

ABSTRACT

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Fifteen collegiate swimmers (8 females, mean age = 18.38, 7 males, mean age = 19.43) volunteered as subjects to determine differences between 5 kinematic variables and 2 kinetic variables using the grab start and track start. Subjects attended a 1 hour practice session, completing a minimum of 15 starts of each technique. Subjects were videotaped performing 14 trials of each start technique. Force data were collected from the last 5 trials of each technique. A MANOVA revealed the grab start had a significantly ($p < .05$) longer flight distance for all subjects. Subjects who preferred the grab start achieved 13.1% increase (normalized to body height) in flight distance with the grab start, while subjects preferring the track start had a 9.6% increased flight distance with the grab start. A significant difference ($p < .05$) was also found between the preferred starting technique and the absorption force (AFz) in the vertical direction. This force was attributed to the back leg pushing against the block during this time period. Male subjects who preferred the track start had a significantly ($p < .05$) faster start time for the track start than males who preferred the grab start. No other significant differences were found between any other variables. Further investigations on different populations would allow the results to be more generalized. More practice sessions should also be completed to decrease the effect of learning on the performance of the start techniques.

**A KINETIC AND KINEMATIC COMPARISON OF THE GRAB
START AND TRACK START IN SWIMMING**

**A THESIS PRESENTED
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THE GRADUATE FACULTY
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CHAPTER I

INTRODUCTION

Background

In the sport of swimming the start is one of the most exciting parts of the race. One reason for this is the explosiveness that is displayed by the swimmers. Starting techniques have evolved over the past 30 years and now include the conventional start, the grab start, and the track start. Each of these techniques have variations that can be used to increase the speed of the start. There is no doubt the techniques currently in use will continue to evolve as the demands of the sport change.

The start is an important, albeit small, part of the race. According to Lewis (1980), the swimmer with the fastest start has two advantages; one is the psychological advantage of being ahead of the competition, the second is swimming in smooth water, which increases the efficiency of the swimming stroke. Hay (1986) reported that 11% of the total race time for the 50-yard freestyle involved the start. The percentage of total time the start contributed to the race decreased as the length of the event increased, with the start contributing .5% in the 1000 yard freestyle (Hay, 1986). The importance of the start is also noted by the fact that in the 1996 Summer Olympic Games held in Atlanta, only .44 seconds separated first and fourth place in the women's 50 meter freestyle, with first and second separated by .03 seconds. In the men's 50 meter freestyle, first and eighth

place were separated by .60 seconds, with first and third separated by .13 seconds (Swimming World, 1996).

Throughout the 1960's, the conventional start was the start of choice. With the conventional start, the swimmer would assume the "take your mark" position with his or her hands held in front of or behind the body. The swimmer would then swing his or her arms in a forward or backward direction. As the swimmer left the block, the arms were swung forward adding to the forward momentum of the swimmer.

In the late 1960's the grab start was introduced. The difference between the conventional and grab start was, when using the grab start, the swimmer holds the front edge of the block. The swimmer pulled up against the block causing the body to move forward, thus allowing the legs to drive back against the block quicker than with the conventional start. After the initial pull, the arms swung forward to add momentum to the dive. With the introduction of the grab start, the conventional start quickly fell out of favor. Today, the conventional start is effectively used by swimmers in relay starts, where the swimmer can begin movement before the swimmer touches the wall.

In 1974, the track start was introduced into competition (Kirner, Bock, & Welch, 1989). The track start was different from the conventional and grab start because the swimmer placed one foot toward the rear of the block, similar to the starting position used by a sprinter in track. Since that time, studies comparing the track start to the grab start have had conflicting results in determining which technique is superior (Ayalon, Van Gheluwe, & Kanitz, 1975; Kirner et al., 1989; Shin & Groppel, 1986).

Numerous studies have used strain gauges to measure different forces and reaction times in swimming. Stevenson and Morehouse (1979) used a strain gauge to measure hand reaction forces with different starting block angles. The authors found that the hand reaction forces decreased as the block angle increased. Elliott and Sinclair (1971) used a force plate to measure the force time curve produced using three different block angles. They concluded that there was no difference in the force time curves produced when using block angles of 0, 10, and 15 degrees. Lewis (1980) used a Kistler Force Platform to compare reaction time and take off time in five variations of the grab start and conventional start. The results showed that although there was no significant difference in reaction time, the grab start had a faster take off time. Zatsiorsky, Bulgakova, and Chalinsky (1979) used a force plate to measure ground reaction forces for the conventional, grab, and track starts. Zatsiorsky et al. (1979) concluded that the conventional start and grab start were superior to the track start.

There have been numerous studies comparing the different racing starts in swimming. Unfortunately, the research has not been able to conclusively show if the track or grab start is faster. Areas that need further research are the differences between the forces of each start and how these forces relate to kinematic data including time and distance variables. Most research shows that the track start is faster in the block time but equal to or slower than the grab start to a set distance. One explanation offered, but not researched, is that the back leg in the track start is unable to produce a large force due to a lack of support. This lack of force production would decrease the size of the impulse, and therefore, the momentum of the start.

Need for the Study

The start in swimming is a critical part of the race. Previous research comparing the grab start and the track start have shown conflicting results. Also, these studies have not reported any comparisons of the forces that are produced using the grab and track starts. This study was designed to compare the ground reaction forces that are produced by each start. Results of this comparison are intended to help coaches decide which starting style swimmers should use.

Purpose

The purpose of this study was to compare kinematic and kinetic variables associated with the grab start and track start used in swimming. The kinematic variables that were compared included block time, flight time, start time, take off angle, entry angle, body angle, and distance to fingertip entry. The kinetic variables included the anterior/posterior (F_y) ground reaction forces, and the vertical (F_z) ground reaction forces.

Null Hypothesis

There will be no significant differences between the kinematic and kinetic variables between the grab start and the track start.

Assumptions

This study has the following assumptions:

1. Techniques used to assess the kinetic and kinematic variables are assumed to be accurate.
2. Subjects were normal, healthy swimmers.
3. Subjects performed the starts in the study the same as in a competitive race.

Delimitations

This study had the following delimitations:

1. Subjects used in this study were members of an intercollegiate swim team.
2. Videotape recordings were used to obtain kinematic data.

Limitations

The following limitations were recognized:

1. Subjects for this study were volunteers, thus a random sample was not used.
2. Subjects performed the starts from a slightly different starting surface, which may have affected the starting technique.
3. The study was completed at the beginning of the intercollegiate swimming season, therefore the subjects had limited practice with the starting techniques.

