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## Factors Affecting Block Performance From The Omega OSB11 Starting Platform

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Graduate Program in Kinesiology  
A thesis submitted in partial fulfillment of the requirements for the degree in Doctor of Philosophy  
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FACTORS AFFECTING BLOCK PERFORMANCE FROM  
THE OMEGA<sup>®</sup> OSB11 STARTING PLATFORM

(Thesis format: Integrated Article)

By

Andrew J. Dragunas

Graduate Program in Kinesiology

A thesis submitted in partial fulfilment  
of the requirements for the degree of  
Doctor of Philosophy

The School of Graduate and Postdoctoral Studies  
The University of Western Ontario  
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## **Abstract**

In 2009, the international governing body of swimming approved the use of the Omega OSB11 platform. It features a back foot kick plate that can be shifted into five positions. The purpose of this thesis is to identify set stance characteristics of the track start that may produce a faster start from the OSB11. The first project evaluated: optimal kick plate location, its relationship to segment lengths, and rear foot position as high and low on the kick plate. The swimmers demonstrated significantly greater horizontal take-off velocity and decreased time to 2 m with the rear foot in the high position. However, no moderate or strong relationships were detected between optimal kick plate location and segment lengths. The second study examined the power limb position. The swimmers were tested for limb power using the single-leg triple hop for distance. They had a significantly greater horizontal take-off velocity when the power limb was placed at the front edge of the platform in the track start. The third study examined optimal, rear- and front-weighted center of mass (COM) location in the set stance. The rear-weighted start had a significantly greater horizontal take-off velocity and reaction time than the front-weighted. However, front-weighted track starts showed a significantly shorter block time than in the rear-weighted position. Most swimmers in the group demonstrated optimal performance when the COM locations were in a mid-weighted stance. The final project compared: coached and kinetic feedback (round 1), and the two forms of feedback in different orders (round 2) on 2 m time performance. After the first round, the kinetic group showed a significant increase in time but no significant change was found in the coached group. After the second round, there were no significant differences between groups. However, each group demonstrated a significant increase in time from the pre-test. Overall the thesis

suggests that changes in start stance can impact performance. In addition, optimal positioning may also be unique to each swimmer which requires testing, and feedback and practice should be routine. The findings of this thesis support the need for future work to establish methods of determining optimal start positions for individual swimmers.

**Key words:** swimming, starts, Omega, OSB11, body position, center of mass, limb power, kick plate, foot position, feedback, force plate, horizontal take-off velocity, start time

## Co-Authorship

The following people have contributed to one of more pieces of work which make up the current body of work. Their contributions are outlined below in more detail along with an attestation of the accuracy of the statements by the supervisor.

### **Dr. Jim Dickey**

- the design and construction of the replica starting platform
- initial programming of LabVIEW™ software for data analysis
- contributed to writing and editing of manuscripts

### **Joseph Bartoch**

- the design and construction of the replica starting platform.
- data collection of the first project
- contributed to the writing and editing of the Chapter three manuscript

### **Ryan Frayne**

- assistance with editing and statistical methods
- design and data collections

I, **Dr. Jim Dickey**, attest to the accuracy of these statements of co-authorship.

---

Dr. Jim Dickey  
Associate Professor & Project supervisor

## **Dedication**

*To my wife for her years of patience, understanding, and love.*

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## List of Abbreviations, Symbols, and Nomenclature

2MT	-	2 m Time
BT	-	Block Time
COM	-	Center of Mass
COM <sub>yi</sub>	-	Initial Center Of Mass location in the anterior-posterior direction
COM <sub>yo</sub>	-	Final Center of Mass location in the anterior-posterior direction
COP	-	Center of Pressure
COP <sub>y</sub>	-	Center of Pressure in the anterior-posterior direction
PLF	-	Power limb on Front
PLR	-	Power limb on Rear
dt	-	Delta time / change in time
t <sub>i</sub>	-	Initial time
t <sub>o</sub>	-	Final time
F <sub>y</sub>	-	Force in the anterior-posterior direction
F <sub>z</sub>	-	Force in the vertical direction
m	-	Mass
RT	-	Reaction Time
SD	-	Standard deviation
TOV	-	Take-Off Velocity
v <sub>y</sub>	-	Horizontal velocity

## Chapter 1. Introduction

### Background

The start phase in swimming is an important part of any swimming performance. The start phase which is measured to the 15 m mark can make up as much as 30% of a swimming race. Maglischo (2003) states that a swimmer can make gains of hundredths, even tenths of a second from an improved swim start performance. Gains of this magnitude could make the difference between first and second place, or making a final or not.

Previous studies examined various aspects of the set position to identify factors for optimal performance. One well researched aspect is the comparison between the track and grab start (Juergens, 1994; Breed et al., 2000; Kirner et al., 1989; Jorgic et al., 2010). Others have examined different widths of the stance in the track start (Holthe & McLean, 2001) and footedness as it applies to the track start (Hardt et al., 2009). Researchers have also examined different weighted track starts in females (Welcher et al., 2008). Although, the abovementioned studies shed light on factors in set position that may affect swim start performance, they were all performed on a traditional platform model.

In 2009, a new starting platform was approved for use in competition by the world swimming governing body (FINA) (Omega Watches, 2008). The Omega OSB11 made its Olympic debut at the 2012 games in London, England and has become the standard at national and international competitions. The main platform is angled at nine degrees from horizontal, however, the unique feature of this model is the kick plate located on the posterior portion of the block. The face of the kick plate is angled at 30 degrees to the

main platform and can be shifted to five different positions that span 0.2 m (Honda et al., 2010).

Although relatively new to the swimming community, some studies examining factors of the set position on the OSB11 have been published. A few projects have compared the track versus grab start using the OSB11 (Biel et al., 2010; Murrell & Dragunas, 2012).

While others have compared track starts from the traditional platform to those performed from the OSB11 both with and without the kick plate (Beretic et al., 2012; Nomura et al., 2010; Petryaev, 2010). In both types of studies, there was a consensus that start performance from the OSB11 platform was better using the track start and faster than from the traditional model.

The addition of the kick plate offers more variation in swim start technique and a new area of swimming research. At this juncture, there are several trends in swim start research using the OSB11: *(i)* the track start should be the technique of choice, *(ii)* the kick plate seems to improve swim start performance, and *(iii)* body position in the set position can significantly affect swim start performance. However, there are many areas of swim start performance from the OSB11 that need to be explored. For example, the optimal kick plate location, dominant limb placement, and foot position on the kick plate in the start stance need further investigation. We intend to investigate these and other factors of the set position that have not previously been explored.

### **Scope**

Elements of the set position were examined in three projects using varsity, junior national, or senior national team members. A fourth project was performed to evaluate



the use of feedback in a short session which may be typical of those given in a camp or practice session. The second chapter reviews current literature regarding factors of set position from both traditional and OSB11 platforms. Chapters three, four, and five examine factors of the set position: location of the kick plate and rear foot placement, location of the dominant limb, and front- and rear-weighted starts, respectively. In Chapter three, high and low foot positions on the kick plate were compared as well as the optimal location of the kick plate. Chapter four compared the power limb at the front edge versus placing it on the kick plate while Chapter five evaluates center of pressure location and each swimmers' optimal position. The final project, Chapter six, compared two forms of feedback in a crossover design. Lastly, the general discussion is presented in Chapter seven followed by two appendices. Appendix A describes the ranking system used to identify the optimal location of the kick plate and center of mass while Appendix B provides details of the OSB replica used for testing.

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## Chapter 2. Review of Literature

In 2009, the Omega OSB11 platform was approved for use by the world swimming governing body (FINA) (Omega Watches, 2008). A new feature of this platform is the kick plate located on the rear portion of the block that can be shifted to five different positions over a span of 0.2 m (Honda et al., 2010). The addition of the kick plate enables variation in swim start technique not seen before in the sport and new directions for swim start research. Since this platform has become the standard at all major swimming events, it is imperative to gain a better understanding of how swimmers can optimize performance when diving from it.

### **The kick plate**

Swim start research has explored the contribution of the kick plate by comparing track starts on the OSB11 platform with a kick plate to traditional platform starts without a kick plate. For example, Biel et al. (2010) found that swimmers were 0.2 s faster to 7.5 m, and had shorter block times and increased horizontal take-off velocity from the OSB11 than the traditional block when performing the track start. However, details of their methodologies and results were excluded since this study was reported as a conference proceeding. Another group had similar findings when comparing the track start on a platform with a kick plate and one without (Beretic et al., 2012). They found that when swimmers performed starts using the kick plate, they had increased rear knee flexion by  $11^{\circ}$  (less extended), a greater average flight velocity, and were 0.03 s faster in reaction time and 0.15 s faster to 10 m. Although giving some validation to Biel et al. (2010) and having similar methodologies, Beretic et al. (2012) did not use the OSB platform. Their platform was steeper than the OSB11 which may influence start performance, and the

kick plate was set at 0.44 m, which is not relevant to the kick plate on the OSB11. These factors make the comparison between studies difficult. Similarly, Nomura et al. (2010) evaluated swim starts from a traditional start platform and with a supplementary track and field start pedal to evaluate the influence of the kick plate. They assessed the kinematics of the start performance and noted that when the swimmers were using the kick plate, the rear knee flexion was increased by 13° (less extended) and center of mass was 0.05 m closer to the front edge. Unfortunately, this study did not measure key variables of start performances such as reaction time, block time, horizontal take-off velocity, and time to 5 m which makes their results difficult to evaluate. Unlike Beretic et al. (2012), it appears that they did not utilize an OSB11 platform for this project, but similar to Biel et al. (2010) the results were only reported in a conference proceeding which may exclude key information. Petryaev (2010) also examined start performance from blocks with and without the kick plate. He filmed races from two major international competitions: a 2009 world cup competition (Moscow) and the 2009 European swimming championship in Istanbul. In Moscow, the traditional start platform was used and the new OSB11 was used in Istanbul. Although their findings were collected at different meets, the researchers noticed that when the same swimmers started from the OSB11 the start times to 15 m were significantly faster than when they started from the traditional start platform. However, these researchers were not able to control for several important variables such as shaving, recovery, and training status between competitions.

Unfortunately, these studies are difficult to interpret and compare since three of the four mentioned projects (Biel et al., 2010; Nomura et al., 2010; Petryaev, 2010) were published as conference proceedings. This drastically reduces the ability to critique

methods and results of each piece of work effectively since key details may be omitted due to space requirements. However, each of these studies evaluated kinematic data and it appears that the traditional and OSB11 block comparison has not been performed using kinetics. Using kinetics via load cells in the start platform is important as we could gain a better understanding of the forces applied by both feet combined and individually. In addition these studies all reported a time over a set distance of 7.5 m, 10 m, or 15 m. Although these outcome measures are important for overall swim race performance, they are not specific to the swim start (Tor et al., 2014).

There are several trends in these studies comparing start performance from a traditional platform to that with the kick plate. The findings agree that when swimmers use the kick plate they have an increased take-off velocity (Biel et al., 2010; Beretic et al., 2012; Nomura et al., 2010). In most of the above mentioned projects, the swimmers also had significantly faster times to distances of 7.5 m, 10 m, and 15 m when they used the kick plate. The increased take-off velocity with decreased block times is of particular interest. Time is a factor when calculating take-off velocity using the impulse-momentum relationship. Impulse is function of both force and time and a greater impulse would result in a larger take-off velocity. However, in swimming, there is a trade off since shorter times are better. In order to achieve greater take-off velocities from the OSB11, the swimmers in these studies must have applied larger forces to the OSB11 than the traditional platform since block times appear to be reduced as mentioned in Biel et al. (2010). The shorter block times may have been caused by swimmers having the center of mass closer to the front edge, as noted in Nomura et al. (2010). Greater forces may be

attributed to the kick plate's effect on foot position which may allow the swimmer to apply force more effectively.

### **Equipment positioning**

Studies have examined the effect of kick plate position on swim start performance. Takeda et al. (2012) used a custom-built start platform with a kick plate to evaluate different kick plate angles and distances from the front edge. They examined three different positions of the kick plate at 0.29 m, 0.44 m, and 0.59 m from the front edge. While testing the different positions, they kept the kick plate angle at 45°. They found that at 0.44 m from the front edge, the swimmers had a significantly faster horizontal and resultant take-off velocity than the 0.29 m location. However, the 0.59 m distance was not significantly different than the 0.29 m in horizontal and resultant take-off velocity. It would appear that there may be an optimal location for the kick plate, but their custom platform makes comparison to the OSB11 difficult. Takeda et al. (2012) also tested different inclinations of the kick plate with it located at 0.44 m from the front edge. The data showed that start performances were not significantly different from each other at different inclinations. This is different than a track study evaluating different block angles (Guissard et al. (1992). Guissard et al. (1992) tested three different block angles (70°, 50° and 30°) in the track start, and found that as the angle decreased, velocity and block acceleration increased. At this point, the Omega OSB11 seems to be the standard at international competition, and it has a fixed kick plate angle at 30°, so different kick plate inclinations are not possible. However, the findings of Guissard et al. (1992) might help explain why Swiss Timing designed the kick plate to be angled at 30° from the platform surface.

Slawson et al. (2011) examined different locations of the kick plate as well. However, they only examined the furthest three positions that correspond to locations three, four and five on the OSB11. They report that when swimmers used positions four and five horizontal take-off velocity was significantly faster than in position three and peak forces were higher in the fifth position than in three or four. Similarly, Honda et al. (2012) examined different kick plate locations using an instrumented OSB11 platform. They tested swimmers in three different kick plate positions as well: preferred and one above and one below. They showed a significant increase in horizontal take-off velocities when the kick plate is shifted back one position above the swimmers' preferred kick plate location. This increase in take-off velocity may be due to the noted significant increase in peak horizontal force applied to the kick plate between the preferred and one above. Unfortunately, they only explored three of the five kick plate positions available on the OSB11 platform (the swimmers' preferred position plus or minus one position) and did not report the preferred position for each swimmer. Both Slawson et al. (2011) and Honda et al. (2012) tested different kick plate locations on a platform that emulated the OSB11 better than Takeda et al. (2012) but all three projects only examined three of the five possible kick plate locations on the OSB11. Slawson et al. (2011) only examined position three, four, and five, leaving questions around the first two positions, while Honda et al. (2012) examined the preferred along with one position above and one position below neglecting the other two positions available.

The results of these studies examining different kick plate positions offer some insight into kick plate location for optimal start performance. However, due to limited evaluation of kick plate positions, they offer an incomplete perspective on the effects of different

inclinations and positions on block performance. Nonetheless, a common thread that links all of them is that some kick plate positions are better than others. In Takeda et al. (2012) this was 0.44 m from the front edge, and according to Slawson et al. (2011) it was position four or five on the OSB11. Honda et al. (2012) demonstrated that the preferred is not always the best position. There are currently no studies that have examined all five of the kick plate locations in a single project, nor has the individuality of the kick plate position been explored.

The proper positioning of block equipment is an important aspect in track events as well. For example, in sprint track events, there are generally three different ranges of block positioning: bunched (<0.3 m apart), medium (0.3 to 0.5 m apart) and elongated (> 0.5 m apart) (Harland & Steele, 1997). Harland & Steele (1997) report that researchers have examined the different ranges of sprint starts and discovered that runners employing the bunched start had the fastest start times, but when they used the elongated start they generated the greatest amount of force. Researchers theorized that this allowed for optimal use of the extensor reflex (Guissard et al., 1992). Guissard et al. (1992) believe that when runners start with the block angle 30 or 50 degrees the length of the muscles is increased thus improving the stretch shortening cycle and helps in the contraction speed of the muscle. Perhaps this may also help explain the results from Honda et al. (2012) and Slawson et al. (2011). They both found that swimmers had improved block and start performance when the kick plate was shifted rearward. This would change the initial lengths of the muscles and might possibly contribute to greater force output as noted in their results.



## **Body position**

There are several factors regarding body position that have been explored using a traditional starting platform. For example, Welcher et al. (2008) evaluated swim start performance in both front- and rear-weighted positions in female swimmers. Typically in the literature, the front-weighted position is characterised by the center of mass being closer to the front edge of the platform where the rear-weighted start places the center of mass towards the rear of the platform. They noted that the front-weighted set position had a significantly faster block time than the rear-weighted. However, the rear-weighted start had a significantly greater take-off velocity than the front-weighted configuration. They concluded that swimmers should use the rear-weighted track start due to its higher velocity at 5 m. At this time, some researchers have evaluated the front- or rear-weighted track start from the OSB11 platform (Barlow et al., 2014; Honda et al., 2012; Kibele et al., 2014). These studies have consistently shown that swimmers in a front-weighted configuration produce a faster block time than in the rear-weighted position while swimmers had a faster horizontal take-off velocity using a rear-weighted starts (Honda et al., 2012; Kibele et al., 2014). However, each experiment differentiated between front- and rear-weighted starts differently. Honda et al. (2012) defined them as the location of the shoulders relative to the hands in the set positions. Kibele et al. (2014) had the swimmers move their hip forward or rearward one standard deviation based on previously collected kinematic data. Barlow et al. (2014) instructed swimmers to shift their weight to the front, evenly distribute, or shift their weight to the rear for a front-, neutral or rear-weighted start respectively. These shifts were based on the swimmers perceptions of their weight bearing. Accordingly, there appears to be little control for the

start positioning when testing front- and rear-weighted starts. In addition, testing of front- and rear-weighted starts typically evaluates two or three different positions. Perhaps there is an optimally weighted stance that may be located in between the two extremes similar to the findings of Takeda et al. (2012). They identified that the middle (0.44 m) of the three kick plate locations tested produced the greatest horizontal take-off velocity. An increased number of different weighted positions would be a logical progression for future studies. Interestingly, in track and field studies there seems to be a lack of consensus regarding the optimal location of the center of mass relative to the start line. Harland & Steele (1997) report that there is large variation between world class sprinters in center of mass distance and height from the start line. They speculated that these athletes were able to make up for sub-optimal starting technique in exceptional running ability. The front- and rear-weighted swimming starts may have greater similarity to the block spacing in track and field events rather than the location of the center of mass with respect to the start line. The larger spacing of track blocks shifts the center of mass rearward and has been shown to have a longer start time but greater force production and the inverse is true of the bunched start (shorter block distance). These findings are consistent with the front- and rear-weighted starts in swimming. However, in track and field there seems to be a middle ground where runners can get the best of both in the medium block distance (0.3 to 0.5 m apart), and it is not clear whether this middle ground applies to swim starts as well.

