As it appears, false step decreases the time needed to reach peak force, while at the same it increases push-off force. The combination of these mechanisms results in higher overall accelerations and sprint velocities (Brown et al., 2010). The activation of the SSC improves an athlete’s ability to produce higher forces during the initial step of a sprint (Cusick et al., 2014). Utilizing the SSC has been shown to improve performance.

Having to lean forwards to position the center of mass ahead of the feet to initial movement with the false step alters the segment mechanics and changes the athlete's ground contact, mainly in the first step which is crucial. Making the use of the false step also alters the way an athlete produces force at push-off by changing their segment mechanics and utilizing the SSC, resulting in higher horizontal velocities at the first ground contact (Cronin, & Frost, 2011).

Therefore, the false step has a potential to result in superior sprint performance. However, any benefit that is provided by the utilization of the SSC goes away if the forward step is used instead, as this will not allow for the activation of the SSC and the production of greater forces and higher velocities (Cusick et al., 2014). With a parallel stance, the center of mass must be repositioned before horizontal force can be developed. This delay with the effects of the SSC are conclusive to improving an athlete's acceleration and movement time (Cronin et al., 2008).

Sprinting

Many strength and conditioning practitioners, coaches, and athletes is the development and improvement of sprint speed (Brughelli, Chaouachi, & Cronin, 2011). In sports like baseball, soccer, and football, just to name a few, being able to sprint at high velocities could determine the level of success. Sprinting is a high velocity running skill during which the goal is to cover a certain distance in the least possible time (Bezodis, Kerwin, & Salo, 2008).

This complex task places high neuromuscular demand on the athlete and requires high level of coordinated movement and appropriate sequence of muscle activations in order to perform at peak levels (Young, 2008). Many mechanisms take place in sprinting that separate the elite and their counterparts. Whether it's within the technical aspect such as stride length and stride frequency, or from a biomechanical standpoint such as force production and impulses, a better understanding of the movement is crucial.

Speed is a function of stride length and stride frequency. These two variables are interdependent and inversely related, as one variables increases, the other may decrease. Therefore, it is important to reach an optimal balance between stride length and stride frequency without manipulated either as if they were completely independent (Young, 2008). The limit to speed is reached when foot-ground contact times and effective vertical impulses decrease to the minimums that provide just enough aerial time to reposition the swing limb for the next step (Bundle, Prime, Sandell, & Weyand, 2010).

To increase sprint speeds, an athlete must increase the force they apply to the ground and be able to apply those forces in shorter periods of time. Just as the amount of force applied is important, the direction of the force applied is also important. For maximal speed velocities, the athletes should minimize horizontal braking forces and maximize vertical propulsive forces. Vertical propulsive forces are important because once momentum has been maximally developed during acceleration, the balancing of internal and external forces acting on the body are important to keep the body moving forward at the same speed (Young, 2008).

The benefit of greater force application is two-fold. First, greater force application will increase stride length. The greater force applied into the ground will result in a larger displacement of the athlete's body in the air and greater distance will be covered. Second, the increased force application results in an increased stride frequency as well. Stride frequency is comprised of ground contact time and flight time (Young, 2008). To improve the specific abilities that will enhance speed, the ability to withstand and produce large forces in a short period of time is crucial.

There are three primary goals in maximizing the velocity of sprinting: preservation of stability, minimization of braking forces, and maximization of vertical propulsive forces. The first goal of sprinting mechanics is the preservation of stability. Stability is crucial to any athletic movement by ensuring that the body is able to move with maximal efficiency. When stability is disrupted, dysfunctional movement patterns are often the result along with loss of elasticity. As with many aspects of sprint performance, posture is the core of enhancing stability. Posture refers to the positioning and functional capacity of the core region of the body (Young, 2008).

Without proper internal stability and appropriate postural alignment, preservation of stability is often affected. To enhance the stability, the musculature surrounding the spine should be strong and remain stable during the movement of all limbs (Young, 2008). It is important to recognize that stabilization is dynamic in nature and not always static. This is especially true of the pelvis. While the general position of the pelvis should have some posterior tilt, efficient sprinters exhibit pelvic rotation in all three planes (Novacheck, 1998).