Definitions of Terms

Bertec Force Plate - A force plate that measures ground reaction forces in the medial/lateral (F_x), anterior/posterior (F_y), and the vertical (F_z) planes.

Block Time - The time from the start signal (flash) until the subject's feet left the starting platform.

Center of Gravity - The theoretical point around which all body mass is equally distributed.

Flight Distance - The distance from the edge of the starting platform to the spot of fingertip entry into the water.

Flight Time - The time from when the subject's feet left the block until the fingertips entered the water.

Momentum - A measure of inertia of the body determined by the mass of a body times its velocity.

Track Start - During this start the swimmer places the toes of one foot over the front of the block and the other foot is placed toward the rear of the block. The swimmer grabs the front of the block with the "take your mark" signal.

Grab Start - During this starting technique the swimmer places the toes of both feet over the front of the block. The swimmer grabs the front of the block with the "take your mark" signal.

Starting Commands - Commands in official NCAA competition. The commands are "take your marks", followed by an electronic beep and a corresponding flash of light.

Stretch Reflex - The contraction of a muscle as a result of a pull exerted upon the tendon of the responding muscle (Thomas, 1989).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The start in swimming has been the subject of a variety of studies. Many components of the start have been analyzed including: force production of the hands and feet, optimum block angle, and the angle of water entry. This review will discuss the types of starts used over the last 30 years, the types of water entries used during the start, and the numerous studies on the forces produced during starts.

Background

The swimming start has evolved throughout the past 30 years. Different starts have included the conventional start, the grab start, and the track start. Each of these starts has incorporated different techniques to try and increase the speed of the start. The conventional start can be varied by swinging the arms in a forward or backward direction. The grab start has different hand positions that include grabbing the block between the feet, outside of the feet, or on the side of the block. The track start can be varied by using different hand placements or by varying the spacing of the feet.

The start is an important aspect of the race. According to Lewis (1980), the swimmer with the fastest start gains two advantages. The first is the psychological advantage of being ahead of the competition. Second, the lead swimmer is able to swim in

smooth water. Swimming in smooth water should increase the efficiency of a swimmer's stroke (Lewis, 1980). Hay (1986) reported that 11% of the total race time for the 50-yard freestyle involved the start, however, the percentage of total time the start contributed to the race decreased as the length of the event increased. For the 1000 yard freestyle, the percentage decreased to less than a .5% (Hay, 1986). The importance of the start is noted by the fact that in the 1996 Summer Olympic Games held in Atlanta, only .27 seconds separated first and third place in the women's 50 meter freestyle and in the men's 50 meter freestyle first and eighth place were separated by .60 seconds (Swimming World, 1996).

Types of Starts

The conventional start was the choice of starts throughout the 1960's. With the conventional start, swimmers would hold their hands in front of or behind their body when they took their mark. At the sound of the gun, the swimmer had a choice in swinging the arms in a forward or backward circular motion. As the swimmer left the block, the arms were swung forward thereby adding to the forward momentum of the swimmer.

In the late 1960's the grab start was introduced. For the grab start the swimmer would hold the front edge of the block placing the hands either inside or outside of the feet. At the sound of the gun, the swimmer pulled up against the block. This motion moved the center of gravity forward, allowing the legs to drive back against the block. After the initial pull on the block, the arms were swung forward to add momentum to the dive.

Studies comparing the conventional and grab starts show the grab start to be superior (Hannauer, 1972). Bowers and Cavanagh (1975) used six female swimmers of national caliber to compare the two starts, using time to 10 yards. The results showed that the subjects were significantly faster to the 10 yard mark when using the grab start. The authors concluded that the grab start was faster because the swimmers were able to leave the block faster than with the conventional start. In their discussion, the authors stated that the swimmer was slower leaving the block with the conventional start because of the amount of time involved in the arm swing.

Wilson and Marino (1983) used 12 male and 12 female swimmers from the Canadian Olympic Swim Team to compare the grab start and the conventional start in time to 10.93 meters. The results showed that the grab start had a significantly faster block time than the conventional start. The grab start was also found to be significantly faster in time to 10.93 meters. The authors attributed the faster time to 10.93 meters to the faster block time of the grab start. Wilson and Marino (1983) concluded that the grab start was superior because of the pulling action of the hands, as well as the subjects' lower center of gravity on the block.

Lewis (1980) compared three variations of the conventional start and two variations of the grab start. Ten male volunteers with no competitive swimming experience practiced each of the 5 starts 42 times. During testing, subjects were instructed to swim at maximal speed to the 11 meter mark. The starts were compared using time to 8 meters. Lewis (1980) concluded that there was no significant difference

between the three conventional starts and two grab starts. Ayalon and colleagues (1975) also used untrained males (seven) as subjects. Ayalon et al. (1975) found that there was no significant difference between the grab and conventional start in the time it took the hip to cross the 5 meter mark. Even with the conflicting results of some studies, the grab start became the preferred starting technique in the early 1970's.

In 1974 the track start was introduced in international competition (Kirner et al., 1989). Since that time, studies comparing the track start to the grab start have had conflicting results (Ayalon et al., 1975; Counsilman, Nomura, Endo, & Counsilman, 1988; Kirner et al., 1989; Shin & Groppe, 1986). Shin and Groppe (1986) used 11 varsity swimmers (six female and five males) in a study comparing the track start to the grab start. The results showed the track start was significantly faster in block time, however, there was no significant difference in time to the 11 meter mark. Shin and Groppe (1986) concluded that although the subjects were quicker off the blocks with the track start, the grab start had a longer flight distance, making up the lost time.

Ayalon et al. (1975) compared the conventional, grab, bunch, and track starts using the time it took the subjects' hips to reach the 5 meter mark. In this study the bunch start, where one leg is placed toward the back of the block without additional support, is now referred to as the track start. For this study, the technique used for the "track start" was similar to the bunch start with the exception that additional support was provided for the leg at the back of the block, similar to a block used by a track sprinter. This type of support for the back leg is currently not a legal start in swimming. Film analysis showed

that the bunch and track starts were significantly faster than the conventional and grab starts in block time. Even with this advantage, the bunch start was significantly slower than the other three starts in the time it took the hip to cross the 5 meter mark. Ayalon et al. (1975) suggested that this may be due to the back leg's inability to generate a significant force against the block.

Kirner et al. (1989) used 12 experienced swimmers to compare the grab and track starts using the hole and flat entries. The subjects participated in five 45 minute training sessions. Each subject was filmed and timed performing 12 starts, 3 trials of each start combination. The results showed the track start was significantly faster in time to water entry than the grab start. There was no significant difference between the grab and track starts in sprint time to eight meters.