Footedness, limb dominance, and preferred foot position have been examined using older start platforms. Hardt et al. (2009) tested swimmers for dominance using the Waterloo Footedness Questionnaire - Revised and strength using a single leg countermovement

jump. In addition, they also collected their preferred foot to place at the front in the swimming track start. Using these measures, they determined that track start stance preference was not related to either test of strength or footedness. Similar results were noted by Eikenberry et al. (2008) in a track and field study that reported that preferred foot position was not related to footedness. However, the results of Hardt et al. (2009) and Eikenberry et al. (2008) could be attributed to the tests used to assess the strength and footedness of swimmers. The Waterloo Footedness Questionnaire - Revised does not require any physical assessment. Previous studies correlating the counter movement and squat jump to swim start performance have determined that the relationships are weak or not statistically significant (Benjanuvatra et al., 2007; Arellano et al., 2005; Breed & Young, 2003).

In a more recent case study, using the OSB11 platform, Slawson et al. (2011) demonstrated that the swimmer had a greater flight distance when the right leg was placed at the front in the track start. However, they did not identify which leg was the swimmers' dominant limb, nor was it clear if this was their preferred stance. However, similar to Hardt et al. (2009), they showed that there are differences in start performance depending on which foot is placed at the front. Slawson et al. (2011) also examined the width of the rear foot relative to the midline of the body. Narrower stance width (closer to the midline) was associated with faster block times, increased peak force and horizontal take-off velocity in male swimmers.

## **Feedback**

Several studies examined the use of feedback in various sports and have employed different methodologies. Specific to the sport of swimming, Blanksby et al. (2002) used

coaching and video feedback to aid swimmers to learn and practice the handle or track start techniques. The swimmers performed between two and four practice sessions a week and were tested again after 14 sessions were completed. They showed that swimmers improved swim start performances in all three techniques and concluded that regular start practice should be included in the training regime. Similar to Blanksby et al. (2002), Fischer & Kibele (2010) used video feedback to teach swimmers the flat or pike entry. It appears that their intervention was a single session where swimmers received feedback concerning take-off and entry. Results show that the swimmers were able to significantly improve their take-off angle, take-off velocity and entry angle. Comparison of results and methodologies was difficult since this was a conference abstract, so many important details have been omitted due to space constraints. Nonetheless, both Blanksby et al. (2002) and Fischer & Kibele (2010) show that the use of video feedback is an effective means for improving start performance. In a related project, De La Fuente & Arellano (2010) performed an intervention where the experimental group received 10- and 15 m times as feedback from an start timing system with a touch pad at 15 m, and the other did not. Interestingly, after 10 practice sessions the group exposed to the timing system demonstrated a significantly greater improvement in 10- and 15 m start time than their counterparts. It was noted that both groups did demonstrate a significant improvement in start times of 5% and 2% for the experimental group and control group respectively. De La Fuente & Arellano (2010) provide evidence that start practice alone is able to improve start performance, however, this improvement is augmented with the use of knowledge of results (KR feedback). More information about this study would be required to make additional comparisons to other studies of swim start feedback and start improvement. It

appears that they did not use coaching or video and showed improved start performance based on immediate feedback of their time to either 10- or 15 m.

Several feedback studies have also been performed with track athletes. One such study used a kinetic system to help athletes develop their start (Mendoza & Schollhorn, 1993). Their project was designed as a one-time test where the athletes performed the first two starts in their preferred position, and the following six to eight starts using a controlled stance. Over the course of the single session, the runners demonstrated a statistically significant decrease in 10 m time. Like the De La Fuente & Arellano (2010) study, it does not appear that they provided any verbal feedback to the athletes. The 10 m time, horizontal velocity, and block times from each start were displayed on a computer screen for the athlete to interpret. It would appear that displaying start data as feedback may improve start performances. Contrary to the previous studies, Fortier et al. (2005) performed a feedback study with track sprinters. In the first part of the study they statistically identified kinetic factors that separated elite sprinters from intermediates. It was determined that the delay of the rear foot, rear peak force, total block time, and time to rear peak force were the variables they would use in their feedback session for intermediate sprinters. The feedback portion of the study began with a six week time period where no feedback was provided. Then, feedback was provided once a week for six weeks following the no feedback period. The feedback phase was followed by a retention phase where feedback was withheld again. They concluded that providing sub elite with kinetic feedback based on elite runners was, in general, not successful. An issue may have been that the sessions were held once a week for six weeks, which may not have provided the athletes enough time to rehearse the skill to become proficient. If any

new skills had been learned in one session, they may have been forgotten by the time the next session occurred and required the athlete to re-learn the technique. These studies have explored the use of either video or kinetic feedback on start performance, and in most cases were successful. In addition these studies all provide evidence that starts can be improved over a long period of time (a few weeks) or with short interventions (one session).

### **Summary**

In summary, the addition of the kick plate is a new feature on a start platform. The optimal positioning of it and the swimmer for maximal performance, however, is unclear at this point. There are factors of the set position on the OSB11 that have not been explored yet and need to be investigated to gain a better understanding. The purpose of this thesis was to investigate optimal kick plate locations, dominant foot location, and centre of mass positions of the set position that affect swim start performance.

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### **Chapter 3. The Omega OSB11 Kick Plate: One Size Fits Some.**

#### **Introduction**

In 2009, the international governing body of aquatic sports (FINA) approved the use of a new starting platform configuration (Figure 3.1) (Omega Watches, 2008). The Omega OSB11 style platform is the new standard at national and international competition. A new feature to this model is the kick plate (Honda et al., 2010; Nomura et al., 2010). The kick plate is angled at 30° to the block surface and can be moved (front to back) in five different positions over a range of 0.20 m (Honda et al., 2010).



**Figure 3.1: The Omega® OSB11 start block. The kick plate is angled at 30 degrees from the surface of the platform. The platform is angled at nine degrees from horizontal.**

Recent studies have demonstrated improved performance with the OSB11 platform (Biel et al., 2010; Honda et al., 2010). These studies have shown that use of the kick plate significantly reduces swimmers' block time over previous blocks without it. When testing the track start from the OSB11, with and without the kick plate, swimmers demonstrated a significant increase in horizontal take-off velocity when using the kick plate, and faster times to distances of five and 7.5 m (Honda et al., 2010).

Research of optimal start position on the OSB11 has been performed by several researchers (Biel et al., 2010; Murrell & Dragunas, 2012; Slawson et al., 2011; 2012). The track start and grab start were evaluated both kinematically and kinetically from the OSB11 platform. The results suggest that the track start is significantly faster than the grab start from this platform (Biel et al., 2010; Murrell & Dragunas, 2012). Using the track start technique, knee angles and stance width has also been explored. Slawson et al., (2011) examined widths of stance in the set position and knee angles at different kick plate positions. They found that swimmers performed better with a narrow stance than with the wider shoulder width option. Swim start position research has not explored the effect of high or low foot position, or the relationship between optimal kick plate position and anthropometrics. There were three purposes of this study: (i) to determine if there are differences between a high or low foot placement on the kick plate, (ii), to evaluate whether there are any relationships between anthropometrics and optimal kick plate position, and (iii) to examine plate position differences between our optimal position calculation and the swimmers' preferred position. Given that Honda et al. (2012) observed differences between preferred and the other kick plate settings, we hypothesized that the optimal kick plate placement for each swimmer would differ from their preferred

position, and that a higher posterior foot placement on the kick plate would produce a faster block performance. Furthermore, we hypothesized that there would be strong relationships between anthropometrics and kick plate position.

## **Methods**

### *Experimental Approach*

To identify relationships between optimal kick plate position and segment lengths, swimmers' anthropometrics were measured and their swim starts were tested in ten different conditions: five kick plate settings with two foot positions (high and low at each of the kick plate positions). A ranking system was used to identify an optimal kick plate position (based on performance variables). This optimal kick plate position was then correlated to the anthropometrics to examine relationships. The differences between high and low foot position on the kick plate were evaluated by comparing reaction time, block time, horizontal take-off velocity, and 2 m time.

### *Participants*

We tested 13 swimmers, 10 males (mean  $\pm$  SD; age,  $21.8 \pm 3.71$  years; height,  $1.85 \pm 0.07$  m; mass,  $80.5 \pm 6.9$  kg; 2012 FINA world pts,  $759 \pm 68.5$ ), and three females (mean  $\pm$  SD; age,  $20.3 \pm 2.3$  years; height,  $1.72 \pm 0.06$  m; mass,  $59.8 \pm 3.5$  kg; 2012 FINA world pts,  $759 \pm 90.5$ ) who were actively training and competing with a varsity or club program. Swimmer height, weight, age, preferred kick plate position, and personal best times were collected. Personal best times were converted to FINA (Federation Internationale de Natation Amateur) world points based on the 2013 tables (FINA, 2013).

Several swimmers in this group have competed at past Olympic and international competitions and one female swimmer has competed at the Paralympic games in the S13 class. All have experience on the Omega OSB11 platform and utilize the track start technique. Before participating in the study, each swimmer provided informed consent that was approved by the university's Research Ethics Board.

### *Set up and Instrumentation*

A replica of the Omega<sup>®</sup> OSB11 platform was installed on the bulkhead of the pool (Figure 3.2). The replica platform was equipped with a tri-axial force plate beneath the main starting platform (OR6-WP-2000, AMTI, Watertown, MA, USA) similar to other researchers (Hardt et al., 2009; Slawson et al., 2013; Vantorre et al., 2010). A starting signal (Daktronics, Inc., Brookings, SD, USA) was used to start each dive to replicate competition starting conditions. Voltage signals from the force plate and starter were digitized using a 16-bit analogue to digital conversion board (DAQPad-6015, National Instruments, Austin, TX, USA) and sampled at 1000 Hz. All voltage data were saved for post processing using a custom designed LabVIEW program (Version 10.0, National Instruments, Austin, TX, USA).

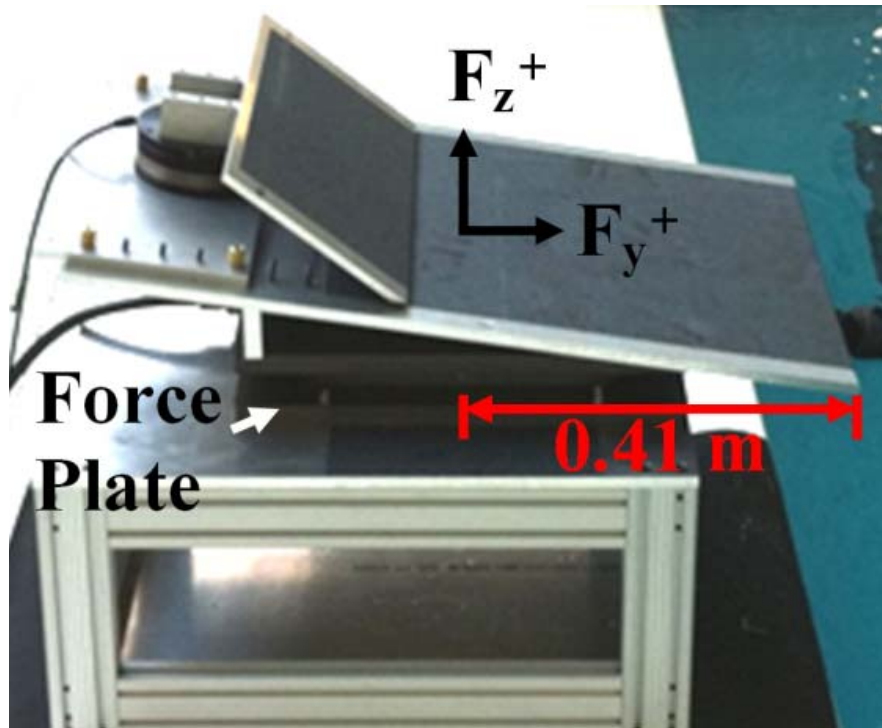


Figure 3.2: The replica of the OSB11 start platform. The force plate is located underneath the main start platform.

#### *Testing procedure and data collection*

Anthropometrics (body height, body mass, foot length, shank length, calf circumference, thigh length, thigh circumference, torso length, arm length, bicep circumference, forearm length, hand length) were collected according to standardized procedures (Norton & Olds, 1996). Once the testing procedures were explained, all swimmers completed a standardized swimming warm-up of 1,000 m and then performed four swimming starts to familiarize themselves with the start signal and procedure. The swimmers performed a total of 30 starts in the track style from the replica starting platform (Figure 3.2). The swimmers performed six starts at each of the five different kick plate settings (1-most forward through 5-most rearward on the OSB11 platform). At each kick plate position, the six starts were performed in two different posterior foot conditions; three with the

foot on the top half (high) and three on the bottom half of the kick plate (low) (Figure 3.3). The order of performance of the 30 trials was randomized to control for learning and were performed on a two minute interval to reduce fatigue. Swimmers were asked to perform each start at maximal effort.

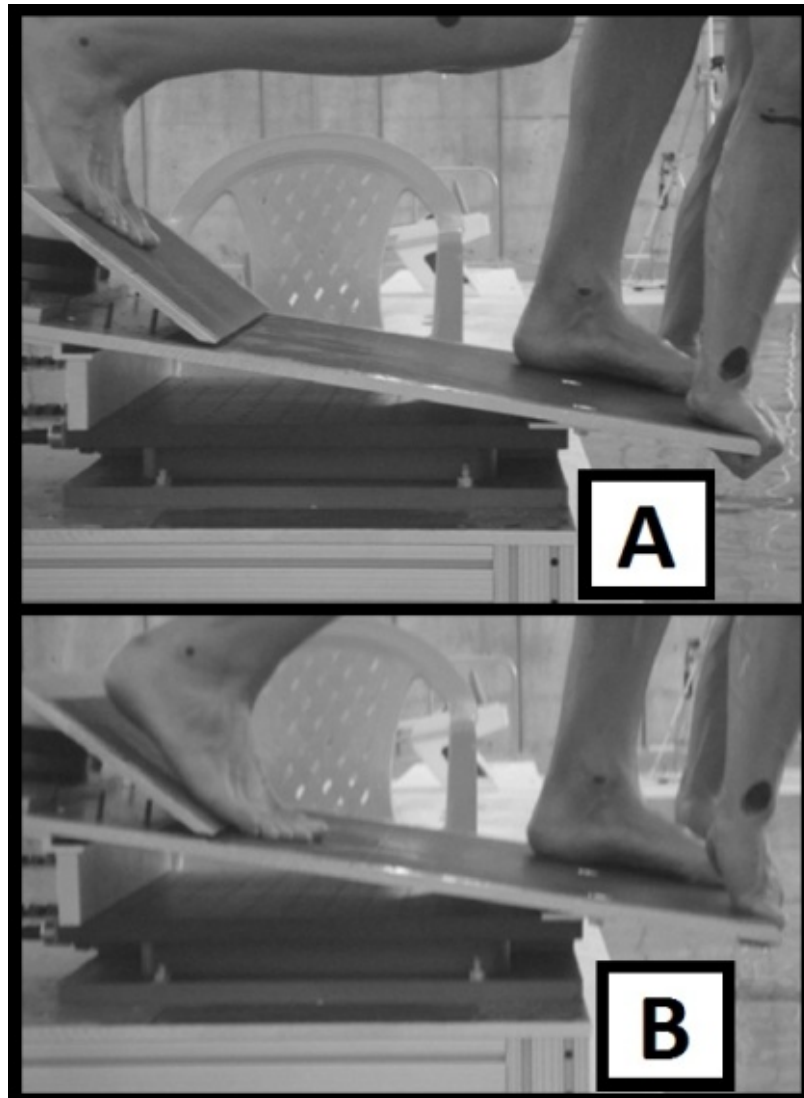


Figure 3.3: Two variations of the rear foot placement on the kick plate.  
(A: "high" top half, B: "low" bottom half)

### *Data analysis*

Post-processing included converting the force plate voltage data to forces and low-pass filtering at 25 Hz using a 2nd order Butterworth filter. We calculated reaction time, block time, horizontal take-off velocity, and 2 m time using the force data. The start signal, first movement, and time of take-off were identified using the integration method of Santello & McDonagh (1998). These three time points allowed us to calculate the reaction time (start to first movement) and block time (start to take-off). The horizontal take-off velocity was calculated using the impulse-momentum relationship (Eq.1) (Galbraith et al., 2008; Hay, 1993; Murrell & Dragunas, 2012; Tor et al., 2015)

$$v_y(t) = \int_{t_i}^{t_o} \frac{F_y(t)}{m} dt \quad \text{Eq. 1}$$

where  $F_y$  is the horizontal force,  $t_i$  is the time of the start signal, and  $t_o$  is when the diver leaves the block. Body mass ( $m$ ) was calculated as the average vertical force during a 500 point sample (0.5 s) of quiet stance prior to the start signal divided by  $g$  ( $9.81 \text{ m/s}^2$ ). To calculate the time to 2 m, we used the horizontal velocity (Eq. 1) and the initial location of the whole body center of mass (COM) in the anterior-posterior direction ( $y$ ). The initial ( $\text{COM}_{y_i}$ ) was calculated from the center of pressure (COP) location in the anterior-posterior direction, since the whole-body COM will be directly above the COP in quiet stance (Winter et al., 1996). The  $\text{COM}_{y_i}$  was calculated by dividing the moment about the x-axis ( $M_x$ ) by the vertical force ( $F_z$ ). The initial  $\text{COM}_{y_i}$  was calculated as the average over the same 0.5 s interval of quiet stance that was used to calculate body mass. The  $\text{COM}_{y_i}$  was expressed relative to the front edge of the block by adding the distance between the front edge of the platform and the center of the force plate (0.41 m). The



final center of mass position ( $COM_{y_o}$ ) position with respect to time was calculated by solving the projectile motion equation (Eq.2)

$$COM_{y_o}(t) = COM_{y_i} + \int v_y(t) dt \quad \text{Eq. 2}$$

where  $v_y$  is the horizontal velocity (Eq. 1),  $COM_{y_i}$  is the initial center of mass location, and  $COM_{y_o}$  is the final location of the center of mass relative to the edge of the pool.

From the position data, the time that the horizontal displacement of the  $COM_{y_o}$  was equal to 2 m was extracted.

### *Statistical analysis*

A sum of ranks method was used to determine an optimal kick plate and foot position combination. This optimal kick plate setting was correlated (Kendall's Tau) to body height, body mass, foot length, shank length, thigh length, torso length, arm length, forearm length, hand length, calf circumference, thigh circumference, and bicep circumference to evaluate the relationship between optimal kick plate and anthropometrics. Since the data were not evenly distributed, we interpreted the Kendall's Tau ( $\tau_b$ ) measure of correlation.

For each athlete, an average reaction time, block time, take-off velocity and 2 m time was calculated for each foot placement (high and low). Two-tailed paired t-tests were used to evaluate the statistical significance between the high and low foot placement in the four parameters collected. The correlations and t-tests were performed using SPSS Statistics software (Version 22, International Business Machines, Armonk, NY, USA).