Along with stabilization of the core, the sprinter's head, neck, and spine should be neutrally aligned. This posture gives freedom of movement and relaxation, both to enhance elastic energy from the core and extremities. An upright posture promotes front-side mechanics and limits backside mechanics. Front-side mechanics refers to the actions of the lower extremities that occur in the front of the body, while backside mechanics refer to the actions occurring behind the body. This is crucial to sprinting efficiency (Young, 2008).

The second objective of sprinting mechanics is minimizing braking forces that the athlete produces at ground contact. Braking forces are the forces which occur in the opposite direction of the desired movement and tend to lead to deceleration. Although completely removing braking forces is impossible, attempts with technique should be made (Young, 2008). The primary cause of an excess in braking forces is due to the athlete over striding and making contact with the ground too far in front of their center of mass.

Two scenarios are often the cause of excessive braking forces. The first cause is the stride length and the attempt of "reaching out" with each step. This often creates a ground contact point further in front of the athlete's center of mass. Stretching out with each step in an attempt to increase stride length will ultimately have an opposite effect and create horizontal braking forces (Young, 2008).

The second scenario is instability. When the body is experiencing instability, the attempt to regain stability by a premature grounding of the swing leg. The premature grounding means that the foot will still be moving forward with respect to the body when contact is made with the ground (Young, 2008). The premature grounding is often referred to as positive foot speed. This is potentially disruptive to efficient sprinting because of the increase in the braking forces. This is referred to as negative foot speed at ground contact and is highly correlated with increased sprinting speeds. Any negative foot speed is a byproduct of efficient front-side mechanics and sufficient flight time (Young, 2008).

The final objective of sprinting is enhancing vertical propulsive forces. Increasing vertical propulsive forces increases vertical displacement of the athlete, which leads to a more effective ground contact position and increased likelihood of negative foot speed. Better sprinters tend to have greater upward vertical displacement during flight and less downward vertical displacement following ground contact. Their counterparts have difficulty producing vertical forces, resulting in a dropping of their hips at ground contact. This leads to a lengthening time of ground contact and reduces the elastic components at push-off (Young, 2008).

Increased vertical force application results in a more effective ground contact position. With better vertical displacements occurring in faster sprinters, longer time is available for the athlete’s swinging leg come in contact with the ground closer to the center of their center of mass. Insufficient flight time may result in a ground contact point further in front of their center of mass. This will result in an increase in braking forces (Young, 2008). The main mechanism that repositions the leg during a sprinting cycle is the storage and release of the mechanical energy of the flexor muscles of the swinging leg. Therefore, it is now believed that in order for an athlete to achieve faster speeds, the athlete has to apply greater ground forces to minimize ground contact time rather than just attempting to increase stride frequency by trying to propel the limp forward. (Brughelli et al., 2011).

Acceleration

Maximal running speed and acceleration are essential components when it comes to performance in sport. A faster athlete has the ability to reach the destination in a shorter period of time, thus a greater advantage of winning (Kawamori et al., 2013). Although maximum velocity is important in sport, it is generally accepted that the ability of greater acceleration is of greater importance in sport because of the rarity of reaching top speeds in field sports (Coutts, Lockie, & Murphy, 2003).

Maximal sprinting speeds depend on the increasing in speeds that occur prior in the acceleration phase. Therefore, the ability to accelerate the body is crucial to performance (Nagahara, Matsubayashi, Matsuo, & Zushi, 2014). In team sports, acceleration is of main importance because of sprint capabilities in short durations (Kawamori et al., 2013). The ability of quickness over the first few steps during a sprit is vitally important during the game (Coutts et al., 2003).

Acceleration is defined as the rate of change of velocity. Although, in a practical sense, acceleration ability is referred to as sprint performance over smaller distances such as 5-10 meters, and is assessed using sprint time or velocity (Coutts et al., 2003). In contrast to the upright posture sprinters adopt during maximal velocity, sprinters have a forward trunk lean that assists acceleration as the whole body's center of mass is brought ahead of the base of support (Nagahara et al., 2014).