Councilman et al. (1988) used two groups to compare the scoop start (grab start with a hole entry), the flat start (grab start with a flat entry), and the track start. The first group consisted of 37 collegiate male swimmers of national caliber. The mean times for the start and sprint to 12.5 yards were 4.16 seconds for the flat start, 4.25 seconds for the track start, and 4.37 seconds for the scoop start. No statistical analysis were performed on the data so it is unclear if these differences were significant. The second group consisted of 121 male and female swimmers between the ages of 10 and 17. The results of the second study showed that the flat and the track starts had similar times in sprinting to 10 yards and were faster than the scoop start with a sprint to 10 yards. Again, no statistical analysis of the differences were performed, so it is unclear if this difference was significant.

Stone (1988) used 26 highly competitive males in a study comparing the grab start and track start. The subjects were assigned to perform the track or grab start during the study. Each subject practiced the start 6 times per day for an 11 day period. Each subject performed three trials, which were filmed with a high speed camera. The results showed that the track start had a significantly faster block time and time to enter the water. The track start also had significantly faster times to the subjects' first and second swimming stroke. The grab start had a significantly greater horizontal flight distance and total distance to the first and second stroke. Stone (1988) concluded that the track start may be a faster starting technique than the grab start.

Juergens (1994) used 10 female swimmers who were proficient at both starting techniques, to measure the forces produced by the grab start and track start. Juergens (1994) found that the track start produced significantly larger forces for the average horizontal force, average vertical force, and vertical impulse. The results also showed that the subjects' center of gravity achieved the same horizontal flight distance with the grab start and track start, but the track start had a significantly faster time to this distance. Juergens (1994) concluded that the track start was the more effective start.

Types of Entry

The flat entry and the hole entry are the two entries commonly used in swimming. The flat entry has been called a misnomer by Counsilman et al. (1988). With the flat entry, the swimmer's hands enter the water in front of the head and body, giving the swimmer a slightly "flatter" entry than the hole entry. With the hole entry, the swimmer enters the

water at a steeper angle, allowing the swimmer's head and body to enter through the same hole as the hands.

These two entries have been compared in numerous studies with conflicting results (Counsilman et al., 1988; Kirner et al., 1989; Wilson & Marino, 1983; Zatsiorsky et al., 1979). Counsilman et al. (1988) found that the flat entry was faster than the hole entry to 12.5 yards when used with the grab start. Kirner et al. (1989) found the flat entry to be faster than the hole entry to 8 meters using both the grab start and the track start. In contrast, Wilson and Marino (1983) found the grab start with the hole entry significantly faster in time to 10.93 meters than the grab start with a flat entry. Zatsiorsky et al. (1979) found a low correlation ($r = .04$) between the angle of entry and time to 5.5 meters.

Force Measurements

Numerous studies have used strain gauges to measure different forces and reaction times produced during starts. Cavanagh, Palmgren, and Kerr (1975) described the construction of a strain gauge to measure the reaction forces produced by the hands on the starting block. Stevenson and Morehouse (1979) used this design to measure hand reaction forces with 0, 10, 20, and 30 degree block angles. The authors found that hand reaction forces decreased as the block angle increased. Stevenson and Morehouse concluded that the 20 degree block angle had the fastest block time and time to complete a 22.86 meter swim. Elliott and Sinclair (1971) used a force plate to measure the force time curve of three different block angles; 0, 10, and 15 degrees. Forty-two novice swimmers attended 14 training sessions to become proficient with the swimming start. Each subject

performed three starts at each block angle in a random order. Elliott and Sinclair concluded that there was no difference in the force time curves produced when using block angles of 0, 10, and 15 degrees.

Lewis (1980) used a Kistler force platform to compare reaction time and take off time in five variations of the grab start and conventional start. The results showed that although there was no significant difference in reaction time, the grab start had a faster take off time. Lewis (1980) also measured time to 8 meters using the various starts and found there was no significant difference between the starts to 8 meters.

Zatsiorsky et al. (1979) used a force plate to measure ground reaction forces for the conventional, grab, and track starts. The study consisted of two experiments with a total of 105 subjects. The results showed that even with different block times, the conventional and grab starts produced impulses that were not significantly different. The authors did not report any comparisons of the track start impulse to those of the conventional or grab start. The track start was significantly slower in time to 5.5 meters than the conventional and grab starts. Zatsiorsky et al. (1979) concluded that the conventional and grab starts were superior to the track start.

Summary

There have been numerous studies over the years comparing the different racing starts in swimming. Most of the literature and practitioners support the idea that the conventional start is too slow to be used in individual races. Unfortunately, the research has not been able to conclusively show whether the track or grab start is faster.

One area that needs to be researched is the difference in the components of the track and grab starts. Most research shows that the track start is faster in block time, but equal to or slower than the grab start in time to a set distance. One explanation that has been suggested, but not researched, is that the back leg in the track start is not able to produce as much force as the front leg due to the lack of a support to push against (Ayalon et al., 1975). This lack of force production would decrease the size of the impulse a swimmer produces, and therefore, decrease the speed of the start.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The experimental design for this research was modeled after numerous studies on swimming starts. One of the more challenging aspects of the study was securing the Bertec force plate to a starting platform. This required building a special platform specifically for this purpose. A pilot study was undertaken to determine the effectiveness of this platform, as well as to test the study's experimental design.

Pilot Study

To test the data collection methods, a pilot study was undertaken. One male and one female intercollegiate swimmer were used in the pilot study. Each subject performed five grab starts and five track starts. Each trial was videotaped and force data collected.

From the pilot study it was determined modifications were needed to ensure proper data collection. First, the force plate needed to be covered to prevent water damage. Initially, four layers of plastic were used to protect the plate. This surface was found to be too slick for the subjects' feet, therefore, one layer of a tackier plastic was used to cover the force plate during data collection. Second, a hand bar was placed at the front of the block to simulate holding the front edge of the block during a start. The final adjustment involved moving the starting platform to the deep end of the pool to ensure the subjects' safety.

Subject Selection

The subjects consisted of seven male and eight female Division III intercollegiate swimmers. This population was chosen because of the subjects' high skill level for either the grab start or the track start. Prior to the practice session, the subjects were given an explanation of the type of activity they were required to perform and any risks associated with their participation. At that time, the author answered any questions the subjects had concerning their involvement in the study. After answering questions, each participant signed an informed consent form in accordance with University policy (see Appendix A). All subjects were collegiate swimmers from two Midwest universities.