## Results

The high foot placement had a significantly greater horizontal take-off velocity ( $p = 0.024$ ) and time to 2 m ( $p = 0.034$ ) than the low foot placement (Table 3.1). However, the t-tests showed no statistically significant difference in RT ( $p = 0.203$ ) and BT ( $p = 0.113$ ) between the high and low foot placement.

A ranking system was used to determine the optimal condition for each swimmer (Table 3.2). Most of the swimmers' (12 of 13) optimal kick plate location was in one of the three most rearward positions (three, four or five). The optimal kick plate location was not the same as the swimmers' preferred position in 11 of 13 cases (Table 3.2). In addition, 12 of 13 swimmers' optimal condition involved placing the foot in the high position.

The correlations did not reveal statistically significant relationships

**Table 3.1:** High and low foot placement means and standard deviations for reaction time (RT), block time (BT), horizontal take-off velocity (TOV), and 2 m time (2MT).

Position	RT (s)	BT (s)	TOV (m/s)	2MT (s)
High	0.258 (0.014)	0.804 (0.021)	4.271* (0.060)	1.040* (0.020)
Low	0.254 (0.014)	0.821 (0.022)	4.213 (0.070)	1.053 (0.023)

Note: \* indicates significant difference between high-low

**Table 3.2:** Swimmer preferred and optimal start position. Plate position is based on the numbers found on the OSB11 platform, 1 is closest to the water, and 5 is furthest from the water.

Swimmer	Preferred	Optimal	
	Plate position	Plate position	Foot position
A	4	4	HIGH
B	4	5	HIGH
C*	4	5	HIGH
D	4	3	HIGH
E	4	5	HIGH
F*	5	4	HIGH
G <sup>!+</sup>	3	3	HIGH
H	3	4	LOW
I <sup>!</sup>	3	5	HIGH
J	3	2	HIGH
K	4	4	HIGH
L <sup>*!</sup>	2	4	HIGH
M	1	3	HIGH

Note: \* denotes junior/senior national team status  
! denotes female swimmer  
+ denotes paraswimmer

between the optimal kick plate setting any of the anthropometric measures (Table 3.3).

The greatest  $\tau_b$  value was between the optimal plate setting and shank length ( $\tau_b = 0.440$ ), thigh length ( $\tau_b = -0.369$ ), and arm length ( $\tau_b = -0.369$ ). However, none of these tau values were statistically significant.

**Table 3.3:** Correlations between optimal plate position and anthropometrics

Height	Weight	Length							Circumference		
		Foot	Shank	Thigh	Torso	Arm	Hand	Forearm	Calf	Thigh	Bicep
.143	.074	.162	.440	-.369	-.162	-.369	-.251	.192	-.134	-.060	.000

Note: \* indicates significant values

## Discussion

The first purpose of this experiment was to evaluate differences in swim block performance between a high and low foot placement on the kick plate. Our data supports the first hypothesis that a higher foot placement would produce a faster block performance. The data shows a significant increase in horizontal take-off velocity and a significant decrease in 2 m time when placing the foot on the top half of the kick plate. At any given kick plate position, placing the phalanges of the foot in the high position positions the foot further rearward and obviously increases their height relative to the platform (Figure 3.3). This position allows for the ankle to be positioned even higher than the toes and allows the shank to be positioned closer to horizontal than when the phalanges are on the bottom half of the kick plate. This position may drastically change the angle of force application to the platform, and potentially allow the swimmer to apply force more directly rearward. In turn, this allows for a rear knee angle to be closer to 90 degrees, and slightly extends the hip compared to the low foot position on the kick plate. This may cause the hip extensors to be closer to their optimal length for force production. By shifting the foot to the top half of the kick plate the swimmers may be achieving a

better force production from the hip extensors and applying force more effectively to the platform. This may help explain the noted increase in take-off velocity with the not statistically significant decrease in block time. For this to occur the swimmer must applying a greater force to the platform in the rearward direction since the impulse is calculated as the integral of the force with respect to time.

Similar research has found analogous results when manipulating start stance. For example, Slawson et al. (2011) explored differences in start performance with different stance widths on the kick plate. Their data demonstrate that a narrowed stance results in a significant decrease in block time and significant increase in take-off velocity when compared to a wider stance. The narrower rear foot position on the kick plate would allow for more force to be applied directly rearward. The differences in time between altered stances may seem small; however, they are improvements of approximately two percent, which is substantial. These improvements in swim block performance should be important to swimmers and coaches. The start phase of the swim extends to the 15 m mark, the maximum distance the swimmer is allowed to be under water. This portion of the race is comprised of many components, and all components are linked (Tor et al., 2014). Changing foot position may increase take-off velocity and lead to improvements in subsequent components such as flight time, and entry velocity. The magnitude of the differences found in both the present project and Slawson et al. (2011) may be the difference between winning a gold or silver medal.

A recent study explored the relationship between kick plate position on knee angle (Slawson et al., 2012). They discovered that changes in kick plate position did not cause significant increases or decreases in knee angle. However, they did not control for foot

position (high/low) on the kick plate. They reported that the swimmers would move the rear foot to a lower or higher location when the kick plate was shifted to a different position. It is clear from the present study that foot position on the kick plate makes a difference in horizontal take-off velocity and time to 2 m. We believe the location of the kick plate may influence the knee and hip angle of the posterior leg in the track start (from the OSB11), thereby changing muscle lengths and joint excursions during the start, similar to starts in track and field (Harland & Steele, 1997). We expect that these factors may still contribute to the observed differences in block performance with various start configurations (Honda et al., 2010; Nomura et al., 2010; Takeda et al., 2012).

The second purpose of this project was to examine the relationship between the optimal kick plate location and anthropometrics. We hypothesized that there would be strong relationships between the plate location and body measures, but we did not find support for this theory in our data. The results show that the correlation coefficients are not different from zero since all of them are not statistically significant. Some coaches believe taller people should place the kick plate further away from the front of the block. However, our analyses do not support this theory. Given that we did not observe strong correlations between the kick plate position and swimmers' anthropometrics, optimal kick plate may have a stronger relationship to strength or flexibility than to anthropometrics.

The final purpose of this study was to compare the optimal kick plate locations to the swimmers' preferred positions. The data from this project show that in most cases the optimal kick plate location differed from the swimmers' preferred positions, in some cases by as much as two positions. These results are similar to Honda et al. (2012) who identified significant differences between preferred location and plus or minus one

position. Unfortunately, they did not analyze the other two available settings which may have held more information about the kick plate position. Our data show that some of the swimmers had optimal kick plate positions that were two settings different than their preferred. In an earlier study, Slawson et al. (2011) examined different kick plate positions. They determined that swimmers were faster in position four and five than position three and believe that swimmers should use these settings when performing the track start from the OSB11. This is the case with most of our swimmers (9 of 13) as well who had optimal kick plate positions at either four or five. In addition, position four was the optimal location for the largest number of swimmers. Yet similar to Honda et al., (2012), they omitted certain kick plate locations and did not examine position one or two in their study. Perhaps this was done since this is not a popular position for swimmers; one of the swimmers in our test group identified kick plate position one as preferred. Most swimmers likely select their preferred kick plate setting based on comfort or perhaps a 10- or 15 m time. Neither of these are ideal measures for block performance. Comfort is a subjective measure that may not be related to performance, and there are too many variables in a 10- or 15 m start time to distinguish performance differences between kick plate positions. Variables such as entry angle, dive distance, entry depth, underwater dolphin kicks, angle of attack to the surface, and break out distance can all affect time to 15 m and dilute the effect of kick plate position on start performance (Tor et al., 2015).

The results from the present study should be interpreted with some caution since there are a few limitations. We did not collect information on the swimmers' preferred location (high or low) of the rear foot on the kick plate. In addition, the ranking system evenly weighted the parameters used to calculate the optimal position. Lastly, we used a

predicted 2 m time as an outcome measure of the swim start. Without disregard to other start variables outlined in other studies (Tor et al., 2015; Slawson et al., 2011, Honda et al., 2010), the 2 m time reflects the swimmers' block performance before they enter the water and results are diluted with other independent variables. Future research should examine the optimal limb to place at the front of the block and the contribution of the front and rear limb to start performance.

### **Practical applications**

The results of the current project indicate that swimmers should place the rear foot on the top half of the kick plate to maximize horizontal take-off velocity and time to 2 m. In addition, all swimmers should be tested for optimal kick plate placement as there may be significant differences in block performance between kick plate settings and most preferred positions were not the optimal. However, since most swimmers and coaches do not have access to sophisticated testing equipment, we suggest starting with the kick plate in the fourth position. Most of the swimmers in our test group had optimal kick plate positions that were within one location of this arrangement. This range covers 92 percent of our test group and may be an appropriate place to have the kick plate without scientific testing.

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## **Chapter 4. Putting Your Best Foot Forward: Limb Power and Block Performance.**

### **Introduction**

In 2009, the Omega<sup>®</sup> OSB11 starting platform was sanctioned for use at international competition by the world swimming governing body (FINA) (Omega Watches, 2008). This start platform is the new standard in national and international competition. The unique feature of the Omega<sup>®</sup> OSB11 is the kick plate angled at 30 degrees from the platform surface (Figure 4.1) (Honda et al., 2010). The kick plate can be shifted front to back to five different locations that span 0.2m (Omega Timing, 2009).



**Figure 4.1: The Omega<sup>®</sup> OSB11 start block The kick plate is angled at 30 degrees from the surface of the platform. The platform is angled at nine degrees from horizontal.**

Recent research using the new OSB11 platform shows that swim starts are faster than those from previous models (Biel et al., 2010; Murrell & Dragunas, 2012). They found that swimmers produced shorter block times and increased take-off velocities when starting from the OSB11 compared to previous models without the kick plate. The ability to apply greater impulses to the starting platform may be the reason for faster starts from the OSB11. Studies have compared the track and grab start techniques from the OSB11 platform. They discovered that the track start is faster to 2 m and 7.5 m (Biel et al., 2010; Murrell & Dragunas, 2012). The results of these projects indicate that all swimmers should consider utilizing the kick plate and learn to use the track start technique when diving from the Omega OSB11 platform.

With evidence pointing to the use of the kick plate in the track start position being advantageous when using the OSB11, research has evaluated different foot locations in the set position. Research has shown that changing the foot position on the kick plate can change a swimmer's start performance. As demonstrated in chapter three, placing the foot on the top half of the kick plate demonstrated a significant increase in horizontal take-off velocity and reduced time to 2 m. In addition, there is evidence demonstrating that a narrower foot position on the kick plate in the set position had a greater take-off velocity and block time than a wider stance (Slawson et al., 2011).

Footedness, limb dominance, and preferred foot position has also been explored in the track start stance with an older model and new OSB11 start platforms. Researchers did not find a significant difference in start times with either foot at the front of the block when using a previous platform model (Hardt et al., 2009). In a more recent study, using the OSB11 platform, a case study demonstrated that the swimmer had a greater flight

distance when the right leg was placed at the front as opposed to the left (Slawson et al., 2011). However, they did not identify the swimmers' limb as dominant or non-dominant, but showed that there are differences in start performance depending on which foot is placed at the front. Limb placement in the track start has been examined in track and field (Eikenberry et al., 2008; Radford, 1990). Previously, coaches believed that runners should place the stronger limb at the front of the block (Radford, 1990). According to Radford (1990), this was based on findings from Henry (1952) who found that the front leg was responsible for 66.1% of the horizontal velocity. However, he goes on to say that these and current (1990) findings are not sufficient evidence to suggest which limb should be placed at the front. However, the question of determining dominant limb still remains. Recently, Eikenberry (2008) examined footedness in the track and field start, and discovered that when the swimmers started with the right leg forward they had an advantage of almost 80 ms. These findings are in line with the case study presented by Slawson et al. (2011). However, studies have not examined the power limb location in the track start set position on swim start performance from the OSB11.

The purpose of this study was to examine differences in block performance between two different limb configurations: power limb or non power limb on the kick plate. Pilot data that were collected showed that (i) the majority of the impulse was applied to the kick plate, and (ii) the kick plate contact time was approximately 70% of the block time. Thus, we hypothesize that swimmers will have faster starts if they place their power limb in the rear position (on the kick plate). This should maximize impulses to the kick plate throughout the contact period when starting from the OSB11. As a secondary purpose, we examined the ratios of contributions of the rear foot and front foot in the start from the

OSB11. We hypothesized that the average kick plate contact time and impulse would be in the range of 70-90% of the block time and total block impulse respectively for the test group.

## **Methods**

### *Experimental Approach*

This project included a jump test to determine the power limb and a swim start test to assess block performance. The start test evaluated performance in two different start conditions; left foot and right foot forward. For analysis, the location of the power limb in the swim start test was later converted to either a power limb on rear (PLR), or power limb on front (PLF) and block performance was assessed with regard to reaction time (RT), block time (BT), 2 m time (2MT), and horizontal take-off velocity (TOV).

### *Participants*

We tested 15 swimmers (mean  $\pm$  SD; age,  $20.35 \pm 1.38$  years; 2012 FINA world points,  $735.6 \pm 45$ ) who were actively competing and training with a varsity or club program. The group included Junior and Senior National team members who have competed at the national and international level. All swimmers provided informed consent with a signed form approved by the university's Research Ethics Board before participating in the study. The swimmers had multiple exposures to the Omega OSB11 start platform at competitions and utilized the track start technique.

### *Power Limb Test*

To determine the power limb, all swimmers performed a single-leg triple jump for distance. This tests has been shown to be a reliable test of lower limb strength and power (Hamilton et al., 2008). They were instructed to start with the toe of the shoe at the start line, and hop three times on one leg and attempt to reach the greatest distance possible. Once the procedure was explained, three practice trials were allowed to familiarize themselves with the hop technique before initiating the test. The test consisted of six trials; three on the right and three on the left leg. The swimmers alternated jumping limb between trials. Measurements were taken to the front edge of the shoe; the leg used to reach maximal distance defined the power limb.

### *Set up and Instrumentation*

A replica of the Omega<sup>®</sup> OSB11 starting block was installed on the bulkhead of the pool (Figure 4.2). The replica platform was equipped with a tri-axial force plate beneath the main starting platform (OR6-WP-2000, AMTI, Watertown, MA, USA) and a second tri-axial force sensor (load cell: Omega 160, ATI, NC, USA) under the kick plate that was mounted on top of the main start platform similar to other researchers (Hardt et al., 2009; Mason et al., 2007; Slawson et al., 2013). A starting signal (Daktronics, Inc., Brookings, SD, USA) was used to start each dive to replicate competition starting conditions. Voltage signals from force sensors and a starter (Daktronics, Inc., Brookings, SD, USA) were digitized using a 16-bit analogue to digital conversion board (DAQPad-6015, National Instruments, Austin, TX, USA) and sampled at 1000 Hz. All signal data were

saved for post processing using a custom designed LabVIEW program (Version 10.0, National Instruments, Austin, TX, USA).

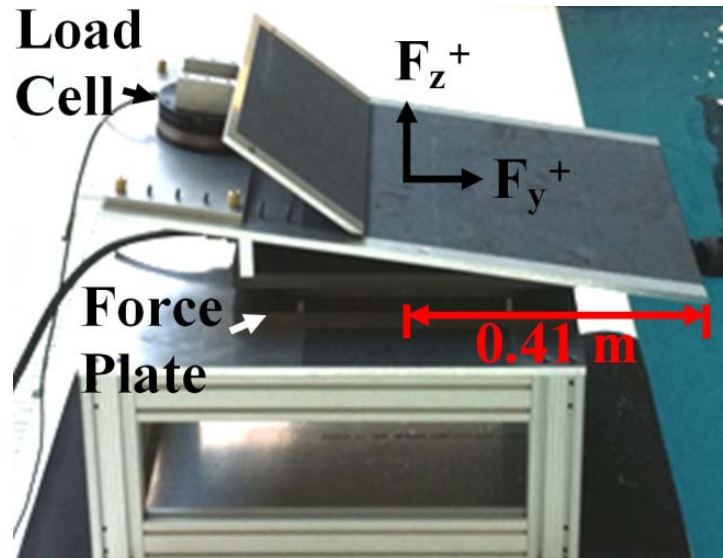


Figure 4.2: The replica of the OSB11 start platform. The force plate is located underneath the main start platform (white arrow) and force transducer under the kick plate (black arrow).

#### *Swim Start Test Procedure*

Before the start test began, preferred locations of start stance set up were recorded; front foot (right or left), kick plate location (1 to 5) and kick plate foot position (high or low). After a standardized warm-up (1000 m), each swimmer performed two starts to familiarize themselves with the start signal and procedure. The test consisted of 20- 10 m swimming starts in two different conditions; 10 with the right and 10 with the left foot at the front edge of the block. Start trials were all performed in their preferred set positions according to the recorded information. All trials were randomized to control for learning and performed with approximately two minutes of rest to reduce fatigue. Swimmers were instructed to perform each start with maximal effort.

### Data Analysis

Voltage data from the force plates were converted to forces and low-pass filtered at 25 Hz using a second-order Butterworth filter. The forces applied by the front foot were calculated by subtracting the kick plate forces from the main platform forces. The start signal, first movement, kick plate toe off, and time of take-off were identified using the integration method of Santello & McDonagh, (1998). From these time points we calculated the reaction time (start to first movement), kick plate movement time (first movement to kick plate toe-off), kick plate contact time (start signal to kick plate toe-off), block movement time (first movement to take-off), block time (start signal to take-off), and front foot only time (kick plate toe-off to take-off) (Figure 4.3). For this project, we calculated an average kick plate contact time and front foot only time for each swimmer.

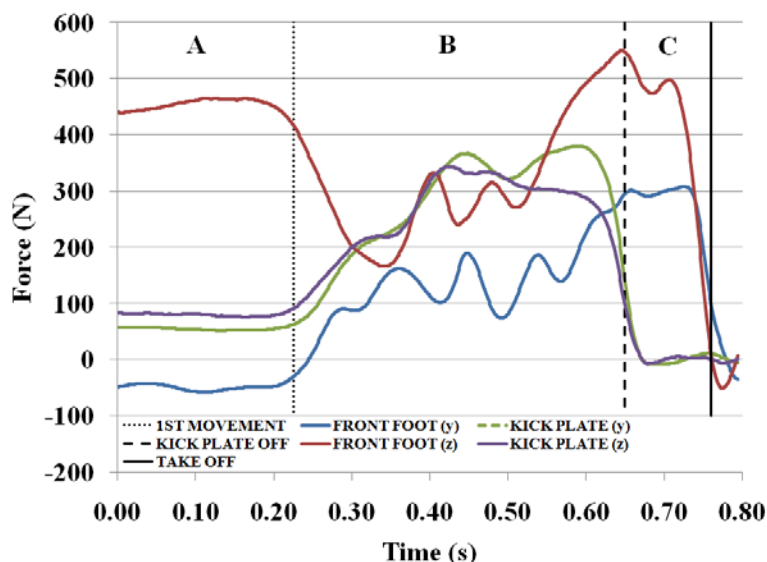


Figure 4.3: Calculated front foot and rear foot forces. Vertical lines identify start signal ( $x = 0$ ), first movement, kick plate toe-off and take-off. Reaction time (A: time between the start signal and first movement), kick plate movement time (B: time between first movement and kick plate toe-off), front foot only time (C), kick plate contact time (A+B: time between start signal and kick plate toe-off) block movement time (B + C: time between first movement and take-off) and block time (A + B + C: time between start signal and take-off).