Many mechanisms partake in the acceleration phase of sprinting, both from the technical and biomechanical aspects. From a biomechanical standpoint, kinematic variables such as ground reaction force (GRF), impulses, and force production. From a technical standpoint, stride length and stride frequencies play an important role and the difference from maximal velocity also play important roles in the acceleration phase. The duration at which force is produced during the stance phase is also important for acceleration. Relationships between ground reaction force and ground contact time have been shown to enhance acceleration, but also the relationship between ground reaction force and time can also be analyzed through impulse, specifically vertical impulse, horizontal impulse, and resultant impulse (Callaghan et al., 2013).

During the acceleration phase, faster sprints speeds were developed from a correlation between step length, ground contact time, and flight time with sprint velocity, concluding that greater step lengths, shorter ground contact times, and longer flight times were evident. Longer step lengths are indicative of higher strength and power development in the leg muscles specific to the sprint step (Callaghan et al., 2013).

Results have shown that greater vertical force production during the stance phase of acceleration contributes to a shorter ground contact time. Faster subjects who produce shorter ground contact times tend to produce greater vertical and ground reaction forces. Shorter contact times have been related to faster sprint speeds both during maximum velocity sprinting in track and field sprinters, as well as acceleration in sport athletes (Callaghan et al., 2013). During acceleration, sprinters accelerate with a rapid increase in stride frequency and a rapid decrease in ground contact time, contacting their foot on the ground behind the position of their center of mass (Nagahara et al., 2014).

Stride frequency is also important during the acceleration phase. The results showed that individuals with high acceleration ability produced a higher stride rate of 9% when compared to their counterparts. Athletes who are able to generate higher sprint velocities over a short duration have the capabilities due to greater stride frequencies produced by the reduced ground contact time (Coutts et al., 2003). Step length and step frequency have to be coordinated to enable ground contact times to be equal to the duration of time of the flight phases within the shortest amount of time capable (Coh, Stuhec, & Tomazin, 2003).

Controversy has been shown between the importance of vertical or horizontal force and impulse production. It has been suggested that horizontal force is what influences high running velocities, while others claimed that it is the vertical forces that contribute the most (Brughelli et al., 2011). Impulse is a term frequently used by sport scientists in literature reviews as it strongly correlates with sprinting, jumping, throwing, and generally any sport that requires high velocities, accelerations, and forces (Dayne, Haines, Kirby, & McBride, 2011). The influence of impulse generated during the stance shows a relationship with stride length.

It has been argued from past researchers that vertical impulse is more important that horizontal impulse. A greater vertical impulse suggests either a high production of vertical force or a higher rate of vertical force production. Results suggest that subjects with longer step lengths early in acceleration generate greater vertical impulse values. As previously stated that faster subjects produce longer step lengths, faster acceleration can be derived from greater vertical impulses. Faster performances in the first 5 m of a maximal sprint can influence sprint efforts over 10, 15, and 30 m. Therefore, greater early vertical impulse production for athletes producing longer steps within the first 5 m would assist with early speed generation during a short, or extended maximal sprint (Callaghan et al., 2013).

Researches have also argued that the horizontal component of the production of force and impulse and its effects on acceleration. During the first three steps of acceleration, the body's center of mass has to rise gradually in the vertical direction to maximize the horizontal component at push-off (Coh et al., 2006). It has been suggested that faster participants over a 10 m sprint produced larger net horizontal impulses by applying larger net horizontal forces, resulting in greater acceleration of the center of mass during each ground contact. This has been seen to be true as long as there is not an increase in ground contact time or excessive flight time (Kawamori et al., 2013).

Net horizontal impulse production is more important immediately after the start of acceleration where the athlete needs to overcome inertia of the body from a stationary position. Strong correlation has been seen between sprint time and net horizontal impulse during first ground contact during a maximal sprint initiated from a parallel starting position (Kawamori et al., 2013).

A greater ground reaction force directed in the line more toward horizontal results in greater acceleration (Callaghan et al., 2013). Additional studies found that peak horizontal force significantly increased with incremental running velocity. The researchers concluded that increasing running velocity from moderate to maximum, sprint velocity is more dependent on horizontal force production than vertical force production (Brughelli et al., 2011).