Practice Session

All subjects attended a one-hour practice session. During this session, the subjects performed a minimum of 15 grab starts and 15 track starts. The only feedback given to the subjects related to foot placement on the starting block. This information was given to those subjects with little experience using the track start. No other feedback was given due to the limits of skill acquisition in one practice session. If it was deemed necessary by the author, individual subjects were asked to perform additional practice starts.

Data Collection

A special starting platform was built to secure the force plate. A three-quarter-inch piece of oak plywood was secured to the top of a wooden frame at an angle of 5 degrees. This angle was chosen to fall within the guidelines of the NCAA, which require a block angle between 0 and 10 degrees (Brown, 1996). The Bertec force plate was secured to

the plywood base by four bolts, one in each corner of the plate. Once the force plate was secured to the base, the plate was covered with plastic to prevent water from damaging the circuitry during the trials. After the plate was covered with the plastic it was zeroed. This procedure prevented the plastic from skewing the collected data. The ground reaction forces for each start were collected during trials 10 through 14. Trials one through nine provided subjects with additional practice and adjustment to the starting surface and block design. The subjects were informed that data were collected for all trials to eliminate subject bias during the study. The force plate was triggered when the instruction "take your mark" was given.

The video camera, operating at a nominal rate of 30 frames per second, was set up approximately 40 feet from the middle of the force plate and perpendicular to the subjects' plane of motion. The video camera was started 5 seconds prior to the command "take your mark" was given, thus ensuring that the camera was operating at full speed. The flight distance (distance from the edge of the block to fingertip entry) was acquired by an observer marking the entry point of the finger tips into the water for each trial. A tape measure was secured to the side of the pool to obtain the distance. The same observer was used throughout all testing sessions to ensure consistency in measuring the flight distance.

At the beginning of the testing session, age, weight, height, number of years in competitive swimming, and preferred starting technique were recorded for each subject (see Table 1). After this information was obtained, each subject was allowed to perform a

Table 1. Subject Characteristics

Males (n = 7)		
	Mean	Standard Deviation
Age(years)	19.43	± 1.59
Height (inches)	73.14	± 2.80
Weight (lbs)	173.14	± 24.14
Year in School	1.86	± 0.99
Years of Competition	8.86	± 1.81
Females (n = 8)		
	Mean	Standard Deviation
Age (years)	18.38	± 0.48
Height (inches)	66.38	± 2.18
Weight (lbs)	140.88	± 16.37
Year in School	1.38	± 0.48
Years of Competition	7.50	± 2.60

warm-up, which included stretching and swimming. During testing, each subject completed 14 trials of each start. The subjects performed all 14 trials for one technique, then performed all 14 trials for the second technique. The order of techniques was reversed for each subject. Subjects were started using commands approved by the NCAA (Brown, 1996). An electronic beeper with a light flash was used for the starting signal. After each trial, subjects had a rest period of 1 to 2 minutes. Feedback concerning technique was not given to the subjects during the testing session.

Data Reduction

Kinematic data were obtained from the videotape analysis. Block time, flight time, and start time were calculated using a representative trial for each subject. This trial was

chosen by comparing the mean distance of trials 10 through 14 to each distance of trial 10 through 14. The trial with the closest distance to the mean was used for analysis. A Horita Time Code generator was attached to the VCR, allowing accurate measurement of the time variables. The time between each frame was .033 seconds. Block time was calculated by counting the number of frames from the start signal until the subject's feet left the starting platform. Flight time was calculated by counting the number of frames from the frame where the feet lost contact with the force plate until fingertip entry. The start time was the total time from the starting signal until fingertip entry.

The flight distance (distance from the edge of the block to fingertip entry) was measured by an observer, who marked the entry point of each dive. This point was then measured from the edge of the block with a tape measure. The same observer was used for all subjects and trials to ensure consistent measuring. The mean flight distance for each start technique was calculated using trials 10 through 14. The mean flight distance for each subject was normalized to a percentage of the subject's body height. This allowed for a more uniform measurement of flight distance.

Following the data collection, the kinetic information from trials 10 through 14 was obtained. The Bertec force plate sampled the ground reaction forces every 0.006 second. The resulting graphs for the anterior/posterior forces (F_y) and vertical forces (F_z) for each trial were printed. The medial/lateral forces (F_x) were not analyzed due to insignificant force production. A second printout, which listed the forces for each .006 second sample of each trial, was obtained. The force values were analyzed to find the first

peak force, the accommodation force, and the second peak force. The time between the peak forces was calculated by adding up the number of samples between each peak and multiplying by 0.006. The mean forces and mean time data were calculated from the last five trials of each start technique. The mean F_y and mean F_z forces for each subject were normalized to a percentage of the subject's body weight. This measure of force, relative to body weight allowed for a uniform measure of the forces produced during the starts.

The videotaped performances of two subjects performing both start techniques were digitized using the ARIEL Performance Analysis System (APAS). The most representative trial (as identified above) was chosen to obtain the angle data. Nine points on the right side of the body were digitized. These points included the toe, heel, ankle, knee, hip, shoulder, elbow, wrist, and head. The center of gravity (COG) was traced for both subjects performing both trials. It was found that the center of the shoulder traveled in a line parallel to the COG throughout the start. To obtain the angles for the remaining subjects, the center of the shoulder was traced using a Goldstar television monitor and a JVC videocassette recorder with stop action motion.

The take off angle (TOA) and entry angle (EA) were obtained by measuring the angle between the shoulder trajectory and a horizontal line. The edge of the pool, which was visible in all trials, was traced for the horizontal line. A hand-held goniometer was used to measure the angle between the shoulder tracing and the horizontal line. The angle of the body at fingertip entry into the water was also measured. To obtain body angle (BA), a line was drawn through the center of the shoulder and the greater trochanter. The

edge of the pool was again used as the horizontal reference and the angle was measured using a hand-held goniometer.

Data Analysis

To determine if there were statistical differences between the grab start and track start, a MANOVA was used with an alpha level of $p < .05$. The means and standard deviations for the time, distance, angle, and force variables were calculated and used for all analysis. Variables were analyzed according to preferred start, gender, and the interaction of preferred start and gender.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to compare five kinematic and two kinetic variables of the grab start and the track start. The results and discussion are divided into kinematic data and kinetic data sections. The kinematic variables that will be discussed are time, distance, take off angle, entry angle, and body angle at fingertip entry. The kinetic variables include the ground reaction forces in the anterior/posterior (F_y) direction and in the vertical (F_z) direction.