Total horizontal impulses for the kick plate and platform were calculated by integrating the horizontal force data with respect to time. The horizontal take-off velocity was calculated using the impulse-momentum relationship (Eq.1) (Galbraith et al., 2008; Hay, 1993; Murrell & Dragunas, 2012)

$$v_y(t) = \int_{t_i}^{t_o} \frac{F_y(t)}{m} dt \quad (\text{Eq. 1})$$

where  $F_y$  is the horizontal force,  $t_i$  is the time of the start signal, and  $t_o$  is when the diver leaves the block. Body mass ( $m$ ) was calculated as the average vertical force during a 500 point sample (0.5 s) of quiet stance prior to the start signal divided by  $g$  ( $9.81 \text{ m/s}^2$ ). To calculate the time to 2 m, we used the horizontal velocity (Eq. 1) and the initial location of the whole body center of mass (COM) in the anterior-posterior direction ( $y$ ). The initial ( $COM_{y_i}$ ) was calculated from the center of pressure (COP) location in the anterior-posterior direction, since in quiet stance, the whole-body COM will be directly above the COP (Winter et al., 1996). The  $COM_{y_i}$  was calculated by dividing the moment about the x-axis ( $M_x$ ) by the vertical force ( $F_z$ ). The  $COM_{y_i}$  was calculated as the average over the same 0.5 s interval of quiet stance that was used to calculate body mass. This average  $COM_{y_i}$  was expressed relative to the front edge of the block by adding the distance between the front edge of the platform and the center of the force plate (0.41 m). The final center of mass position ( $COM_{y_o}$ ) with respect to time was calculated by using the projectile motion equation (Eq.2)

$$COM_{y_o}(t) = COM_{y_i} + \int v_y(t) dt \quad \text{Eq. 2}$$

where  $v_y$  is the horizontal velocity (Eq. 1),  $COM_{yi}$  is the initial center of mass location, and  $COM_{yo}$  is the final location of the center of mass relative to the edge of the pool.

From the position data, the time that the horizontal displacement of the  $COM_{yo}$  was equal to 2 m was extracted. Prior to statistical analysis, individual trials were identified as either the power limb on the front (PLF) or power limb foot on the rear (PLR) of the block based on the triple hop test results for statistical assessment of reaction time, block time, 2 m time, and take-off velocity.

The kick plate forces were adjusted to the horizontal to account for the nine degree slope of the platform (Juergens, 1995). We calculated x- and y-axis impulses for two periods (kick plate movement time and block movement time: Figure 4.3) from the rear foot and front foot by integrating the forces with respect to time. The front and rear foot impulses were expressed as a percentage of the total impulse (platform impulse).

### *Statistical Analysis*

For each swimmer a reaction time, block time, take-off velocity, and 2 m time average was calculated for each start condition (PLF and PLR). The averages from each swimmer were grouped by condition for group analysis. Each parameter was tested for normality and homogeneity of variances where the Shapiro-Wilk and the Levine's test were interpreted respectively (SPSS Version 15.0 for Windows; IBM, Corp., Armonk, NY, USA). Two-tailed paired t-tests were performed to assess the statistical significance of the difference between power limb location for each of the four parameters (RT, BT, TOV, and 2MT). The acceptable level of significance was set at  $p = 0.05$ .

## Results

Eight of the swimmers in this group reported their preferred front foot as the right.

Whereas the results of the triple-hop for distance demonstrated that the right limb was the power limb in 10 of 15 swimmers (Table 4.1). For 11 of the swimmers, the power limb was also their preferred foot to place at the front of the block.

**Table 4.1:** Reaction time (RT), block time (BT), 2 m time (2MT), and horizontal take-off velocity (TOV) group averages ( $\pm$ SD) for each start parameter with the power limb on rear (PLR) or power limb on front (PLF).

	<b>RT</b> (s)	<b>BT</b> (s)	<b>2MT</b> (s)	<b>TOV</b> (m/s)
<b>PLR</b>	0.217 (0.028)	0.808 (0.058)	1.153 (0.081)	3.21 <sup>!</sup> (0.280)
<b>PLF</b>	0.205 (0.024)	0.809 (0.059)	1.160 (0.072)	3.28 <sup>!</sup> (0.243)

Note: <sup>!</sup> indicates significant difference ( $p < 0.05$ )

The results showed a significant increase in horizontal take-off velocity when the power limb is placed at the front of the OSB11 (Table 4.1). The horizontal take-off velocity was on average 0.07m/s faster with the power limb on the front than when it was on the rear. However, no significant difference was detected in any of the other parameters.

The contact time analysis shows that, on average, the swimmers spent approximately 84 percent of the block time in contact with the kick plate, and only 16 percent of the time using the front limb only. The contributions show that, during the kick plate movement time, the rear foot contributes on average 80% ( $\pm$  6.60%) and 65% ( $\pm$  13.9%) of the impulse in the y- and z- direction to the platform respectively (Figure 4.4). This changes during the block movement time to 65% ( $\pm$  5.08%) and 54% ( $\pm$  12.37%) total contribution from the rear foot (Figure 4.5).

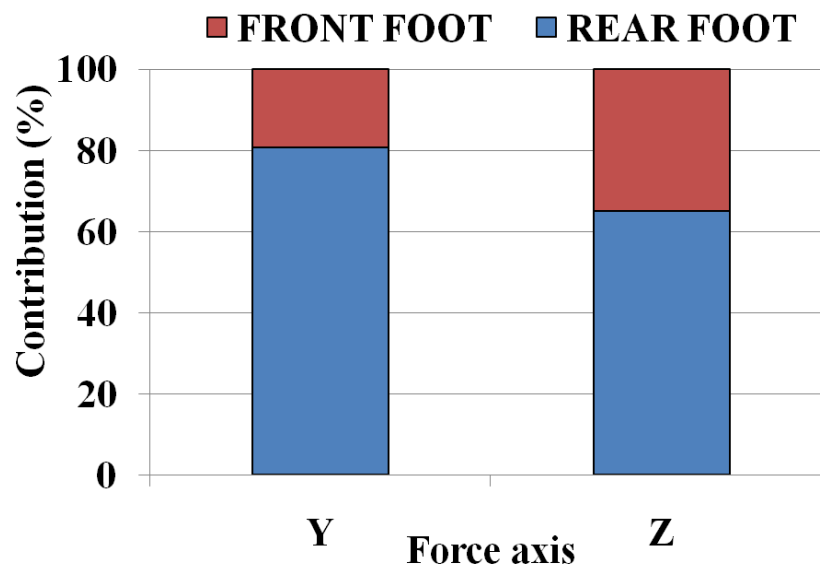


Figure 4.4: Front and rear foot contribution in the y- and z-directions as a percentage of the total impulse applied to the start block for the kick plate movement time (between the first movement and kick plate toe-off).

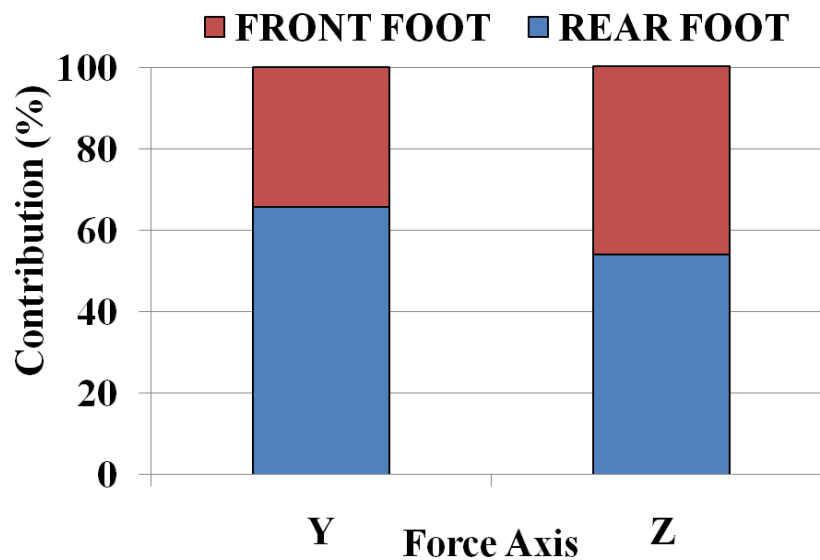


Figure 4.5: Front and rear foot contribution in the y- and z-directions as a percentage of the total impulse applied to the start block during the entire movement time (between the first movement and take-off).

## Discussion

The primary purpose of this project was to examine differences between the power limb and non-power limb at the front of the block when starting from the OSB11 platform.

The swimmers demonstrated a greater horizontal take-off velocity when the power limb was placed at the front of the block when using the track start technique from the OSB11 platform. However, this result does not support our first hypothesis, that placing the foot of the power limb on the rear would be advantageous. Although the differences are small between foot locations, they should not be dismissed. The 0.07 m/s increase in horizontal take-off velocity is the equivalent to 2% (Table 4.1). ~~This would also translate to a greater dive distance or horizontal displacement if all other factors were equal. Increase in horizontal take-off velocity and decrease in reaction time occurred when the power limb was placed on the front. Additionally, the power limb was found to be the right for two-thirds of the swimmers.~~ This is analogous to pilot data presented by Slawson et al, (2011) ~~who.~~ They examined different leg start positions in a case study and showed that the swimmer was able to dive further with the right leg on the front ~~versus the left.~~ ; ~~h~~ However, they ~~did not differentiated limbs as~~ right or left rather than elements such as limb dominance or power; they did not perform individual limb testing to enable these evaluations. ~~dominant for this swimmer. Our results show that for four of our swimmers the left foot should be placed at the front.~~

On a previous model start platform, researchers explored differences in footedness (Hardt et al., 2009). They found that there were no significant differences to having either the right or left foot at the front of the platform and were not able to make a link to footedness or strength. Conversely, findings from this project show differences between

power limb locations when starting from the OSB11. One key difference between this study and Hardt et al. (2009) is limb tests used. We used the Single-leg triple hop for distance where Hardt et al., (2009) used the Waterloo Footedness Questionnaire - Revised and a one-legged countermovement jump to assess limb dominance and strength. In addition, we selected the triple hop test since it can easily be replicated by swimmers and coaches with minimal equipment and space. However, the present data with the OSB11 platform shows small but significant differences in horizontal take-off velocity between feet. Perhaps the findings vary between starting block models.

The second purpose of this study was to assess the contributions of each foot and to examine the time periods of different block phases. In order to perform this analysis, we divided the block phase into identifiable segments. After careful examination we determined that these new segments are: kick plate movement time (first movement to kick plate toe-off), kick plate contact time (start signal to kick plate toe-off), and front foot only time (kick plate toe-off to take-off) (Figure 4.3). To the best of our knowledge, research specific to these phases of swim start has not been presented when assessing start or block performance from the OSB11 (Tor et al., 2015; Slawson et al., 2011; Honda et al., 2012). Nonetheless, during the kick plate movement phase, swimmers applied most of the impulse from the rear foot (in both directions: Figure 4.3). However, this drops below 70% when it is assessed as the whole movement time (first movement to take-off: Figure 4.4). With the exception of the impulse applied in the y-direction during the kick plate movement time, the impulse results did not support our hypothesis that 70-90% of the impulse is generated from the rear foot. In addition, they spent 84% of the block time in contact with the kick plate. This proportion of time spent in contact with the

kick plate supported out hypothesis. Even though our data show that the power limb should be on the front of the block, forces applied to the kick plate should not be ignored. In fact, they appear to be instrumental to block performance. Previous research has shown that the kick plate and rear foot forces are important parts to the swim start from the OSB11 platform (Slawson et al., 2013). It is interesting to note that despite the contributions of the rear foot, the power limb should be placed at the front. Perhaps this is due to the nature of the final push phase of the start leading into take-off that requires strength and control to leave the starting block in the best form possible.

### **Practical applications**

This study demonstrated that both feet play an important role in block performance from the OSB11 platform. The main finding of this study showed that when utilizing the track start from the OSB11 the power limb should be placed at the front of the platform. For most swimmers tested this was the right limb, but not for all swimmers. If one is to be sure then testing is required. The single-leg triple hop for distance that was in this study should be performed by swimmers and coaches to determine the power limb. The test requires minimal equipment, space, and time to execute. This project also determined that the rear foot is important to block performance and is the source for most of the rearward impulses applied to the platform and therefore should not be overlooked. Future studies should explore the use of the single-leg triple hop test for assessing limb power and differences in front foot selection when performing the track start from previous block models since they are still in use.

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## Chapter 5. Location, Location, Location: Optimal Center of Mass Position

### Introduction

The Omega OSB11 is the new standard for starting blocks in international swimming competition. This block was introduced and first seen in competition in 2009. The main new feature of this block is the kick plate on the posterior portion of the platform (Figure 5.1). The kick plate is angled at 30 degrees with respect to the surface of the platform (Honda et al., 2010). The kick plate can be placed in five different positions over a range of 0.2 m (Omega Timing, 2009).



Figure 5.1: **The Omega® OSB11 start block The kick plate is angled at 30 degrees from the surface of the platform. The platform is angled at nine degrees from horizontal.**

In the OSB11's infancy, researchers examined start performance using the two main start techniques (grab and track) and compared start performance from the OSB11 and previous starting block models. Researchers found that the track start was significantly faster than the grab start from the OSB11 (Biel et al., 2010; Murrell & Dragunas, 2012). It was also noted that the starts from the OSB11 platform are significantly faster than those from previous models. Biel et al. (2010) found that swimmers had shorter block times and increased take-off velocities when diving from the OSB11 compared to its predecessors.

Recent research utilizing the OSB11 has focused on optimizing the set position for improved start performance. Researchers have examined, stance width, limb placement in the track start, kick plate position, and rear foot position. For example, Slawson et al. (2011) found that swimmers had a faster block time and take-off velocity when they narrowed their stance width. In the same project, they reported that a swimmer had a greater flight distance when placing the right foot on the front of the block. Similarly, in Chapter four, we found that horizontal take-off velocity was significantly faster when placing the power limb on the front of the block. Along the same vein, the findings of Chapter three showed that horizontal take-off velocity and time to 2 m is significantly improved by placing the foot on the top half of the kick plate.

Accordingly the swimmer's center of mass must move a greater distance to the front edge at take-off, which will take more time. Since take-off velocity is proportional to integral of the force with respect to time, this additional time allows the swimmer to increase their impulse applied to the platform. Accordingly biomechanical principles indicate that there is a trade-off between take-off velocity and block time, as is reflected in the research

studies. It is uncertain if there is an optimal position in between the typically measured extremes of weighted starts where the swimmer can maximize both block time and take-off velocity. This project had two purposes: (i) to determine optimal centre of mass location in the set position, and (ii) to evaluate front- and rear-weighted starts on the Omega OSB11 start block. Research from an older model platform found that a front-weighted set position had a significantly faster block time than the rear-weighted (Welcher et al., 2008). In addition, the rear-weighted start had a significantly greater take-off velocity (Welcher et al., 2008). Based on the findings of Welcher et al. (2008) and our outcome measure of 2 m time, we hypothesized that the average optimal center of mass position would be more rearward than forward. Our second hypothesis was that the rear-weighted start would produce a faster horizontal take-off velocity than the front-weighted start and conversely, the front-weighted start would produce a faster block time than the rear-weighted.

## **Methods**

### *Experimental Approach*

To evaluate a range of front- or rear-weighted starts a light strip was used to indicate the location of the swimmer's center of mass location. The lights identified eight different center of mass locations along the anterior-posterior axis over a range of 0.24 m. Once asked to "take their marks", the swimmers shifted their center of mass to the respective position indicated by the light strip, and were started. Swimmers were randomly tested three times at each position. We used a ranking system to evaluate the overall optimal position for each swimmer based on reaction time (RT), block time (BT), 2 m time

(2MT), and horizontal take-off velocity (TOV). To examine front- and rear-weighted starts, we extracted results from the first and eighth light positions and compared differences with regard to the four outcome measures (RT, BT, 2MT, TOV).

### *Participants*

Eleven adult swimmers from a Canadian sport centre volunteered to participate in this study (8 men and 3 women;  $M \pm SD$ ; age,  $21.7 \pm 2.5$  years; World points,  $817 \pm 40$  pts). The swimmers ranged from national finalists to international competitors. They all utilize the track start technique and have experience on the Omega OSB11 platform. Each swimmer provided informed consent, and the project was approved by the university's Research Ethics Board.

### *Instrumentation*

A replica of the Omega OSB11 starting block was installed on the bulkhead of the pool (Figure 5.2).

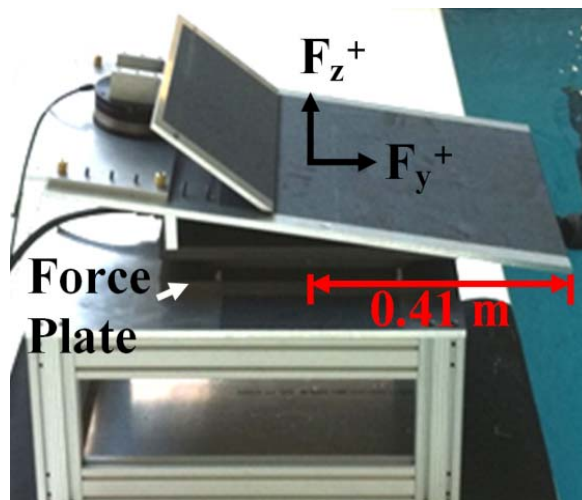
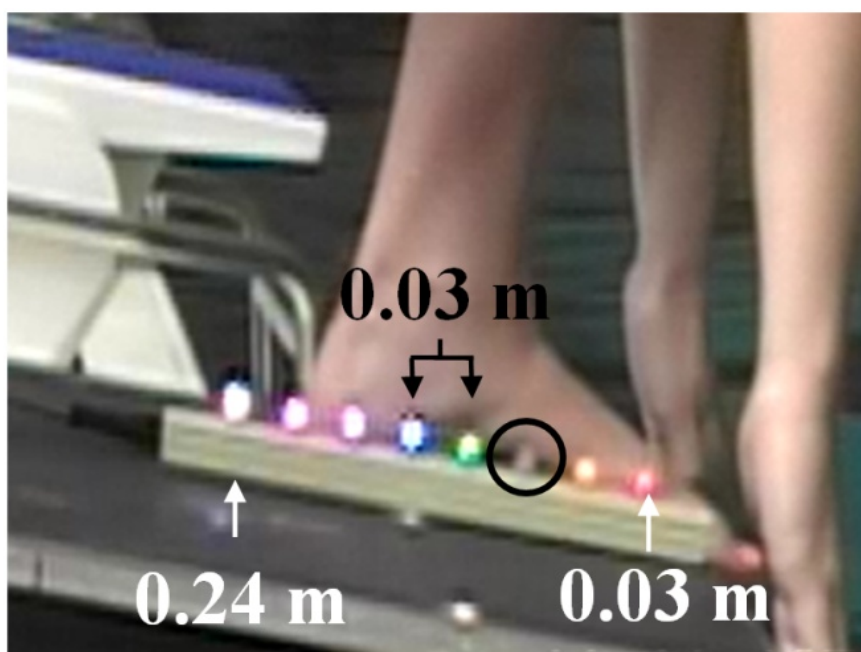


Figure 5.2: The replica of the OSB11 start platform. The force plate is located underneath the main start platform.