Furthermore, a study examining a block start using an elite a sprinter indicated that during the first three steps of the sprint the horizontal velocity was substantially higher than the vertical one. Therefore, the horizontal component of the ground reaction force has to be much greater than the vertical one, in order to provide the necessary horizontal impulse for accelerating forward (Coh et al., 2006). During the first steps of a sprint, there is a strong correlation between horizontal impulse and faster accelerations (Dayne et al., 2011). Similar findings comparing the forward step and false step concluded that horizontal force production and horizontal impulse were the main determinants of faster sprint times during the initial phase of a sprint (Cusick et al., 2014).

Conclusion

In summary, the importance of the false step in sport has been expressed through many studies. The vast majority of the previous studies comparing the false step with the other techniques utilized have concluded that the false step is superior for acceleration. With the false step being the more effective technique in the many sports researchers have studied, it is hypothesized that similar results will occur when comparing the three base stealing techniques.

Utilization of the SSC is essential in sport. With its effects on acceleration and speed, sport performance is enhanced. This muscle-tendon mechanism is engaged during quick, explosive movements such as sprinting, jumping, and agility (Markovic, & Salaj, 2011). This phenomenon occurs during the false step movement. Utilization of the SSC by the false step is crucial and increases the force production capabilities, therefore, decreasing sprint times (Brown et al., 2010).

The false step allows for a forward trunk lean that assists acceleration as the whole body's center of mass is brought ahead of the base of support (Nagahara et al., 2014). This allows for a greater GRF directed in the line more toward horizontal results in greater acceleration (Callaghan et al., 2013). From the results of this review, numerous studies conducted have concluded that the false step is the superior technique and results in faster acceleration and sprint times.

CHAPTER III

METHODOLOGY

Research Design

The research design of this study contains an experimental approach to the problem. A counterbalanced, randomized, repeated measures design was conducted to determine the effects of three different base stealing techniques on sprint capabilities. The three base stealing techniques utilized were the CS, JS, and the DS. After familiarization, each subject performed two trials of each technique in an order that was random and counterbalanced.

Research Participants

Nine Division I collegiate baseball players were recruited for this study. After the subjects were informed of the potential risks and benefits pertaining to the study, every subject signed an informed consent to participate in the study. The Internal Review Board of the University of Northern Iowa reviewed all study procedures

Procedures for Collecting Data

All sprint trials were videotaped at 100 Hz on an Edgertronic camera (Edgertronic, 300 Santana Row, Suite 200, San Jose Ca. 95128)**.** The camera was positioned 10 m away with the optical axis perpendicular to a vertical plane containing the middle of the running lane. Upon arrival to the testing facility, the subjects were instructed through a 10-minute dynamic warm-up. Following the warm-up, the subjects were provided instructions of the execution of each base stealing technique that were to be performed. After the introduction of each technique, the subjects were then provided the opportunity to familiarize themselves with the three techniques.

After familiarization, each subject performed two trials of each technique. The order at which the subjects performed each trial was randomly assigned in a counterbalanced order. The subjects were provided no feedback regarding their performance of each trial. All trials were performed on an indoor facility on a turf surface. For analysis, cones were placed at 2.5-m and 5-m away from the starting point. Each subject sprinted through the 5-m mark for completion of each trial.

Data Analysis

All videos were transferred to MaxTraq (Innovision Systems, Columbiaville, MI, USA) for digitization. For each frame, the 21 anatomical landmark locations were digitized for calculation of the subject's center of mass (COM) using a previously described segmentation method using segmental inertia parameters from De Leva (1996). Each technique containing two trials were averaged for each subject for analysis.

For the video analysis, the 2.5-m and 5-m distances were used as calibration distances. The time at which the subject's COM passed the 2.5-m and 5-m marks were calculated for each trial. The distance of the heel drop, displacement of the lead heel at the start of the movement, was calculated to determine the magnitude of the drop and speed time. The distance behind the COM of the heel at first step was calculated.

Descriptive statistics were performed on all performance variables. Repeated-measures multiple of variance (MANOVA) was used to compare the three techniques at the time at 2.5-m and 5-m distances. A Bonferroni correction was used to control for familywise error. Alpha was set at 0.05 for all tests.