A chi-square statistical analysis was performed to determine if there was a statistical difference in preferred starting technique between males and females. The results showed that there was no statistical difference ($p < .05$) between preferred technique and gender.

Kinematic Data

Time

A Horita Time Code Generator was attached to the VCR allowing for accurate measurement of the time variables. The time between each frame was .033 seconds. The time for each start was divided into three variables: block time, flight time, and start time. Block time was the amount of time between the start signal and when the subjects' feet lost contact with the force plate. Flight time was the time from when the subjects' lost

contact with the force plate until fingertip entry. Start time was the combination of block time and flight time.

Both the male and female subjects had similar mean block, flight, and start times across the two starting styles. For males, the mean start time for the grab start was 1.19 seconds (± 0.06 sec), while the mean start time for the track start was 1.18 seconds (± 0.08 sec). The block time for the males using the grab start was slightly slower (.01 sec) than the track start, but this difference was not significant and was offset by a shorter flight time for the track start. The female subjects had similar results, with a mean start time for the grab start of 1.19 seconds (± 0.05 sec) and a mean start time of 1.17 seconds (± 0.06 sec) for the track start. Both the block time and flight time were faster for the track start, however, none of these differences were statistically significant (see Table 2).

A MANOVA was used to calculate the interaction of gender and preferred starting style with block time, flight time, and start time for both starts (see Table 2). Males who preferred the track start had a significantly ($p < .05$) faster start time for the grab start than males who preferred the grab start. No other significant differences were found for any time variables when compared to gender and preferred starting technique.

Table 2. Start Time Data for the Grab Start and Track Start

Males		
	Prefer Grab Start	Prefer Track Start
Grab	1.22 sec. \pm 0.05	1.14 sec. \pm 0.03*
Track	1.22 sec. \pm 0.06	1.12 sec. \pm 0.05
Females		
	Prefer Grab Start	Prefer Track Start
Grab	1.22 sec. \pm 0.05	1.21 sec. \pm 0.02
Track	1.22 sec. \pm 0.07	1.20 sec. \pm 0.04

* significant difference ($p < .05$)

The results of block time and flight time for the track start are opposite to what other researchers have reported. Ayalon and colleagues (1975), Juergens (1994), Kirner et al. (1989), and Shin and Groppe (1986) all found the track start to have a faster block time and flight time when compared to the grab start. The faster block time and flight time for the track start has often been attributed to the lower COG of the swimmer on the starting block. The lower COG allows the swimmer to leave the block faster (Ayalon et al., 1975). Three of the studies (Ayalon, 1975; Kirner et al., 1989; Shin & Groppe, 1986) used high speed filming to record time data. Frame rates ranged from 50 frames per second (fps) to 80 fps. Having a higher frame rate allowed for more accurate measures of each variable and may account for some of the differences found between these studies and the present study.

Miller, Hay, and Wilson (1984) found that between male and female subjects, males had a significantly longer flight time. The authors attributed this to the higher mean height of the male subjects. The present study found no significant difference between male and female subjects start time.

Flight Distance

Mean flight distances were calculated from the flight distances of the last five trials of each start. Both the male and female subjects had a longer average flight distance from the grab start than from the track start. The mean flight distance for the grab start was 3.58 meters ($\pm .29$ meters) for males and 3.05 meters ($\pm .16$ meters) for females. These values were normalized to the subjects' height. Male subjects achieved an average flight distance equivalent to 193% of their body height, while females achieved an average flight distance equivalent to 181% of their body height (see Table 3). The mean flight distance for the track start for males was 3.35 meters ($\pm .28$ meters) whereas females had an average flight distance of 2.87 meters ($\pm .13$ meters). When normalized for height, males had a mean flight distance equivalent to 180% of body height and females had a mean flight distance equivalent to 171% of body height.

Table 3. Normalized Distance Values (Percentage of Body Height)

	Prefer Grab	Prefer Track	F value
Grab Flight Dis	195% \pm 11.5	177% \pm 11.3	.012*
Track Flight Dis	182% \pm 10.7	167% \pm 10.6	.023*
	Males	Females	F value
Grab Flight Dis	193% \pm 14.0	181% \pm 12.0	.122
Track Flight Dis	180% \pm 14.0	171% \pm 10.0	.175

* Significant difference ($p < .05$)

No significant differences were found between the flight distances achieved by males and females. The larger distances for the male subjects might be attributed to males having a larger muscle mass, which can be used for greater force production. The female subjects had a mean increase in flight distance of 10% from the track start to the grab start, while the male subjects had a mean increase in flight distance of 13% from the track start to the grab start. This increased flight distance for the grab start might be attributed to the additional force produced from both legs pushing against the block simultaneously.

A MANOVA was used to determine if there was a significant difference between the mean flight distance of the track start and the grab start using preferred start and gender. There was no significant difference between the flight distance of the grab and track start when both gender and preferred start were factored in. There was a significant difference ($p < .05$) between flight distance when compared with the preferred starting

technique. Subjects who preferred the track start and those who preferred the grab start had significantly longer flight distances for the grab start than the track start. Subjects who preferred the grab start achieved a flight distance for the grab start that was 13.1% larger than the track start. Subjects who preferred the track start achieved an increased flight distance of 9.6% for the grab start. These significantly longer flight distances support the hypothesis that the grab start is a superior starting technique.

It was hypothesized that each preferred start group would perform better with their respective start. An interesting finding was that this hypothesis was incorrect. Subjects who preferred the grab start had larger values for flight distance with both the grab start and the track start. The subjects who preferred the grab start achieved an 18.0% increased flight distance for the grab start and a 14.5% increase in flight distance for the track start over subjects that preferred the track start.

Take Off Angle, Entry Angle, and Body Angle

The videotaped performances of two subjects performing both start techniques were digitized using the ARIEL Performance Analysis System (APAS) to obtain the take off angle (TOA), entry angle (EA) and body angle (BA). The COG was traced for each subject performing one trial of each start. It was noted that the center of the shoulder traveled in a line parallel to the COG throughout the start, and therefore, the shoulder trajectory was used to measure all angle variables.

Female subjects had higher mean angle values for EA and BA of the grab start and the TOA, EA, and BA of the track start when compared to the male subjects

(see Table 4). Male subjects did have a greater TOA for the grab start. Female subjects had higher mean values for the TOA, EA, and BA with the track start when compared to the grab start. For males, the mean TOA of the grab start (6.57 ± 4.34) was larger than the mean TOA of the track start (6.43 ± 3.16). All angles were tested for significant differences using a MANOVA with gender and preferred start as covariates. No significant differences were found between the angles for both start techniques.