The replica platform was equipped with a tri-axial force plate (OR6-WP-2000, AMTI, Watertown, MA, USA) similar to previous studies (Arellano et al., 2000; Slawson et al., 2013). It also had a center of mass (COM) indicator consisting of eight different colour light emitting diodes (LED). The indicator was installed along the center of the platform from the front edge towards the kick plate (Figure 5.3).



**Figure 5.3: The COM indicator placed on the replica platform. The third light (black circle) from the front edge is turned off indicating the COM location. The range of COM locations are shown under the light strip. The distance between the lights is indicated above in black**

The lights were spaced every 0.03m from the edge of the pool (0.03m, 0.06m, 0.09m, ..., 0.24m). A starting signal (Daktronics, Inc., Brookings, SD, USA) was used to start each dive and to replicate competition starting conditions. Voltage signals from the force plate and starter were digitized using a 16-bit analogue to digital conversion board (DAQPad-6015, National Instruments, Austin, TX, USA) and sampled at 1000 Hz. A custom

LabVIEW (Version 10.0, National Instruments, Austin, TX, USA) computer program extracted the instantaneous vertical force ( $F_z$ ) and moment about the x-axis ( $M_x$ ) signals to calculate the center of pressure (COP) location in the anterior-posterior direction (y) by dividing the  $M_x$  by the  $F_z$  signals. The distance between the edge of the pool and the center of the force plate (0.41 m) was added to the  $COP_y$ , so that the center of pressure was expressed relative to the front of the block. Given that the average location of the whole-body COM will be directly above the COP during static stance (Winter et al., 1996), the instantaneous  $COP_y$  location was output to the COM indicator turning the corresponding light off. This enabled the swimmers to receive instantaneous feedback about their COM location while getting into the set position. All voltage data were saved for post processing using a custom designed LabVIEW program.

### *Experiment*

The day before the experiment each swimmer was tested for limb power and given an opportunity to familiarize themselves with the novel block and light strip. Before the start of testing, the swimmers performed a 500 m swim and three starts to become acquainted with the replica block and starting procedure. Each swimmer performed 24 maximal effort starts to the five meter mark. Three starts were performed at each light position with approximately two minutes of rest in between to mitigate fatigue. The order of  $COP_y$  locations was randomized for each swimmer to control for learning. Similar to competition, we used “Take your mark” to cue the swimmers to get into the set and proper light position. Once the proper position was achieved, as indicated by the appropriate light extinguishing on the light strip, the start signal sounded and swimmers

performed their start. The starts were standardised in kick plate height and dominant limb position. The kick plate was set at their preferred position.

### *Data Analysis*

Force plate voltage data collected during the tests were converted to forces and low-pass filtered at 25 Hz using a second-order Butterworth filter. Key time points (start signal, first movement, and take-off) were identified in the data using the onset detection integration method of Santello & McDonagh (1998). These time points were used to identify the reaction time (time between start signal and first movement) and block time (time between start signal and take-off). The horizontal take-off velocity and time to 2 m were also calculated. The horizontal take-off velocity was calculated using the impulse-momentum relationship (Eq.1) (Galbraith et al., 2008; Hay, 1993; Murrell & Dragunas, 2012)

$$v_y(t) = \int_{t_i}^{t_o} \frac{F_y(t)}{m} dt \quad (\text{Eq. 1})$$

where  $F_y$  is the horizontal force,  $t_i$  is the time of the start signal, and  $t_o$  is when the diver leaves the block. Body mass ( $m$ ) was calculated as the average vertical force during a 500 point sample (0.5 s) of quiet stance prior to the start signal divided by  $g$  ( $9.81 \text{ m/s}^2$ ). To calculate the time to 2 m, we used the horizontal velocity (Eq. 1) and the initial location of the whole body center of mass (COM) in the anterior-posterior direction ( $y$ ) as variables in the equation of projectile motion. The initial center of mass location ( $\text{COM}_{y_i}$ ) was calculated as the average over the same 0.5 s interval of quiet stance that was used to calculate body mass. This average  $\text{COM}_{y_i}$  was expressed relative to the front edge of the



block. The final center of mass position ( $COM_{yo}$ ) with respect to time was calculated by using the projectile motion equation (Eq.2)

$$COM_{yo}(t) = COM_{yi} + \int v_y(t) dt \quad (\text{Eq. 2})$$

where  $v_y$  is the horizontal velocity (Eq. 1),  $COM_{yi}$  is the initial center of mass location, and  $COM_{yo}$  is the final location of the center of mass relative to the edge of the pool.

From the position data, the time that the horizontal displacement of the  $COM_{yo}$  was equal to 2 m was extracted.

### *Statistical Analysis*

The optimal  $COM_{yi}$  position was calculated using a ranking system utilizing the reaction time, block time, take-off velocity, and 2 m time results. Shapiro-Wilk tests for normality were executed to examine the distribution of optimal kick plate location.

As a secondary analysis, we extracted the data from the first and eighth position and compared the differences in reaction time, block time, horizontal take-off velocity, and time to 2 m. An average was calculated for each swimmer in the first and eighth position for all parameters. The averages were tested for normality and homogeneity of variances where the Shapiro-Wilk and the Levine's tests were interpreted respectively (SPSS Version 15.0 for Windows; IBM, Corp., Armonk, NY, USA). Two-tailed paired t-tests were performed to assess the statistical significance of the difference between the first and eighth position for each of the four parameters (RT, BT, TOV, and 2MT). If the data were not normally distributed, then non-parametric analyses (Wilcoxon-Signed Ranks Test) were performed. The acceptable level of significance was set at  $p < 0.05$ .

## Results

The 11 swimmers' optimal start position fell between the first and sixth position; no swimmers had optimal positions of 0.21 or 0.24 m (Figure 5.4). The average optimal  $COM_{yi}$  position was close to the middle of our testing range ( $M = 3.90$ ,  $SD = 1.58$ , median = 4.0). The optimal start position results were normally distributed ( $p = 0.645$ ), with skewness of  $-0.379$  ( $SE = 0.661$ ) and kurtosis of  $-0.404$  ( $SE = 1.279$ ).

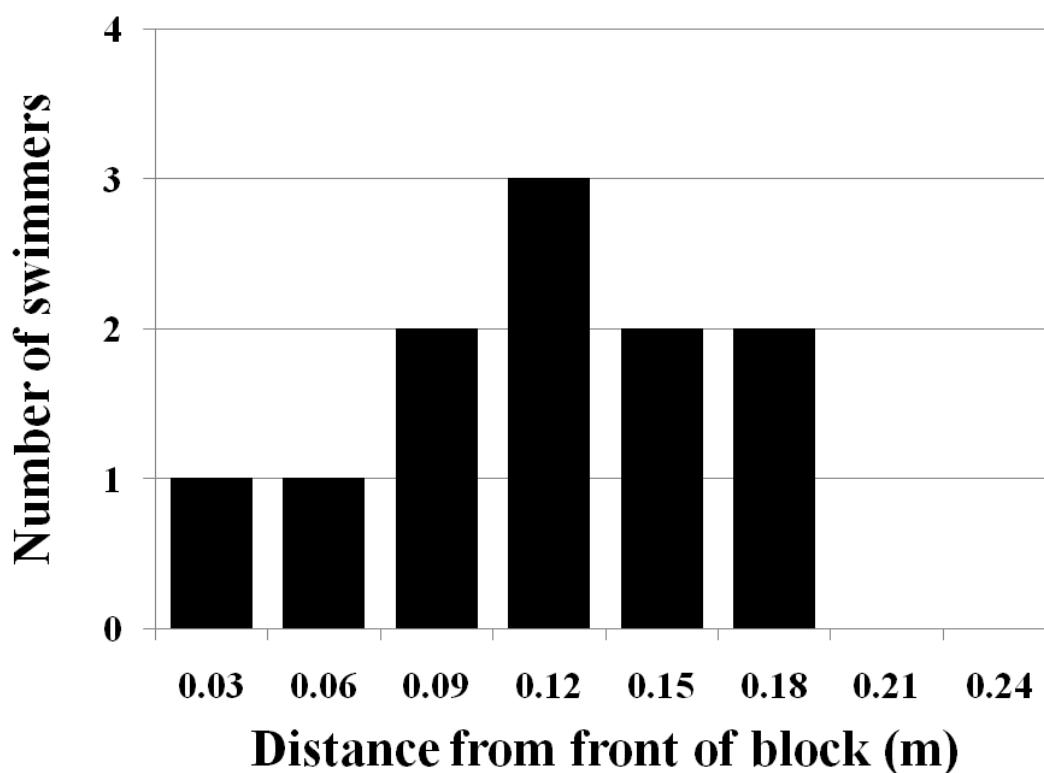


Figure 5.4: Frequency distribution of optimal center of mass locations by distance from the front edge of the starting block.

Considering the front- versus rear-weighted configurations, there were statistically significant differences between three of the four parameters ( $p < 0.05$ ), and the 2 m time difference was approaching significance ( $p = 0.055$ ). On average, the swimmers showed decreased reaction time and increased horizontal take-off velocity in position 8 than in

position 1 (Figure 5.5). However, block time and 2 m time were faster when the  $COM_{yi}$  was in the first position than the 8th (Figure 5.5).

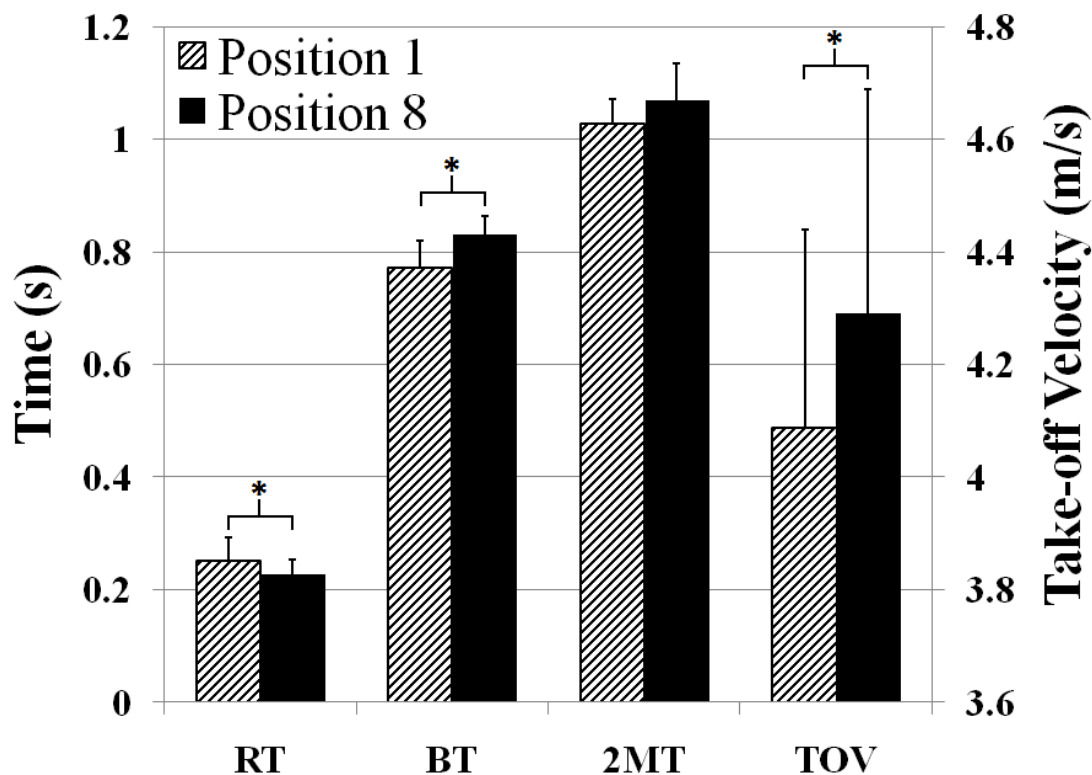


Figure 5.5: Reaction time (RT), block time (BT), horizontal take-off velocity (TOV), and 2 m time (2MT) for the front-weighted (position 1) and rear-weighted configuration (position 8).

## Discussion

The first purpose of this experiment was to examine optimal center of mass location when starting from the OSB11 platform. We hypothesized that the optimal plate position would be towards the rear based on findings by Welcher et al., (2008). However, this hypothesis was not supported by the data. Our data show that all our swimmers' optimal positions were between 0.03 m to 0.18 m. None of the swimmers had optimal COM locations in the two most rearward locations (Figure 5.4; position 7 and 8, with distances of 0.21 and 0.24 m respectively).

The second purpose of this investigation was to examine front- versus rear-weighted starts by comparing the results from position 1 (0.03 m) and position 8 (0.24 m). We hypothesized that the rear-weighted start would produce a faster horizontal take-off velocity than the front-weighted start and that the front-weighted start would produce a faster block time. This hypothesis is supported by the data. Our results show that the swimmers had a significantly greater horizontal take-off velocity in the rear-weighted position and a significantly faster block time in the front-weighted stance.

Welcher et al. (2008) had performed a similar study with similar results. We did not measure time to 5 m, but we measured the reaction time. The reaction time data show that swimmers were faster in the rear-weighted by 0.02 s over the front-weighted. However, the rear-weighted starts spend more time on the block than the front-weighted starts; their block time is 0.06 s longer. This makes sense since the center of mass has further to move, and would obviously take more time to get off the block (if all other parts were equal). Interestingly, the difference between the front- and rear-weighted starts at 2 m is 0.02 s. The greater horizontal take-off velocity from the rear-weighted starts helps the rear-weighted catch up to the front-weighted and likely matches or surpasses the front-weighted starts as time progresses. This likely explains why Welcher et al., (2008), showed that the rear-weighted starts maintained velocity better at 5 m than front-weighted starts. Horizontal take-off velocity may have an overriding influence compared to the other temporal start variables since it may help the swimmer enter the water with a higher velocity, and spend more of the start phase at a higher velocity.

When we examined the optimal center of mass location, it is evident that the majority of the swimmers' results were in the middle four positions (0.09 m, 0.12 m, 0.15 m, 0.18 m)

of our range. We expected the frequency distribution to be more rear-weighted (to the left of the figure) with a greater magnitude of negative skewness given the results from Welcher et al., (2008) (Figure 5.4). The optimal position shows that the swimmers are gaining the best of both extremes. They are optimizing horizontal take-off velocity and block time by being mid-weighted.

In addition, the optimal analysis shows that there is an element of individuality; two swimmers had optimal locations in the first two positions. This may be evidence of outliers since most of the swimmers' optimal positions were between position three and six and suggests that individual testing should be performed. Determining the optimal position via testing may provide the swimmer with gains of hundredths of a second since deviation in block times can be as much as 0.05 s between COM positions which makes up approximately 6% of the block time. Furthermore, 0.05 s (or less) has been the difference between swimmers in many Olympic Games and other international competitions. Similar differences in performance were also found by other researchers evaluating optimal swim start position (Kibele et al., 2014; Welcher et al., 2008). Kibele et al. (2014) examined four different COM configurations in both height and anterior-posterior location. Their findings show that the block time can differ by as much as 0.1 s between their start configurations. These findings are congruent with those of Welcher et al., 2008, who showed that front- and rear-weighted track starts can differ by about 0.07 s in block time alone. The present study, along with Kibele et al. (2014) and Welcher et al. (2008) show that different COM locations can have a substantial effect on block time.

There were several limitations to the present study that need acknowledgement. First of all, the ranking system evenly weighted the parameters used to calculate the optimal

position which is likely not ideal. However, this approach was used as an ideal weighting scheme is not known at this time (Tor et al., 2015). Secondly, the analysis comparing the first and eighth and position did not include the data from positions two through seven, which may have shed additional light on the relationship between COM configuration and swim start performance.

## Conclusions

Given that most of the swimmers' optimal COM positions fell in the middle of the range we tested, we suggest a mid-weighted start. This results in an optimal trade-off between larger take-off velocities with rear-weighted configurations compared to shorter block times with front-weighted configurations. Testing for optimal position is the only way to determine optimal COM location as the swimmers had a large range of optimal positions.

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## Chapter 6. Do Short Feedback Sessions Measure Up?

### Introduction

The start is an important part of all swimming races. The start phase of swimming can represent up to 25% of the race time in the 50 m events. In many races at the 2012 Olympic Games, medals were decided within tenths, and in some cases even hundredths of a second. However, Maglischo (2003) believes that time differences such as these can be gained from an improved start performance.

Some researchers have examined characteristics of better start performances from the Omega OSB11. Some have noticed that different kick plate positions can increase take-off velocity (Honda et al., 2012; Takeda et al., 2012). In chapter five, we found that swimmers' optimal block performance occurred when the COM location was between 0.03 m (front-weighted) and 0.18 m (mid-weighted). In addition, Slawson et al. (2012) examined stance width and knee angles. They found that swimmers had a greater take-off velocity when the stance width was narrowed, and that optimal knee angles were between 135° and 145° for the front leg and the rear limb should have an angle between 75° and 85°. Similarly, in chapter four, we found that swimmers had a greater horizontal take-off velocity when the power limb was placed at the front of the block. These studies all offer pieces of information for optimizing the swim start from the OSB11 platform. However, none have examined the application of these findings during swim start practice.