CHAPTER IV

RESULTS

Descriptive statistics (mean ± SD) of both temporal variables organized by the three techniques are displayed in Table 1. The repeated measures MANOVA indicated that no treatment effect was observed therefore no posthoc analysis was performed (F(4,32)=2.3, p=0.083).

Table 1. Descriptive statistics of temporal variables by technique (n=9).

	Crossover Step		Jab Step		Drop Step	
Variable	Mean	SD	Mean	SD	Mean	SD
$t_{2.5}$ (s)	1.00	0.07	1.01	0.06	1.04	0.06
t_5 (s)	1.45	0.08	1.46	0.06	1.49	0.07

CHAPTER V

DISCUSSION

The purpose of this study is to compare three base stealing techniques on initial sprint kinematics and steal time in Division I baseball players. Nine Division I NCAA baseball players were recruited for participation in this study. All subjects were instructed on how to perform each technique utilized in this study and were allowed for familiarization prior to testing.

Surprisingly, there were no significant effects when comparing the CS, JS, and DS. Actually, the DS resulted in the slowest time when compared to the two other base stealing techniques. This was alarming to the researcher because of the previous studies conducting that the DS resulted in faster acceleration times. Such as the study conducted by Cusick et al., (2014) on linebackers and acceleration, and Cronin et al., (2007) researching acceleration within 5-m distances both resulting in faster sprint times utilizing the DS. LeDune et al., (2012), also showed the DS resulted in faster sprint times in as short as 3-m distances. In these previous studies, along with numerous others, the DS technique was the dominant technique. However, no significant differences resulted from the present study.

Upon further review of the videos taken for analysis, it was observed that the execution of each technique was flawed, which produced incorrect results. It was noticed that during the CS trials, the lead foot did not stay in contact with the ground as instructed, but rather displaced in the negative direction comparable to the DS technique. Although this negative displacement was not as drastic as in the DS technique, this still affected the results of the study. A similar qualitative analysis was done during the JS trials. It was observed that the athlete broke contact with the ground at the start of the movement, as they should, but instead of making a positive movement with the lead foot, many subjects made the same negative displacement as in the JS trials. That is, the majority of the JS trials performed were actually DS.

After noticing these technical errors performed by the subjects, a secondary analysis was performed. The horizontal position of the heel of the lead foot during the lead was compared to the position of the heel after the foot was raised and lowered back to the ground for all three conditions. This was called heel drop displacement (s_{heel}) and for all three conditions was negative in all cases. This confirmed that the visual analysis of the videos during the secondary analysis that the majority of the subjects were performing the DS technique without knowing. Of all the trials conducted, there was only one trial during the JS trials that resulted in the correct positive displacement of the heel as instructed. Specifically, the CS had an average displacement of -0.1-m, the JS averaged a -0.02-m displacement, and the average DS displacement was -0.31-m.

Clearly, the magnitude of the DS has an effect on the temporal variables. To determine the effect of the s_{heel} on the temporal variables, each subject's $t_{2.5}$ (time at 2.5-m) and t_5 (time at 5-m) data were converted to a score relative to each subject's slowest trial. Each of the six trials were rank in ordered for each subject and the slowest trial was given a score of zero. If the next slowest score was 5% faster than the slowest score, it was scored as 0.05. The relative scores ($t_{2.5rel}$, t_{5rel}) were rank ordered and quartiles were calculated in order to group the trials by slowest to fastest trials. Two separate MANOVA analyses were used to determine the changes in s_{heel} and time across the three groups; slow, medium, and fast.

The first MANOVA indicated a significant group effect for the 2.5-m distance (F(4,100)=19.7, p=0.001). There was a significant grouping effect for $t_{2.5rel}$ (p=0.001) but not for s_{heel} (p=0.41). A significant grouping effect was also observed by the second MANOVA that analyzed the 5-m distance (F(4,100)=16.5, p=0.001). The group effect was significant for t_{5rel} (p=0.001) as well as s_{heel} (p=0.047). The results of the posthoc analyses can be found in Tables 2 and 3.

Table 2. Effect of trial grouping on $t_{2.5rel}$ and s_{heel}

	$t_{2.5rel}$ (%) Faster		s_{heel} (m)	
Variable	Mean	SD	Mean	SD
Slow	0.01	0.01	0.16	0.14
Medium	0.07*	0.03	0.11	0.13
Fast	0.17**	0.03	0.16	0.16

*Significantly greater than the “slow”. **Significantly greater than “medium.”