Table 4. Starting Angles (In Degrees)

	Males	Females	F value
Grab Start			
TOA	6.57 ± 4.34	5.88 ± 2.67	.176
EA	37.71 ± 3.81	41.38 ± 5.19	.803
BA	29.57 ± 6.59	35.50 ± 4.09	.842
Track Start			
TOA	6.43 ± 3.16	7.63 ± 3.12	.206
EA	39.43 ± 1.99	43.75 ± 4.49	.681
BA	32.14 ± 3.80	36.63 ± 5.10	.669

TOA - Take Off Angle EA = Entry Angle BA = Body Angle

Kinetic Data

Fz Forces

The ground reaction forces were collected from the last five trials of the grab start and the track start. The force time curves in the vertical direction (Fz) were similar for each starting technique. This pattern was similar to the pattern found by Juergens (1994). The force time curve had two peak forces and an accommodating force.

To discern where each Fz peak occurred in the starting motion, the time element of each curve was compared to the video of each subject. It was found that the first Fz peak (Fz1) corresponded to the subject initiating the starting motion by pulling on the front of the block. During this time, the subject's shoulders were lowered toward the block and the subject's COG began to move forward. As the subject continued to move forward, the Fz forces decreased. As the Fz forces reached the accommodating force (AFz), the upper body began to extend and the angle between the thigh and the torso increased through hip extension. There was also a corresponding increase in knee flexion and ankle dorsiflexion, which was necessary to move the subject into a position to drive the legs back against the block. The increasing knee flexion and ankle dorsiflexion was the reason of the decrease in forces during AFz. During this same phase of the start, the subject began to drive the arms forward and away from the block, while the head extended from a tucked position. As the Fz forces increased, the subject began driving back against the block by continuing hip extension and initiating knee extension. The arms continued to swing forward until reaching a position in front of the head and shoulders. At the second Fz peak (Fz2), the subject was completing hip and knee extension and continued plantar flexion with the ankle until contact with the block was lost.

All Fz ground reaction forces were normalized to the subject's body weight (see Table 5). The Fz1 and Fz2 were larger for the grab start for both males and females. With the grab start, females produced 8.6% more force during Fz1 and 18.0% more force during Fz2 than with the track start. Males had an even larger difference producing 12.6%

more force during Fz1 and 29.1% more force during Fz2 using the grab start. The AFz forces for the track start were larger for both males and females. Females had an increased force production of 23.2% during AFz using the track start, while males had an 18% increase in force production during AFz using the track start.

Table 5. Fz Forces for the Grab Start and Track Start

	Grab	Track
Males		
Fz1	216.1% ± 22.9	203.5% ± 17.1
AFz	74.4% ± 29.1	92.4% ± 35.3
Fz2	157.2% ± 24.7	128.1% ± 28.4
Females		
Fz1	205.4% ± 27.7	196.8% ± 25.4
AFz	74.1% ± 16.2	97.3% ± 29.0
Fz2	151.8% ± 26.5	133.8% ± 22.0

Fz1 = First peak force AFz = Accommodating force Fz2 = Second Peak Force

A MANOVA was used to calculate significant differences between the Fz reaction forces and gender and preferred start technique. No significant difference ($p < .05$) was found between the forces using gender and preferred start. A significant difference ($p < .05$) was found with the track start AFz force and the preferred start. Subjects that preferred the track start had a significantly increased force production (17.2%) during AFz. This difference is most likely due to the motor control of the starting techniques.

Subjects with experience using the track start would know how to maximize force production throughout the track start. Therefore, track starters may have produced more force with their back leg during the AFz, than the grab starters, who had little experience with the track start. This higher force production in the vertical direction may also account for the higher TOA of the female subjects using the track start.

Fy Forces

The anterior/posterior (Fy) forces had a similar force time curve to the Fz forces, although some subjects did have more than two peaks. The first peak Fy (Fy1) occurred slightly after Fz1 occurred. Fz1 corresponded to the subjects pulling against the block and initiating the COG movement. Fy1 corresponded to the hands releasing the front of the block in both starts. The Fy accommodation force (AFy) occurred while there was an increase in knee flexion and dorsiflexion. This allowed the subject to assume a position to drive off the blocks. During AFy the upper body continued to extend increasing the angle between the thigh and the torso. The second peak Fy (Fy2) was the largest Fy produced and corresponded to the hips and knees extending and the ankles plantar flexing against the block.

For the track start, Fy2 was found to correspond to one of two events, which varied from subject to subject. With some subjects, the knee and the hip had finished extending and the foot had lost contact with the block during AFy. This meant that Fy2 was produced only by the front leg of the subject. Other subjects continued to maintain contact between the back leg and the block until the front leg was almost completely

extended. This meant that Fy2 had front and back leg components. The amount of force produced by the back leg during Fy2 was probably limited because the knee and ankle were almost completely extended by the start of Fy2.

The results for the Fy (anterior/posterior) forces are presented in Table 6. Both male and female subjects had larger values for Fy1 when using the track start. Females produced a 6.7% larger Fy1 and males produced a 3.4% larger Fy1 using the track start. Females also produced more force during AFy using the track start ($34.2\% \pm .5$) than the grab start ($30.7\% \pm 9.3$). Males had a similar AFy for both the track start ($42.3\% \pm 7.9$) and the grab start ($43.3\% \pm 10.8$). Both males and females had a much larger force production for Fy2 using the grab start. Females had a 33.2% larger force production for Fy2 and males had a 29.8% larger force production for Fy2 when using the grab start. This increased force production in the Fy2 forces of the grab start may account for the greater flight distances that occurred with the grab start.

Table 6. Fy Forces for the Grab Start and Track Start

	Fy1	AFy	Fy2
Females			
Grab Start	$43.5\% \pm 10.6$	$30.7\% \pm 9.3$	$102.6\% \pm 17.0$
Track Start	$50.2\% \pm 10.2$	$34.2\% \pm 5.5$	$69.4\% \pm 11.0$
Males			
Grab Start	$55.3\% \pm 7.7$	$43.3\% \pm 10.8$	$109.8\% \pm 7.9$
Track Start	$58.7\% \pm 6.7$	$42.3\% \pm 7.9$	$80.0\% \pm 9.7$

PY1 = First Peak Force AFy = Accommodation Force PY2 = Second Peak Force

A MANOVA was used to discern significant differences between the Fy ground reaction forces. Gender and preferred start were used as covariates for the MANOVA. No significant differences were found between the Fy forces when comparing gender and preferred start. Significant differences ($p < .05$) were found between the grab start Fy1 and the track start AFy using gender. Male subjects had an 11.8% larger force production for Fy1 than females. Males also had an 8.1% larger force production for the track start AFy than female subjects. These differences were expected due to the male subjects' ability to produce more force throughout the start.