Several researchers have performed interventions in an effort to improve start performance. The interventions typically lasted between three to nine weeks (Bishop et al., 2009; Blanksby et al., 2002; Breed et al, 2003; Hohmann et al. 2010). Interestingly one of these studies used feedback from a coach as the intervention (Blanksby et al.,



2002), while the others used a form of dry land training (Bishop et al., 2009; Breed & Young, 2003; Hohmann et al., 2010). Three weeks was the shortest length of these interventions that identified meaningful differences in start performance. Conversely, none have explored a shorter time period for an intervention in swimming starts. For example, a single session may be more typical of coaches than to arrange a three week intervention.

The purpose of this study was three-fold (*i*) to evaluate the effect of a short feedback session, (*ii*) to compare kinetic swim start modifications based on platform and body adjustments ~~made~~ using the findings from chapters three, four and five to those made by an age group swimming coach, and (*iii*) to compare two different orders of feedback on block performance. It was hypothesized that the coached feedback will demonstrate a faster time to 2 m than the kinetic feedback since the coached feedback would likely involve start modifications closer to the swimmers' preferred position than the kinetic feedback which may capitalize on the swimmers' well learned patterns. In addition, we hypothesized that the order of the feedback would have no effect on time to 2 m because swimmers would be exposed to both forms of feedback.

## **Methods**

### *Experimental Approach*

To evaluate the effects of a single swim start feedback session, two groups of swimmers received coached and kinetic feedback as they performed a series of dives. Each group was exposed to a different order of feedback; coached then kinetic, or kinetic then coached. The experiment evaluated each of these forms of feedback individually, and two

variations of combined feedback (coached-kinetic vs. kinetic-coached) on the swimmers' time to 2 m.

### *Participants*

Twenty swimmers (7 males and 13 females) from a Canadian club program participated in this study. All swimmers provided informed consent approved by the university's Health Sciences Research Ethics Board. The swimmers were divided into two matched groups that received feedback in one of two different arrangements: coached-kinetic (Group Ck) or kinetic-coached (Group-Kc). To ensure comparable performance levels, a method used by Dragunas et al. (2012) for grouping was utilized (Group-Kc:  $n = 10$ ; mean  $\pm$  SD; age,  $16.2 \pm 1.3$  years; 50 m freestyle,  $28.22 \pm 2.30$  s and Group-Ck:  $n = 10$ ; mean  $\pm$  SD; age,  $15.4 \pm 1.5$  years; 50 m freestyle,  $28.40 \pm 1.75$  s). There was no significant difference in 50 m freestyle time between the groups ( $p > 0.05$ ). Each of these groups was divided into two sub-groups of five swimmers to emulate a camp or circuit style practice where coaches may work with smaller groups to maximize exposure. All swimmers utilized the track start technique.

Before performing the dives, all swimmers performed six trials of a single-leg, triple hop for distance test (3 right, 3 left) to evaluate limb power (Chapter four). Each trial was performed on a five minute interval to avoid muscular fatigue. The trial with the maximal distance determined their power limb. These results were used in the kinetic portion of the feedback.

### *Instrumentation*

For this project, a replica Omega OSB11 starting block was installed on the bulkhead of the pool. The replica platform, similar to that used in other research (Pearson et al., 1998; Slawson et al., 2012), was equipped with a tri-axial force plate (OR6-WP-2000, AMTI, Watertown, MA, USA). It had a custom designed center of mass (COM) indicator consisting of eight different coloured light emitting diodes (LEDs) spaced every 0.03 m from the edge of the pool (0.03 m, 0.06 m, 0.09 m, ..., 0.24 m). The indicator was installed along the center of the platform from the front edge towards the kick plate (Figure 6.1).

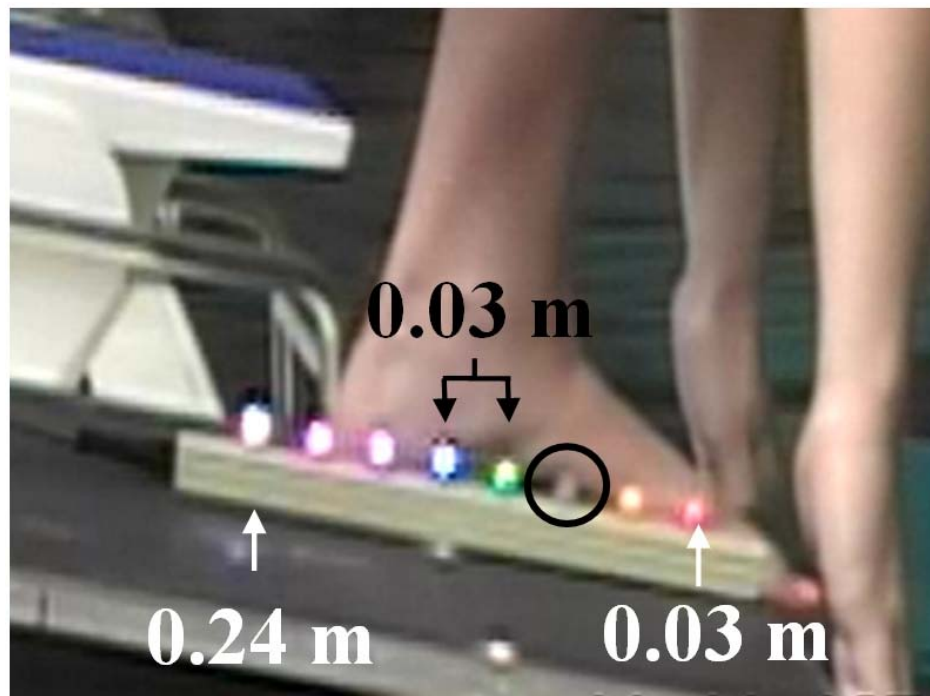


Figure 6.1: The COM indicator placed on the replica platform. The third light (black circle) from the front edge is turned off indicating the COM location. The range of COM locations are shown under the light strip. The distance between the lights is indicated above in black.

Signals from the force plate and starter (Daktronics, Inc., Brookings, SD, USA) were digitized using a 16-bit analogue to digital conversion board (DAQPad-6015, National Instruments, Austin, TX, USA). They were sampled at 1000 Hz, using a custom designed LabVIEW program (Version 10.0, National Instruments, Austin, TX, USA). The software extracted the instantaneous vertical force ( $F_z$ ) and x-axis moment ( $M_x$ ) signals to calculate the real time center of pressure location (COP) in the anterior-posterior direction (y). The real time COP was expressed relative to the edge of the pool by adding it to the distance between the front edge of the platform and the center of the force plate (0.41 m). Given that the average location of the whole-body COM is directly above the COP during static activities (Winter et al., 1996), the instantaneous COP<sub>y</sub> location was output to the COM indicator turning the corresponding light off (Figure 6.1). This enabled the swimmers to receive instantaneous feedback about their COM location when they were in the set position. A second custom designed LabVIEW program saved the force data from the block performance.

#### *Time to 2 m*

Once the swimmer completed the dive, the start data were instantly analyzed and the 2 m time was calculated. The voltages were converted to forces and low-pass filtered at 25Hz using a 2<sup>nd</sup> order Butterworth filter. A horizontal take-off velocity ( $v(t)$ ) was calculated using the impulse-momentum relationship (Eq.1) (Galbraith et al., 2008; Hay, 1993; Murrell & Dragunas, 2012)

$$v(t) = \int_{t_i}^{t_o} \frac{F_y(t)}{m} dt \quad \text{Eq. 1}$$

where  $F_y$  is the horizontal force,  $t_i$  is the time of the start signal, and  $t_o$  is when the diver leaves the block. Body mass ( $m$ ) was calculated as the average vertical force during a 500 point sample (0.5 s) of quiet stance prior to the start signal divided by  $g$  ( $9.81 \text{ m/s}^2$ ). The position of the whole-body COM during the dive was calculated by solving a projectile motion equation (Eq. 2)

$$COM_{y^o}(t) = COM_{y^i} + \int v_y(t) dt \quad \text{Eq. 2}$$

where  $v_y$  is the horizontal take-off velocity (Eq. 2), and  $COM_{y^i}$  is the initial location of the COM relative to the edge of the pool at the onset of the start signal. The  $COM_{y^i}$  was calculated as an average from the same 0.5 s interval of quiet stance that was used to calculate body mass. From the position data, the time that the horizontal displacement,  $d(t)$ , was equal to 2 m was extracted. The 2 m time was output to a monitor as part of the kinetic feedback portion and changes to start position were made based on the result.

### *Experiment*

Before the experiment began, the swimmers performed a standardized warm-up of 500 m and three starts to familiarize themselves with the start signal and platform. The experiment began with a pre-test where the swimmers performed three maximal effort starts (Figure 6.2; pre-test). At least two minutes of rest were provided between starts to minimize the likelihood of muscular fatigue. Swimmers were asked to perform all starts with maximal effort throughout the protocol.

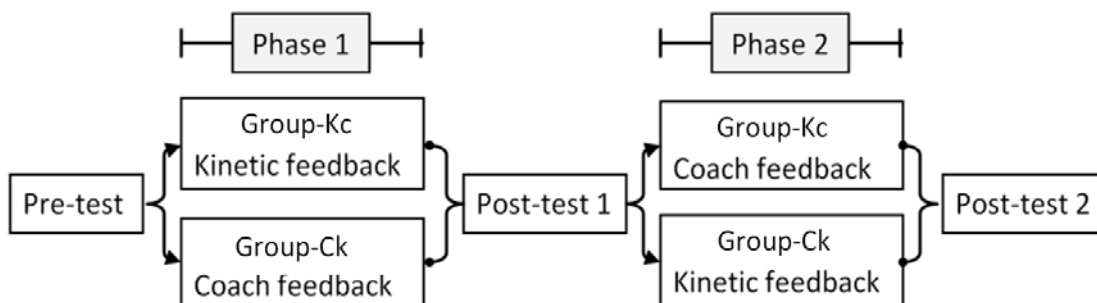


Figure 6.2: **Experiment design flowchart showing the two phases of feedback (Phase 1 and Phase 2) and three testing segments (Pre-test, Post-test 1, Post-test 2) that occur before and after feedback.**

In Phase 1, Group-Kc received kinetic feedback and Group-Ck was given coach feedback. The kinetic feedback incorporated findings from the previous chapters: placing the foot on the top half of the kick plate (a finding from Chapter three), and putting the power limb at the front of the block (a finding from Chapter four). The swimmers were instructed on their front and rear foot placement for the kinetic feedback session. In this portion of the feedback the swimmers did not receive feedback about their technique, only the 2 m time was revealed to them. The first part of the feedback session was spent testing various locations of the kick plate. The third (middle position) was the initial testing location of the kick plate. Then, the swimmer performed a trial at the fourth position (one position rearward), if this was faster than the initial then one more trial was performed in the fifth. However, if the trial at four was slower, then the kick plate was shifted to the second position and another trial was performed. If the 2 m time was faster in the second position then the first position was tested. Once the fastest 2 m time was recorded, they were instructed to use that kick plate setting for the COM location test. For the COM trials, the kick plate was controlled for as well as the foot locations. The same methodology was used for testing the COM location that was used for the kick plate

position. When the kinetic data had determined the optimal kick plate and COM location for each swimmer in the group, the swimmers performed a post-test which consisted of three maximal effort starts representing their performance after assimilating the information provided by the feedback (Figure 6.2: Post-test 1).

The coached part of the feedback was given by a Level 3 (Canada) certified swimming instructor. This coach used a stop watch and iPad (video), as is common practice in sport education (Sinelnikov, 2012). The start signal was used for each trial of the coached feedback session while the coach observed. Once all the swimmers performed a start they returned to the starting area and each received specific feedback from the coach. This specific feedback in verbal and visual form included elements regarding the swimmers' initial body position, joint angles of the lower limb, arm and head position, hip location, and comments about their sequence of efforts for the front and back legs. Once the coach completed his feedback, the swimmers repeated the starts and feedback. When the coach felt that the swimmers would no longer improve at that time, the swimmers moved on to the post-test (three maximal effort starts).

After completing the first post-test, the groups switched feedback type (Figure 6.2: Phase 2); Group-Kc received coached feedback and Group-Ck received the kinetic feedback. After completing the second block of feedback, the swimmers finished the protocol by performing three maximal effort starts representing their performance after assimilating the second round of feedback (Figure 6.2: Post-test 2).

### *Statistical Analysis*

Planned comparisons were performed to evaluate the differences between groups, and within group performance at the post-tests using two-tailed paired t-tests. We evaluated differences between pre-test and post test 1, pre-test and post test 2, post-test 1 and post test 2 in both groups. We also examined differences between groups at post test 1 and post test 2. A modified Bonferroni correction was used to adjust for multiple comparisons (Olejnik et al., 1997; Simes, 1986). All statistical analysis was performed using IBM SPSS Statistics software (Version 22, International Business Machines, Armonk, NY, USA).

### **Results**

Each swimmer performed an average of 27.65 ( $\pm$  3.74) swim starts. On average, the swimmers performed 18.0 ( $\pm$  3.38) swim starts during the feedback sessions. The coach and kinetic sessions involved an average of 6.5 ( $\pm$  1.24) and 12 ( $\pm$  2.50) swim starts, respectively.

At Post-test 1, after receiving the kinetic feedback, Group-Kc showed a statistically significant increase in 2 m time (Figure 6.3). This increase in 2 m time led to a statistically significant difference between the two groups at Post-test 1 since Group-Ck demonstrated no significant difference in 2 m time after receiving the coached feedback ( $p < 0.05$ ).



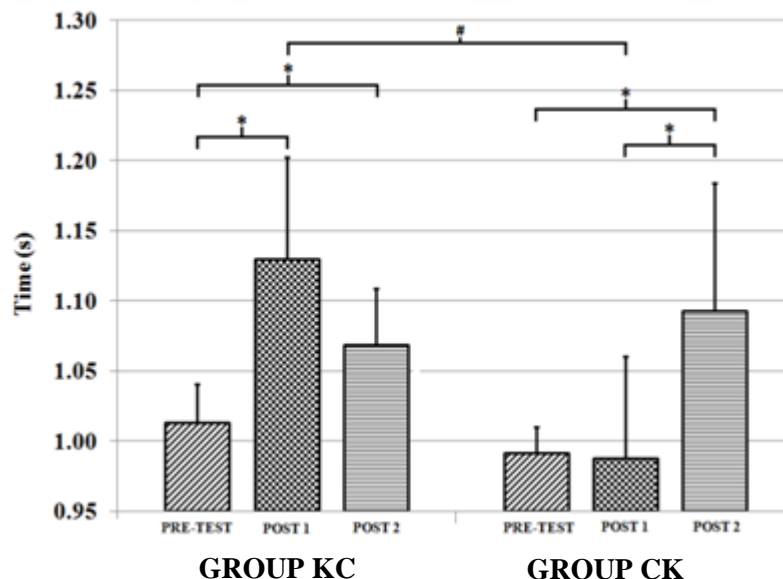


Figure 6.3: Group average 2m time in seconds at each test phase. Both groups were not statistically different at pre-test and after post-test 2. Statistically significant differences occurred between tests in both groups and between groups (after Post-test 1).

Notes: # = Significant differences between groups ( $p < 0.05$ ).  
 \* = Significant differences between tests ( $p < 0.05$ ).  
 Bars indicate SDs

After receiving the coached feedback, Group-Kc showed a statistically significant decrease in 2 m time from Post-test 1 to Post-test 2 ( $p < 0.05$ ). In contrast, after receiving the kinetic feedback, Group-Ck showed a statistically significant increase in 2 m time ( $p < 0.05$ ). At Post-test 2, there was no significant difference in 2 m time between groups.

## Discussion

### *Coached versus kinetic feedback*

This experiment examined the findings of previous projects as feedback compared to coached feedback. We hypothesized that coached feedback would produce a greater reduction in 2 m time than the kinetic feedback (post-test 1 of both groups). This is not

supported by the findings. The results show that at post-test 1, the kinetic feedback increased the 2 m time (decreased performance) whereas the coached feedback did not elicit a change.

Although both groups were slower at the end of the kinetic feedback portion, we do not believe that this indicates that the feedback or the instrumentation is useless. Rather, the explanation of this phenomenon lies in motor learning in which there are several forms of practice: blocked, random, constant and varied (Schmidt & Wrisberg, 2000). The kinetic feedback suggestions on set position were possibly more varied and random than those received in the coached feedback. While in the kinetic feedback session, the swimmers were instructed to place the power limb at the front, vary the amount of lean via COM location, change the kick plate location, and modify rear foot placement which can be drastic changes. All of these changes to the set position may have moved the swimmers much further out of their preferred positions than what was instructed in the coached session. Therefore, the changes suggested in the kinetic feedback may have made the session more random and varied than the coached feedback sessions.

Researchers have compared blocked and random practice over a single session and over longer periods of time. They have shown that in a single session the swimmers in random practice perform worse than those who were in blocked practice (Shea & Morgan, 1979). This may help explain our results after Post-test 1, where Group-Kc was significantly slower than their Group-Ck counterparts, and significantly slower than their own pre-test. We could infer from this that the kinetic session was more random than the coached feedback. However, the benefit of random practice seems to lie in time. Over the long term, Shea & Morgan (1979) have shown that those who were in a random practice group

outperformed the blocked group. Perhaps, if the Kc group was tested at a later date they may perform a better swim start than the Ck group.

Similarly, there is also a Variable and Constant form of practice. Schmidt & Wrisberg (2000) believe that Variable practice is a better form of learning than Constant practice since athletes are exposed to a variety of movements. They believe that exposure to different variations of a movement improves an athlete's "general capabilities" to perform a variety of movements within the given task. It would appear that the kinetic feedback exposed the swimmers to a much more random and varied feedback session than what was presented in the coached feedback and may help explain the statistically significant decrease in their block performance after the kinetic session. We are not able to conclude which form of feedback is better over time; however, neither form of feedback was able to produce improvement in such a short session. We believe that over a longer period of time the swimmers would be able to master the new start technique and be faster to 2 m. It is evident that one session was not enough time for the changes in body position suggested by the kinetic feedback to take effect. Nevertheless, this would make for an interesting exploration that may help identify if these coaching theories hold true to swim start training and performance. In general, most age-group swimmers receive minimal exposure to the Omega OSB11 and should be exploring many different start positions from it when the opportunity presents itself. This may help swimmers and coaches determine a better optimal position as opposed to simply deciding on what feels most comfortable; since this may not necessarily be the fastest position.

### *Combined feedback*

A second purpose for this project was to compare two different feedback sequences; coached then kinetic versus kinetic then coached. We hypothesized that the order of the feedback would have no effect on 2m; this was supported by the results. Although, the difference between both groups was not statistically significant, both sequences (groups) were significantly slower to 2 m after Post-test 2. The swimmers who went through the kinetic feedback first ended with a faster average 2 m time (by 0.02 s) than their counterparts who performed the coached feedback first, although this difference was not statistically significant. We believe that based on the inter-group comparison of the 2 m time, that feedback should be given as kinetic first then coached. From a practical perspective, the difference of a few hundredths of a second over 2 m can be meaningful in swimming despite the lack of statistical significance. This is evident in world class competition where medals are determined in such small amounts of time.