Table 3. Effect of trial grouping on t_{5rel} and s_{heel}

	t_{5rel} (%) Faster		s_{heel} (m)	
Variable	Mean	SD	Mean	SD
Slow	0.01	0.01	0.19	0.17
Medium	0.04*	0.01	0.16^	0.14
Fast	0.08**	0.02	0.08^^	0.08

*Significantly greater than the "slow". **Significantly greater than "medium." ^Significantly greater than "slow." ^^Significantly greater than "medium."

Through the first 2.5-m, the amount of displacement of the lead heel during the DS was not significant. Due to the limited amount of time to accelerate up to the 2.5-m mark, the ability to see an effect was eliminated. With an interplay between variables, such as shin angle, trunk lean etc., created with a larger displacement during the DS, the foot travels in the negative direction in a greater magnitude when compared to a smaller magnitude of a drop with less negative displacement of the heel.

There was a significant effect on the magnitude of negative displacement during the DS on the speed of the trial at 5-m. The results showed that the smaller magnitude of lead heel displacement during the DS lead to faster trials through 5-m. As shown above, the fastest trials through 5-m occurred with a 0.08-m heel drop. As the length of negative displacement of the heel during the DS increases, the speed of the subject decreases, resulting in slower time trials. Therefore, a shorter drop is more effective than a longer drop.

The reason for the faster sprint speeds through 5-m using a smaller DS results from the direction of the GRF, pointing in an optimized direction enhanced by both horizontal and vertical forces. As stated, there has been controversy between the importance of maximizing horizontal or vertical forces. Previous studies have indicated that maximizing horizontal forces is more important for acceleration, while other studies claim that vertical forces are more important for acceleration. Nagahara et al., (2014) have stated that increasing stride frequency and decreasing ground contact time are crucial for acceleration. To do this, vertical force production is critical. However, Kawamori et al., (2013) claimed that net horizontal impulse production is more important after the start of acceleration to overcome inertia of the body at rest.

In the present study, the mean of heel displacement during the DS ranged from 0.08-0.19-m, with the faster trials resulting from the smaller magnitude of a drop. This is a case for maximizing the vertical component during acceleration. With a larger magnitude of a DS, the subjects COM is positioned further in front of the lead foot, which would require the subject to maximize their horizontal force to accelerate and not fall down. Since this situation resulted in slower sprint times, vertical force production must be more important. From a smaller DS, there is less distance between the COM and the lead foot. This enables the subject to optimize the production of both vertical and horizontal components, rather than so much emphasis on horizontal force production.

It is also possible that these baseball players are not necessarily trained to be sprinters and do not possess the technique to tolerate the greater horizontal impulses generated from a larger magnitude DS. Therefore, utilization of both vertical and horizontal forces is needed to accelerate the body forward.

From the results of the present study, the magnitude of the displacement of the lead heel has an effect on sprint time through 5-m. With the contradiction from previous research on the effects of the drop step technique, force plate data should be utilized in future research to determine the effects of the magnitude of a DS on the amount of GRF generated and total sprint times.

Conclusion

The initial results from the present studied showed the DS was not significantly faster than the CS and JS techniques. In fact, the DS produced the slowest times. After further review of the videos, a secondary analysis was performed.

The secondary analysis showed that most of the CS performed were, in fact, DS unknowingly performed by the subjects. Additionally, all but one trial of the JS were performed correctly. The results also showed that the magnitude of the displacement of the heel during the DS had an effect on sprint times at 5-m. The shorter of displacement of the heel resulted in faster sprint times compared to a larger magnitude of a drop. In the present study, the fastest trials performed had an average displacement of 0.08-m, compared to the slowest trials averaging a displacement of 0.19-m.

From the present study, the results indicate that the magnitude of the displacement of the heel during the DS has an effect on sprint times. A shorter displacement resulted in faster sprint times through 5-m by optimizing the GRF through both the vertical and horizontal forces. The information coaches can use from this study is to teach a shorter drop rather than one of larger magnitude for best performance during base stealing.

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