The amount of time between the peak forces of Fy and Fz was calculated to determine if there was a significant difference between the time element of each start. An important consideration in the timing of the start is the incorporation of the stretch reflex. If the time between peak force productions is too long there would be a decreased response in the stretch reflex, which would decrease the efficiency of the start. A MANOVA was performed to calculate any significant differences between the peak time elements. No significant differences were found between the amount of time between the peak force productions for either start.

Discussion

In comparing the grab start and track start, the present study did not find a dominant starting style. The results of the present study show a similar block time for the grab start, as found by Juergens (1994) and Stone (1988). In contrast, mean block time for the track start was slower than the block time for the track start found by Juergens

(1994) and Stone (1988). Stone (1988) concluded that the track start was better than the grab start because of the faster block time of the track start. One possible explanation for the present study's results was the data were collected at the beginning of the competitive season. With additional practice during the season, the subjects may have mastered both start techniques. According to Maglischo (1993), the less a swimmer needs to focus on how to perform a start, the quicker his or her reaction time would be. Therefore, with additional practice, the subjects may have mastered both starting skills and possibly decreased their individual response times for one or both of the starts.

Other studies have measured time to a set distance. The first study comparing the track start and grab start found that the grab start was significantly faster than the track start in time to 5 meters (Ayalon et al., 1975). Counsilman and colleagues (1988) found that the grab start was faster than the track start in a sprint swim to 12.5 yards. Zatsiorsky and colleagues (1979) also found the grab start was faster than the track start in a glide to 5.5 meters. In contrast to these studies, Kirner et al. (1989) and Shin and Groppe (1986) found no significant difference in time between the grab start and the track start. No studies reviewed found the track start to have a significantly faster time to a set distance from the block.

The results of the present study show a significantly larger flight distance for the grab start than for the track start. These results are supported by other studies. Stone (1988) found that the grab start had a significantly larger horizontal flight distance than the track start. Shin and Groppe (1986) also found the grab start to have a significantly larger

flight distance than the track start. In contrast to these studies, Juergens (1995) found that the subjects' COG achieved a greater distance with the track start than with the grab start, although the difference was not statistically different.

An interesting finding was that the subjects who preferred the grab start had longer flight distances for both the grab start and the track start. This difference is hard to explain. Logic would suggest that each preferred start group would perform their particular starting technique the best. These results show that, in relation to flight distance, the subjects that preferred the grab start, outperformed the track start group. A MANOVA was performed to try and locate any significant differences within the preferred start groups between height, weight, year in school, and the number of years in competitive swimming. It was thought that one of these variables may have had a confounding effect on preferred start and flight distance. No significant differences were found for any of the variables. One possible explanation is that the grab start group was in better physical condition during the testing sessions.

No significant difference was found between the TOA, EA, or BA of the two starts. The research has shown a wide range of results and recommendations for the proper take off angle and entry angle. Groves and Roberts (1972) and Stone (1988) reported that the optimum angle for the start was between 8 and 13 degrees down from the horizontal. Groves and Roberts concluded that a 13 degree angle is optimal, but any angle down from the horizontal is better than any angle above the horizontal. The present study found higher values for the take off angle of each start than did the other studies.

These angles were similar across the two starting techniques and similar between males and females.

The entry angle of the swimmer has also had a variety of recommendations for the optimum angle. Counsilman and colleagues (1988) found that the grab start was much faster in time with a sprint swim to 12.5 yards using the flat entry versus the hole entry. Kirner et al. (1989) also found the flat entry was superior to the hole entry when using both the grab and track starts. Kirner et al. (1989) also recommended the use of the flat entry due to the possibility of swimmers hitting their head on the bottom of the pool with the hole entry. Wilson and Marino (1983) found that with the grab start, the hole entry was better than the flat entry. The present study found that the majority of subjects had a large entry angle and body angle, indicating they used the hole entry. Subject 2 was the only subject that used the flat entry on both the track start and grab start. Subject 7 used the flat entry on the grab start and the hole entry on the track start. The fact that the majority of the subjects used the hole entry probably reflects the belief of practitioners that the hole entry is superior to the flat entry.

The force time curves obtained during this study were similar to the force time curves reported by other researchers (Juergens, 1994; Zatsiorsky et al., 1979). Juergens (1994) reported that the track start had a significantly greater vertical impulse as well as significantly higher average horizontal and vertical forces when compared to the grab start. The current study's evaluation was limited to analyzing the peak forces produced by each start technique.

In comparing the forces of the track start and grab start, the larger Fz1 force found for the grab start during the study may have been caused by the subjects' forward position on the block and the small base of support. When the grab start was initiated, the force would have primarily been in the vertical direction. With the track start, the subjects had a larger base of support so the initiation forces may have been distributed more between the vertical and anterior/posterior directions. The larger AFz force during the track start may be caused by the subjects continuing to extend the knee and hip of the back leg during the AFz time period, thereby increasing force production. The larger force produced by the grab start during Fz2 is easily explained. With the track start, subjects' back foot lost contact with the block before Fz2. Using only the front leg to drive against the block the force produced was much smaller. In contrast, during the Fz2 of the grab start, the subject drove against the block with both legs, producing a much larger force.

The Fy results also correspond well to the video taped trials. The higher values for the track start Fy1 forces corresponds to the back leg's ability to produce a horizontal force earlier in the starting sequence. In comparison with the grab start, the legs are not in a position during Fy1 to produce a significant horizontal force. During the AFy, female subjects had a slightly higher value for the track start than the grab start. In contrast, males had a slightly higher value for the AFy of the grab start. During this period the subjects were moving forward and preparing for the final push off the blocks. During Fy2, there was a large increase in Fy force production for both starting techniques. The grab start had much larger mean force values for Fy2. Again, this is due to the fact that with the grab start subjects were able to push with both legs at the same time.

Summary

The purpose of this study was to compare the grab start and track start. The results of the study show that there were few significant differences between the two techniques. The most important significant difference was found in the grab start's increased flight distance. Since the grab start achieved a significantly longer flight distance in the same amount of time as the track start, it is a strong indication that the grab start is a superior starting technique for collegiate swimmers.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to compare kinetic and kinematic variables between the grab start and track start. Numerous studies have evaluated and compared the track start and grab start with mixed results (Ayalon et al., 1975; Counsilman et al., 1988; Kirner et al., 1989; Juergens, 1994; Shin & Groppe, 1986; Stone, 1988; Zatsiorsky et al, 1979). The intent of this study was to enhance the knowledge base for start techniques and possibly recommend a superior starting style.