There are several limitations to this study that should be noted. The first limitation is the design of the kinetic feedback. The swimmers were likely not given enough information to be able to make appropriate technique changes since they were only provided with the time to 2 m rather than specific feedback about their technique. Second, only one coach provided the coach's feedback, which could make the findings difficult to generalize. In addition, both forms of feedback were performed in one session which may not lead to muscular fatigue, but staying focused may have been difficult, especially with many repetitions of similar tasks. Spreading the feedback over several sessions may yield different results and given the swimmer more opportunity to master the set position characteristics prescribed in the kinetic session. Another limitation is that we solely used

the 2 m time as the outcome measure. There may have been improvements in other block variables that were not detected. While there is empirical evidence to support the modifications used in the present study, however, data from previous work were collected using relatively high calibre swimmers. The previous three chapters generally used swimmers who were at least of varsity calibre and as experienced as Olympic swimmers. Unfortunately, it seems that the factors discovered in the previous three chapters may not be generalized to younger swimmers that use a single feedback session.

### **Conclusion**

The present study suggests that swim start position modification is not effective when it is provided in a single feedback session. Second, the set position modifications identified in chapters three, four and five may require more than a single session for swimmers to familiarize themselves to it and observe meaningful differences. Future studies should examine these forms of feedback and their effect on swim start performance over a longer period of time and how this relates to coaching theories. These intervention studies should avoid the crossover study design as carry over is possible (as seen in group KC).

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## Chapter 7. General Discussion

This thesis examined different track start set positions and their effect on block performance from the new Omega OSB11 platform. In addition this work has also evaluated and compared different forms of swim start feedback that are commonly provided to swimmers in a practice or camp session. This work identified elements of rear foot position, kick plate location, power limb placement, center of mass that may improve a swimmers' block performance. Given that the OSB11 was a new piece of equipment to the swimming community in 2009, empirical evidence of set position characteristics for optimal start performance was non-existent. This body of work sought to identify several characteristics of the set position and answer the following questions:

1. Does the body configuration in the set position differ between individuals?
2. Where should the feet be positioned in the set position when using the track start?
3. Are short feedback sessions effective for improving block performance?

The main findings of the projects were:

**Chapter 3:** Placing the foot on the top half of the kick plate showed a significantly faster horizontal take-off velocity and time to 2 m than when the foot was placed on the bottom half. Secondly, using a correlation between a ranking system's optimal kick plate position and anthropometrics it was noted that all the relationships were weak ( $\tau_b < 0.44$ ). This project demonstrates that placing the foot on the top half of the kick plate is better for block performance to 2 m and there is no relationship between optimal kick plate position and anthropometrics. These findings show that a swimmer should be placing the foot on the top half of the kick plate when performing the track start from the OSB11 platform,



and that swimmers should be tested to determine the optimal kick plate positions since this is not a function of segment lengths and anthropometrics.

**Chapter 4:** Horizontal take-off velocity was greater when placing the power limb at the front of the platform than at the rear when utilizing the track start technique from the OSB11 platform. The contribution analysis determined that swimmers are in contact with the kick plate for approximately 84% of the block time and that the rear foot contributes approximately 80% ( $\pm 6.60\%$ ) of the rearward impulse while the hind foot is in contact with the kick plate, which makes up 65% ( $\pm 5.08\%$ ) of the impulse applied during the block time. The results from this project demonstrate that swimmers should perform the single leg triple hop test to identify the power limb and place it at the front of the block when utilizing the track start from the OSB11.

**Chapter 5:** A mid-weighted start was the optimal center of mass location for most swimmers. Since the optimal locations of all swimmers were within 0.18 m from the front edge of the block, it was suggested that swimmers should be tested to determine the optimal location of their center of mass in the set position. The comparison between front- and rear-weighted starts stance shows that the rear-weighted track start had a significantly faster reaction time and horizontal take-off velocity. However, the front-weighted track start showed a significantly faster block time than the rear-weighted version. When 2 m time was assessed there were no significant differences between the rear- and front-weighted starts.

**Chapter 6:** A short coached or kinetic feedback session did not produce faster start times to 2 m. After the initial portion of the feedback session, the swimmers who received the

coached feedback showed no significant decrease in 2 m time from the pre-test. In contrast, the group who received the kinetic feedback based on the results from previous projects showed a significant increase in 2 m time at post-test 1. After the second round of feedback the groups were not statistically different, however, both were significantly slower than their pre-test (Figure 6.3). Swim start feedback sessions need more reinforcement over a longer period of time to be effective.

### ***Body Configuration***

The results of chapters three and five highlight that body configuration in the set position on the OSB11 platform may differ between individuals. In chapter three, the optimal kick plate location had a weak relationship to any of the anthropometric measures; this indicates that anthropometric measures cannot be used to predict swimmers' optimal kick plate position. Similarly, the findings from chapter five showed that swimmers' optimal center of mass location ranged over 0.18 m from the front edge of the block. Together these data show that swimmers need individual testing to determine the location of the kick plate and center of mass for optimal performance.

The purposes of chapter three and five were to identify an optimal location for the center of mass and kick plate for each individual and attempt to identify any trends. To date, published research evaluating the entire range of kick plate locations or center of mass position as it relates to the OSB11 platform is missing. This includes any attempt to determine an athletes' optimal kick plate and center of mass position. The research that is available on kick plate location has only examined several positions and omitted others which may be excluding important information (Slawson et al., 2011; Honda et al.,

2012). Perhaps, the researchers did this to avoid complexity with more independent variables and trials. As the number of independent variables increases so does the number of trials which can make testing extensive as was the case from chapter three and six. Swimmers performed 30 starts over the course of an hour which provided six trials at each position, but because of large variability and the number of independent variables it made the statistical analysis difficult. Conceivably, other researchers decreased the number of independent variables (kick plate positions) and increased the number of trials to achieve greater statistical power. However, there are five kick plate positions on the OSB11 and swimmers should be tested across all of them to gain a more complete understanding of the platform's intricacies.

Welcher et al. (2008) examined front- and rear-weighted track starts. Some of our results are in agreement with their findings. They found that the rear-weighted had a slower block time, time to entry, and greater take-off velocity than the front-weighted track start. This was congruent with the findings in chapter five for block time and time to 2 m and horizontal take-off velocity. Time to 2 m may be comparable to the time to entry since in both cases the swimmer has not entered the water at these points. A key difference of this thesis compared to previous research is the 2 m time outcome variable. The 2 m time variable allowed us to evaluate the swimmers' overall performance of the block phase before the introduction of other parameters that may dilute block performance variables. Although we acknowledge there are many variables in the swim start phase, the purpose of this method was to strictly evaluate the block phase (Tor et al., 2015).

### ***Foot Placement***

The experiments performed in chapter three and four show how the feet should be placed for optimal block performance from the OSB11 when using the track start. The findings suggest that the rear foot, should be placed on the top half of the kick plate and that the power limb should be placed at the front of the block. By making these changes in stance position, swimmers improved 2 m time by one to two percent which is proportional to a 1.5 s improvement in the 200 m freestyle.

In a recent publication, researchers examined stance width and found that swimmers had faster block times and take-off velocities with a narrower stance width (Slawson, 2011). Although slightly different, our studies show that changing the height of the rear foot can improve horizontal take-off velocity and 2 m time. It would appear that proper rear foot position can cause a significant increase in block performance and should be emphasized. However, our results are not in agreement with a project evaluating foot position on an older start platform model (Hardt, 2009). They examined footedness and stance position as preferred and non-preferred in the track start. They did not find a relationship between the Waterloo Footedness Questionnaire or single-leg hop and the foot at the front for which the fastest start was performed. In contrast, the data from chapter four show that the swimmers had a significantly greater horizontal take-off velocity by placing the power limb at the front of the block. This difference from their findings may be attributed to differences in the methods used to determine power limb. Hardt et al. (2009) used : (i) the Waterloo Footedness Questionnaire and (ii) the one-legged countermovement jump where the single leg triple hop for distance was used in this thesis. We selected the triple hop because it emulates the final push phase of the track start in swimming and is a valid

test of limb power and strength (Gustavsson et al., 2006; Hamilton et al., 2008; Reid et al., 2007; Ross et al., 2002). The limitations of the methods used by Hardt et al (2009) are that the questionnaire does not take a physical measurement and the countermovement jump is solely performed in the vertical direction which is not the case for the track start in swimming.

### ***Feedback***

Lastly, the use of one short feedback session is not an effective means to elicit meaningful changes in block performance. The results of chapter six show that swimmers did not show a significant decrease in their 2 m times after either form of feedback or both in combination. We do not know the minimum amount of time it takes to make meaningful changes in block performance, but these results show that it is longer than one session. Such a short amount of time has not been used in a swim start intervention study but may be utilized by coaches in practice and training camps. Previous intervention studies have taken substantially more time to allow for changes to take effect (Bishop et al., 2009; Blanksby et al., 2002; Breed & Young, 2003; Hohmann et al., 2010; Girold et al., 2006). The shortest of these interventions was three weeks and was able to detect improvements in strength and swimming performance (Girold et al., 2006). Clearly, modifications to start techniques need to be reinforced over time as opposed to a single session. Perhaps this would lead to greater performances later if feedback was reinforced periodically as is suggested by Shea et al. (1979) and Schmidt & Wrisberg (2000).

Our intervention study utilized findings from the previous chapters that demonstrated a significant improvement in performance, for example, placing the rear foot on the top half of the kick plate and the power limb at the front edge of the block. Both of these specific examples showed a significant improvement in a start parameter in their respective chapters. However, the swimmers did not show improvement in a short session using these findings. We made the assumption that the combination of the findings would be complementary. However, this does not appear to be the case. We believe that we may have inadvertently caused a feedback overload and put swimmers outside of their comfort zone. Interestingly, this is not necessarily a negative of feedback and practice. Principles of motor learning have shown that initial performances may be sub-optimal if taken outside the comfort zone, but over time those who were taken out of their comfort zone, tend to perform better than those who were not (Schmidt & Wrisberg, 2000).

### **Future Research**

Although the OSB11 has been the standard at international competition, there is still much to learn about optimising swim start performance from it. The following experiments can help the advancement of our understanding optimal performance from this platform.

- Investigations into optimal joint angles specifically the angle, knee and hip of both the front and rear limb.
- Further testing of the current method or establishing a better method to determine the optimal location of the kick plate and center of mass.

- Examination of the relationship between kick plate location and strength and/or flexibility.
- Future studies controlling for the rear foot height and width on the kick plate.

### **Limitations**

This research has examined several important aspects of start stance on the OSB11 platform. Since the OSB11 was relatively new at the time of the projects several limitations need to be addressed. First, there was no control made for the stance width throughout the projects which can change performance as identified in Slawson et al. (2011). Secondly, most of the collections took place in a transition period of training. This may have caused decreases in strength or changes in technique. Other limitations are the 2 m time and the ranking system. The 2 m time has not been reported in previous literature and may make results difficult to compare; however, the purpose of this thesis was to strictly examine the block phase of the swim start. The ranking system was used as a tool to identify a swimmers' optimal location of the kick plate and center of mass which has not been used in swimming literature of optimal start positions for individual swimmers. Its shortcoming is in that it weights all the parameters equally which is likely not the case. Finally, the studies did not consider the take-off angle, nor vertical and resultant take-off velocities.

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## Appendix A: Explanation of The Ranking Method

The ranking system used reaction time, block time, 2 m time, and take-off velocity. The system is based on the ranking system used in non-parametric statistics such as the Kruskal-Wallis one-way analysis of variance. This Appendix will describe (in detail) step by step how the method calculates an optimal position. The example will use 15 starts with three at each of the five kick plate settings (Table A.1). To begin, the time and velocities were extracted from the force plate data (Table A.1).

**Table A.1:** Example data of reaction time, block time, time to 2 m, and take-off velocity for 15 start trials for swimmer A. Data is shown by kick plate position and is relative to the start signal where time is equal to zero.

Kick Plate Position	Trial	Reaction Time (s)	Block Time (s)	Time To 2m (s)	Take-Off Velocity (m/s)
1	1	0.188	0.689	0.967	3.990
	5	0.193	0.721	0.966	4.202
	9	0.200	0.729	0.970	4.212
2	8	0.188	0.710	0.951	4.244
	10	0.171	0.696	0.939	4.208
	14	0.195	0.705	0.963	4.115
3	6	0.216	0.722	0.958	4.290
	11	0.191	0.697	0.951	4.172
	4	0.190	0.692	0.923	4.325
4	15	0.197	0.704	0.950	4.220
	2	0.176	0.692	0.929	4.286
	13	0.161	0.676	0.908	4.281
5	2	0.186	0.691	0.925	4.283
	7	0.169	0.682	0.935	4.163
	12	0.164	0.677	0.918	4.243

The second step was to calculate the absolute value for each temporal variable (Table A.2). In this example, this meant that the reaction time was subtracted from the block time and block time was subtracted from the 2 m time to provide an absolute block and 2 m time. This was done to ensure we were accounting for the additional time required for the block time and discounting the reaction time which is a component of the block time. The reaction time was taken as the absolute value since it is the first measured variable and begins when time is equal to zero.

**Table A.2:** Data of swimmer A demonstrating absolute value calculations.

The reaction time was subtracted from the block time and block time was subtracted from the 2 m time.

Kick Plate Position	Trial	Reaction Time	Block Time		Time To 2m		Take- Off Velocity
		Raw	Raw	Abs	Raw	Abs	Raw
		(s)	(s)		(s)		(m/s)
1	1	0.188	0.689	0.500	0.967	0.278	3.990
	5	0.193	0.721	0.528	0.966	0.245	4.202
	9	0.200	0.729	0.530	0.970	0.241	4.212
2	8	0.188	0.710	0.522	0.951	0.241	4.244
	10	0.171	0.696	0.526	0.939	0.243	4.208
	14	0.195	0.705	0.510	0.963	0.258	4.115
3	6	0.216	0.722	0.505	0.958	0.236	4.290
	11	0.191	0.697	0.506	0.951	0.254	4.172
	4	0.190	0.692	0.502	0.923	0.230	4.325
4	15	0.197	0.704	0.507	0.950	0.246	4.220
	2	0.176	0.692	0.515	0.929	0.238	4.286
	13	0.161	0.676	0.515	0.908	0.233	4.281
5	2	0.186	0.691	0.504	0.925	0.234	4.283
	7	0.169	0.682	0.513	0.935	0.253	4.163
	12	0.164	0.677	0.513	0.918	0.241	4.243

The third step was to rank all the variables and sort them by condition. The temporal variables in the present example were ranked from one to 15, one being the smallest

amount of time and 15 being the greatest (Table A.3). In the case of take-off velocity, the ranking was inverted making the greatest take-off velocity ranked as one, and the smallest take-off velocity as 15. In the event that the times or velocities were the same to the thousandth, we used the next decimal place as a determinant value to break a tie between two trials.

**Table A.3:** The values used in the ranking method and their rank by parameter. The results for each trial were ranked from one to fifteen shown in the rank column. Reaction time, block time, time to 2 m were ranked from fastest to slowest. Take-off velocity was ranked in reverse making the greatest velocity a rank of one and the slowest a rank of 15.

Kick Plate Position	Trial	Reaction Time		Block Time		Time To 2m		Take-Off Velocity	
		Raw (s)	Rank	Abs (s)	Rank	Abs (s)	Rank	Raw (m/s)	Rank
<b>1</b>	1	0.188	8	0.500	1	0.278	15	3.990	15
	5	0.193	11	0.528	14	0.245	10	4.202	11
	9	0.200	14	0.530	15	0.241	7	4.212	9
<b>2</b>	8	0.188	7	0.522	12	0.241	8	4.244	6
	10	0.171	4	0.526	13	0.243	9	4.208	10
	14	0.195	12	0.510	7	0.258	14	4.115	14
<b>3</b>	6	0.216	9	0.505	2	0.236	1	4.325	1
	11	0.191	15	0.506	4	0.254	4	4.290	2
	4	0.190	10	0.502	5	0.230	13	4.172	12
<b>4</b>	15	0.197	5	0.507	11	0.246	5	4.286	3
	2	0.176	1	0.515	10	0.238	2	4.281	5
	13	0.161	13	0.515	6	0.233	11	4.220	8
<b>5</b>	2	0.186	6	0.504	3	0.234	3	4.283	4
	7	0.169	3	0.513	8	0.253	12	4.163	13
	12	0.164	2	0.513	9	0.241	6	4.243	7

The final step of this method was to calculate the sum of ranks for each condition. The ranks for three trials at each kick plate setting were added together for each start

parameter (Table A.4). The total sum of ranks was calculated for each kick plate setting resulting in an overall total across all parameters for each kick plate condition.

**Table A.4:** The sum of ranks for 15 start trials. A sum of ranks is shown for each parameter by kick plate position. The Total sum of ranks shows the total of ranks across all parameters for each of the five kick plate settings. The lowest total sum of ranks was position 5, and the highest total sum of ranks was position 1.

Kick Plate Position	Trial	Reaction Time	Block Time	Time To 2m	Take-Off Velocity	Total Sum of Ranks
		Rank	Sum of Ranks	Rank	Sum of Ranks	
1	1	8	1	15	15	130
	5	11	14	10	11	
	9	14	15	7	9	
2	8	7	12	8	6	116
	10	4	13	9	10	
	14	12	7	14	14	
3	6	9	2	1	1	78
	11	15	4	4	2	
	4	10	5	13	12	
4	15	5	11	5	3	80
	2	1	10	2	5	
	13	13	6	11	8	
5	2	6	3	3	4	76
	7	3	8	12	13	
	12	2	9	6	7	

The optimal in this example is setting number five because of the lowest total sum of ranks (76). Closer examination of the ranks show that across all the temporal variables and take-off velocity, this swimmer is consistently better when the kick plate is positioned at five.