Fifteen collegiate swimmers, eight females and seven males, volunteered to be subjects. Subjects completed 14 trials of each starting technique. Each trial was videotaped and the flight distance was measured. During trials 10 through 14, the ground reaction forces were measured. The video tape recordings supplied information to calculate take off angle, entry angle, body angle, block time, flight time, and start time. The force plate data included the ground reaction forces in the anterior/posterior (F_y) and vertical (F_z) directions. These data were entered into a MANOVA statistical analysis to locate significant differences.

Significant differences were found between the preferred starting technique and flight distance. Both the subjects who preferred the grab start and subjects who preferred

the track start had a significantly longer flight distance when using the grab start. This flight distance was achieved without a significant difference in the time elements of each start.

In the starting time for the grab start there was a significant difference found between gender and preferred start. Males who preferred the track start had a significantly faster start time compared to male subjects who preferred the grab start. In contrast, males who preferred the grab start had longer flight distances (although not significant), which may be attributed to their longer contact with the starting block. In addition, subjects who preferred the grab start had a longer flight distance for both the grab start and the track start trials. This difference was not explained when compared with the mean height, weight, year in school, and number of years in competitive swimming. There were also significant differences between the genders with the Fy1 grab start force and the AFy track start force. These differences were likely due to the male subjects' ability to generate more force during the start. These results indicate that the grab start is a superior starting technique when used by collegiate swimmers.

Conclusions

Psychological and biomechanical advantages result from a swimmer leading after the start in swimming. Results from the current study show that a swimmer will have a more effective start by using the grab start. This advantage is gained by having a longer flight distance than the track start with a similar starting time. Because of the lack of significant differences in the force time curves of the track start and the grab start it is

difficult to discern how the advantage is gained by using the grab start. None of the significantly different variables would seem to positively affect the performance of the grab start directly.

This study's results concur with previous studies that have shown the grab start to be superior to the track start (Ayalon et al., 1975; Counsilman et al., 1988; Zatsiorsky et al., 1979), however, some studies have shown there is no difference between the grab start and the track start (Kirner et al., 1989; Shin & Groppe, 1986), while other studies show the track start to be superior (Juergens, 1994; Stone, 1988). As a result of these conflicting results, it is difficult to discern which start is superior. It may be possible that individual differences are what make a specific start superior for each swimmer.

Recommendations

1. Since this study was completed at the beginning of the competitive swimming season, it is recommend that a study be undertaken in the middle or immediately after the conclusion of the season. This may eliminate poor performances due to a lack of practice and/or a subject's poor physical conditioning.
2. This study used only one practice session to acquaint the subjects with the two starting techniques. It would be beneficial to have numerous practice sessions over a period of a few weeks or months. This would optimize the subjects' learning of each technique, therefore allowing more meaningful results.

3. To increase the variety of people the results could be projected to, it is recommended that a study be undertaken using swimmers of diversified ages and with a variety of skill levels. The current study used subjects who competed at the Division III college level. Younger swimmers, however, may find more success with the track start due to its wider base of support.
4. Another variable that could be manipulated would be the angle of the block. This study used a block angle of 5 degrees, which is the mean of the 0 to 10 degree recommendation of the NCAA (Brown, 1996). Different facilities have different angles for the starting blocks and it would be useful to know if a start technique was superior with a specific start block angle.
5. A 3-dimensional study should be undertaken to measure all angles of motion during the start. There may be motions that were unidentified using a 2-dimensional model, that would influence the effectiveness of the starting techniques.
6. This study used videotaping to record each trial. It is recommended that high speed filming or videotaping be used to allow for more accurate measure of the kinematic variables.

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APPENDIX A

INFORMED CONSENT FORM

INFORMED CONSENT FORM

University of Wisconsin - La Crosse
La Crosse, WI 54601

Project Title: Kinetic and Kinematic Comparison of the Grab and Track Start in Swimming.

Principal Investigators: David Allen and Dr. Marilyn Miller

I _____ give my consent to participate in this study comparing the grab start and track start in swimming. I consent to publication of the study results so long as the information is anonymous and disguised so that no identification can be made.

1. The purpose of this study is to compare the forces that are produced by the grab start and track start. The data collected will be used to compare the effectiveness of each starting technique. I understand that I will be required to attend one, one-hour practice session. During this practice session I will be expected to perform at least 20 grab starts and 20 track starts. I understand that I may be asked to perform more practice trials if it is deemed necessary by the supervising investigator.

I understand that during the testing session I will be performing 15 grab starts and 15 track starts. The starting surface will consist of a force plate that is mounted on a wooden platform. This starting surface will have some variation from a starting block surface, but this should not affect my starting technique. I understand that a force plate will be used to measure the reaction forces that are produced during each trial and that each trial will be videotaped.

2. As with any physical activity some demands will be placed on the body, and there is a possibility of injury. I understand this risk will be similar to the risk I assume while executing swimming starts in practice and competition. I understand there will be short rest periods in the practice and testing sessions, but that I may experience some discomfort.

3. I have been informed that the results from the study will be useful for the general swimming community with the information which is collected. I also understand that I may request the results of my performance, which may benefit me in performing swimming starts.

4. I understand the procedures that will be followed are based on scientific guidelines and are similar to procedures that have been used by researchers in similar studies. I understand that there is a potential risk in any study that is undertaken and that the outlined procedures have been developed to minimize this potential risk.
5. To ensure confidentiality, I understand the Principal Investigator will assign a subject number for all data that is collected from my performance. I understand that this list of subjects and their numbers will be maintained by the Principal Investigator and will be unavailable to any other person. All data that is reported will be anonymous and will not reference the names or numbers of the subjects. I understand that I may obtain my individual results upon my request to the Principal Investigator and that no other person will have access to this information.
6. Any questions I may have throughout the study may be directed to:
- David Allen - Principal Investigator/Graduate Student
S.M.U. #1469 700 Terrace Heights Winona, MN 55987
507-457-7296
- or
- Dr. Marilyn Miller - Faculty Research Advisor
149 Mitchell Hall
608-785-6527
7. I understand that my participation in this study is voluntary and that I may withdraw from the study at any time without penalty.

 Subject

 Date

 Witness

 Date