## Appendix B: Specifications of The Omega OSB11 Replica Platform

<b>Replica Platform Specifications</b>				
	<b>Height</b>	<b>Width</b>	<b>Length</b>	<b>Weight</b>
	<b>(mm)</b>	<b>(mm)</b>	<b>(mm)</b>	<b>(kg)</b>
<b>Replica Platform (constructed)**</b>	660.4	714.4	914.4	129.87
<b>Notes:</b> * The front edge of the platform is 419.1 mm from the bottom of the riser box. ** See Figure B.1				
<b>Kick plate</b>	127	520.7	396.9	11.45
Load Cell - Omega 160 (ATI)*	56	190	n/a	2.72
Base Plate (Aluminum)**	9.525	520	229	4.45
Foot Plate (Aluminum)**	9.525	520	241.3	4.25
Foot Plate Mounting Brackets	Custom			
Grip Tape	n/a	476.25	196.85	n/a
<b>Notes:</b> * Load Cell specification available at <a href="http://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega160">http://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega160</a> ** See Figures B.2 and B.3				
<b>Platform</b>	209.55	571.5	850.9	67.25
Main Plate (Aluminum)**	12.7	572	864	18.30
Force Plate - OR6-WP-2000 (AMTI)*	83	464	508	45.45
Mounting Brackets	Custom			3.25
Grip Tape	n/a			n/a
<b>Notes:</b> * Force plate specifications available at <a href="http://www.anti.biz">http://www.anti.biz</a> ** See Figure B.1 and B.3				
<b>Riser Box</b>	339.7	714.4	714.4	51.3
Top and Bottom Plate	9.5	714.4	714.4	n/a
<b>Notes:</b> ** See Figure B.1(C)				

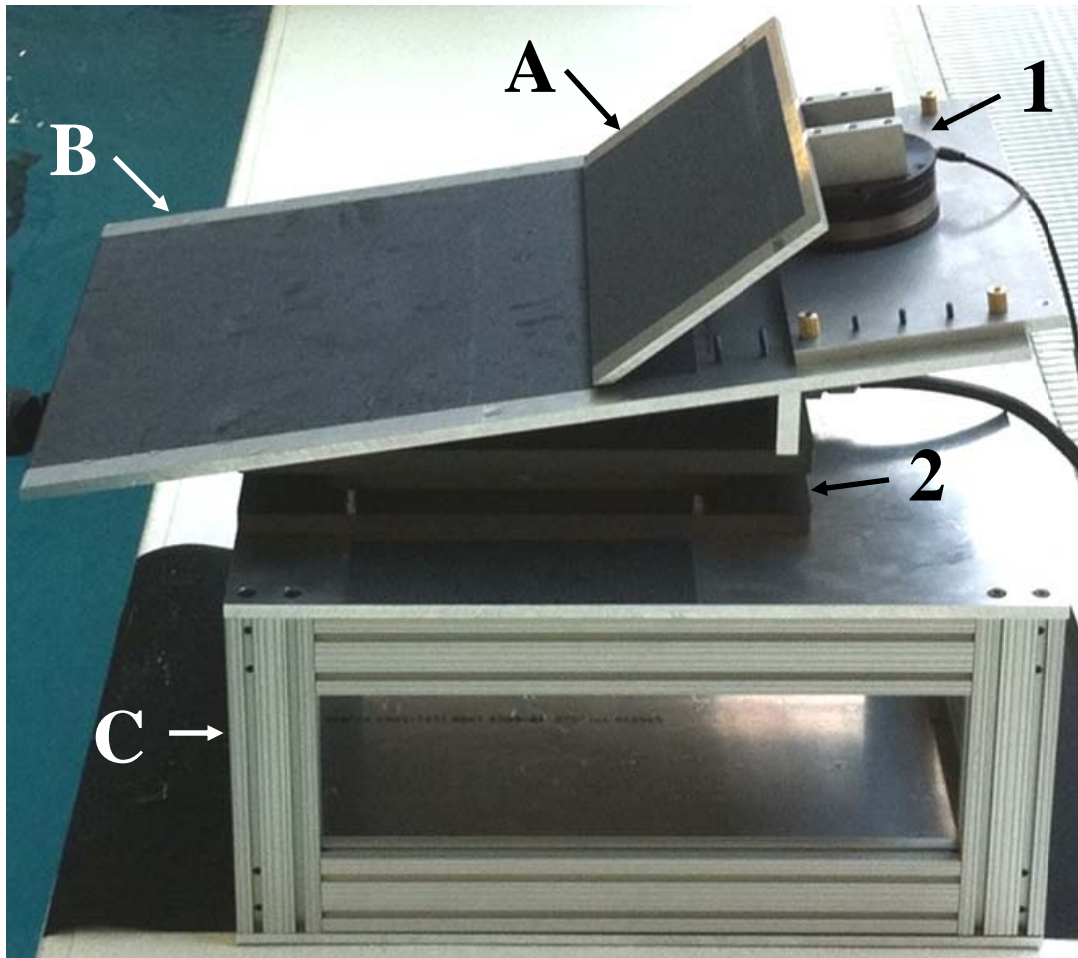


Figure B.1: The complete construction of the replica block. The kick plate (A), platform (B), and riser box (C) are the main components of the replica. The replica has two force transducers: the load cell (1) and force plate (2).

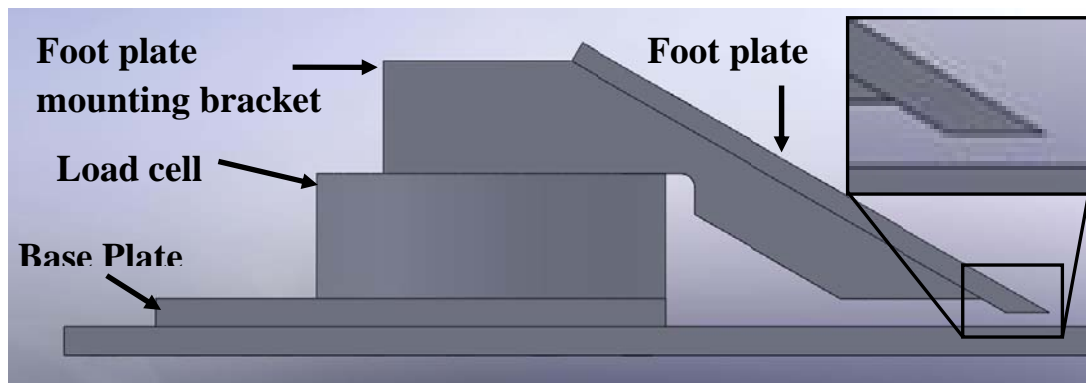


Figure B.2: The kick plate portion of the replica block are made up of the foot plate, mounting brackets, load cell and base plate. The kick plate was designed so that the load cell can measure forces independent of the force plate.

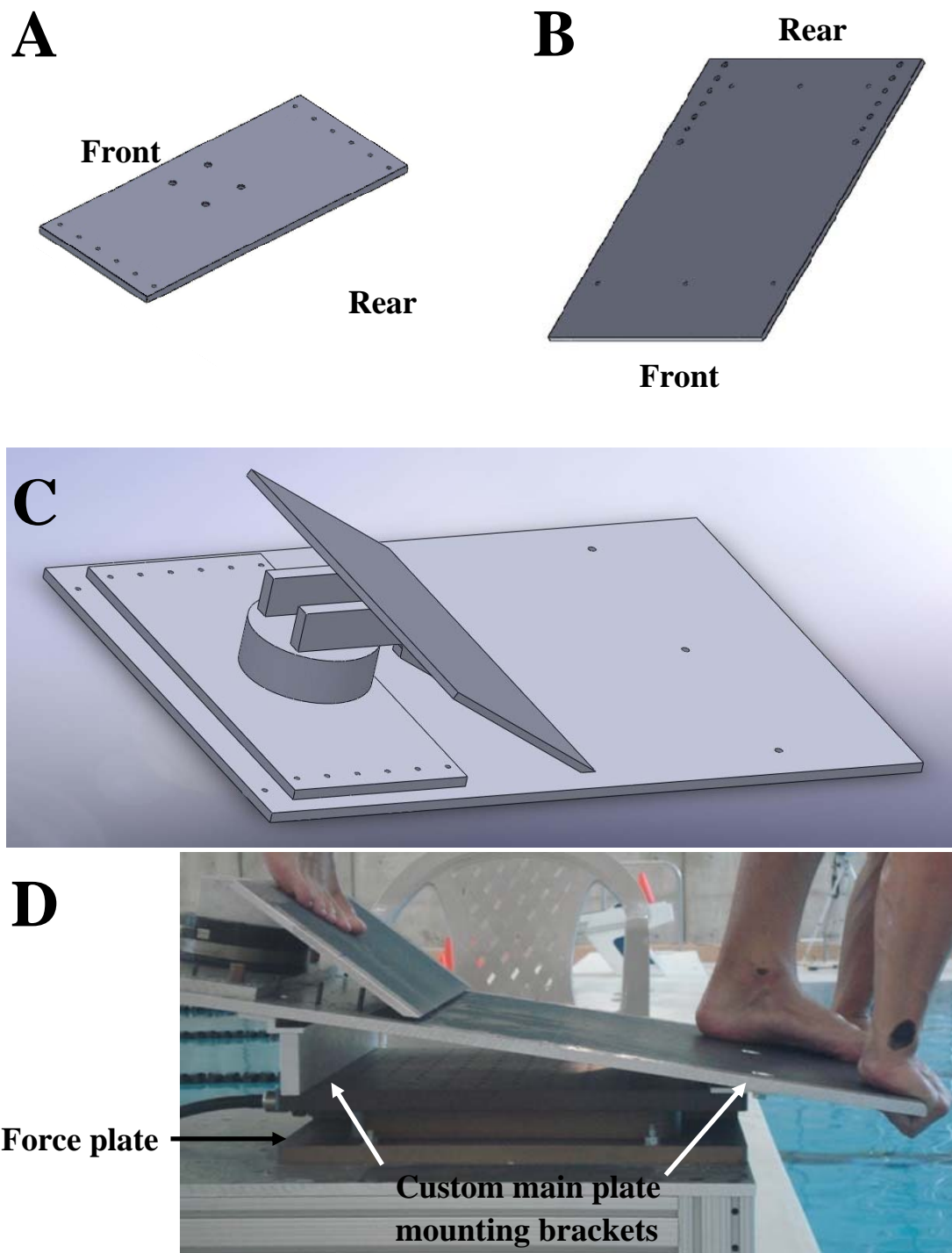


Figure B.3: The base plate (A) of the kick plate and main platform (B) components of the replica block. The base plate was designed to sit on top of the main platform (C) and able to be shifted to positions similar to those found on the Omega OSB11. The main platform was bolted to the force plate via the custom main plate mounting brackets (D) and bolts on the rear portion allowed for the kick plate to be secured.



## Appendix C: Ethics Approvals and Consent

Project 1: The effects of rear foot placement on swimming start performance



### Office of Research Ethics

The University of Western Ontario  
 Room 5150 Support Services Building, London, ON, Canada N6A 3K7  
 Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca  
 Website: www.uwo.ca/research/ethics

### Use of Human Subjects - Ethics Approval Notice

**Principal Investigator:** Dr. J. Dickey

**Review Number:** 17670E

**Review Date:** December 15, 2010

**Review Level:** Expedited

**Approved Local # of Participants:** 15

**Protocol Title:** The effects of rear foot placement on swimming start performance.

**Department and Institution:** Kinesiology, University of Western Ontario

**Sponsor:** Research Program in Applied Sport Sciences (RPASS)

**Ethics Approval Date:** February 04, 2011

**Expiry Date:** June 30, 2011

**Documents Reviewed and Approved:** UWO Protocol, Letter of Information and Consent, Letter of Information and Consent (Parents), Assent Form.

#### Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

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cc: ORE File

## Project 2: The effects of rear foot placement on swimming start performance



## Use of Human Participants - Ethics Approval Notice

**Principal Investigator:** Dr. Jim Dickey  
**Review Number:** 17670E  
**Review Level:** Delegated  
**Approved Local Adult Participants:** 15  
**Approved Local Minor Participants:** 0  
**Protocol Title:** The effects of rear foot placement on swimming start performance  
**Department & Institution:** Kinesiology, University of Western Ontario  
**Sponsor:** research program in applied Sport Sciences

**Ethics Approval Date:** November 07, 2011                      **Expiry Date:** August 31, 2012  
**Documents Reviewed & Approved & Documents Received for Information:**

Document Name	Comments	Version Date
Revised Study End Date	The study end date has been revised to August 31, 2012 to allow for project completion.	

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

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### Use of Human Participants - Ethics Approval Notice

**Principal Investigator:** Dr. Jim Dickey  
**Review Number:** 17670E  
**Review Level:** Delegated  
**Approved Local Adult Participants:** 75  
**Approved Local Minor Participants:** 0  
**Protocol Title:** The effects of rear foot placement on swimming start performance  
**Department & Institution:** Kinesiology, University of Western Ontario  
**Sponsor:** research program in applied Sport Sciences

**Ethics Approval Date:** December 02, 2011

**Expiry Date:** August 31, 2012

**Documents Reviewed & Approved & Documents Received for Information:**

Document Name	Comments	Version Date
Change in Study Personnel	Joe Bartoch has been removed from the study team.	
Revised UWO Protocol	The number of subjects has been increased from 15-75. The study methodology has been revised so that the participants can use either their non-dominant foot or their dominant foot forward.	
Letter of Information & Consent		
Assent		
Letter of Information & Consent	For minors 13+	

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines, and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

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## Project 3: The effects of rear foot placement on swimming start performance



Research Ethics

Use of Human Participants - Ethics Approval Notice

**Principal Investigator:** Dr. Jim Dickey  
**File Number:** 103726  
**Review Level:** Delegated  
**Approved Local Adult Participants:** 0  
**Approved Local Minor Participants:** 0  
**Protocol Title:** The effects of rear vs forward leaning on swimming start performance  
**Department & Institution:** Health Sciences/Kinesiology, Western University  
**Sponsor:**  
**Ethics Approval Date:** May 02, 2013 **Expiry Date:** September 30, 2013  
**Documents Reviewed & Approved & Documents Received for Information:**

Document Name	Comments	Version Date
Western University Protocol	Figure 1: The Omega OSB11 starting block. The back plate is circled in black.	
Letter of Information & Consent	loi and consent	2013/04/21
Western University Protocol		2013/04/10
Instruments	Anthropometric collection instrument with revisions as per Administrative Requirements from HSREB #103726	
Instruments	Collection instrument with revisions as per Administrative Requirements from HSREB #103726	
Revised Letter of Information & Consent	revised consent form	2013/05/02

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/CH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the University of Western Ontario Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

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## Project 4: The effects of stance modification and training on swim start performance



Use of Human Participants - Initial Ethics Approval Notice

Research Ethics

Principal Investigator: Dr. Jim Dickey  
 File Number: 104842  
 Review Level: Delegated  
 Protocol Title: THE EFFECTS OF STANCE MODIFICATION AND TRAINING ON SWIM START PERFORMANCE  
 Department & Institution: Health Sciences/Kinesiology, Western University  
 Sponsor:  
 Ethics Approval Date: February 07, 2014 Expiry Date: August 31, 2014  
 Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Instruments	data collection instrument	2013/12/18
Letter of Information & Consent		2014/01/20
Western University Protocol		2014/01/30
Advertisement	advertisement poster	2014/01/23

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the University of Western Ontario Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

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## Curriculum Vitae

<b>Academic Information</b>	
<p><b>Doctorate in Kinesiology</b>  <i>Thesis in Biomechanics</i>            The University of Western Ontario            School of Kinesiology            London, Ontario, Canada  <b>Dr. J. P. Dickey</b>  <i>Factors affecting block performance from the Omega<sup>®</sup> OSB11 starting platform</i></p>	<p><b>In progress</b></p>
<p><b>Master of Science in Kinesiology</b>  <i>Thesis in Biomechanics</i>            The University of Western Ontario            School of Kinesiology            London, Ontario, Canada  <b>Dr. V. Nolte</b>  <i>The effect of drag suit training on 50m freestyle performance</i></p>	<p><b>August 2009</b></p>
<p><b>Bachelor of Science in Physical education</b>  <i>Minor in Health Studies</i>            East Carolina University            School of Health and Human Performance            Greenville, North Carolina, United States</p>	<p><b>December 2005</b></p>
<b>Teaching Experience</b>	
<p><b>Teaching Assistant</b>, 2<sup>nd</sup> and 3<sup>rd</sup> year Biomechanics courses            Kinesiology Department, The University of Western Ontario.</p>	<p><b>Sep 2007 - May 2013</b></p>
<b>Research Experience</b>	
<p><b>Primary Researcher</b>  <i>The effect of drag suit training on 50m freestyle performance</i>            Prof. V. Nolte, The University of Western Ontario.</p>	<p><b>Sep 2007 - Aug 2009</b></p>
<p><i>The effects of hyper-gravity training on swimming start performance</i>            Prof. J. P. Dickey, The University of Western Ontario.</p>	<p><b>Feb 2009 - Jun 2009</b></p>
<p><i>The effects of rear foot placement in block performance from the Omega<sup>®</sup> OSB11 starting platform.</i>            Prof. J. P. Dickey, The University of Western Ontario.</p>	<p><b>Sep 2010 - present</b></p>
<p><i>Power limb and block performance from the Omega<sup>®</sup> OSB11 platform</i>            Prof. J. P. Dickey, The University of Western Ontario.</p>	<p><b>Sep 2011 - present</b></p>

<p><b>Research Assistant</b></p> <p><i>Joint Biomechanics, Sport Biomechanics, and Teaching Laboratory</i></p> <p>Prof. J. P. Dickey and V. Nolte, <i>The University of Western Ontario</i></p>	<p><b>Sept 2010 - present</b></p>
<p><b>Publications, Abstracts &amp; Presentations</b></p>	
<p>Successful grants</p>	
<p>1. <b>Research Program in Applied Sport Science (RPASS)</b> (2010, 2011)  A grant from the Ministry of Health Promotion (MHP) in conjunction with the Canadian Sport Centres – Ontario (CSC –O) and the Centre for High Performance Sport at the University of Toronto.</p>	
<p>Publication(s)</p>	
<ol style="list-style-type: none"> <li>1. Atkison, R. R., Dickey, J. P. <b>Dragunas, A.</b>, Nolte, V. (2014). Importance of sagittal kick symmetry for underwater dolphin kick performance. <i>Human Movement Science</i>, 28, 298-311.</li> <li>2. <b>Dragunas, A.</b>, Nolte, V., Dickey, J. (2011). The effect of drag suit training on 50m freestyle performance. <i>Journal of Strength and Conditioning Research</i>, 26, 989-994.</li> <li>3. Murrell, D., <b>Dragunas, A.</b> (2012) A comparison of two starting techniques from the Omega OSB11 platform. <i>WURJ: Health and Natural Sciences</i>, 3.</li> </ol>	
<p>Abstract(s)</p>	
<ol style="list-style-type: none"> <li>1. <b>Dragunas, A.</b>, Atkison, R. R., Dickey, J. P. (2014). Center of mass location in swimming starts. Proceedings from the <i>XIIth International symposium for biomechanics &amp; medicine in swimming</i>. Canberra, Australia.</li> <li>2. <b>Dragunas, A.</b>, Atkison, R., Dickey, J.P. (2013). The effectiveness of an instrumented starting block as a training tool for developing optimal swim start technique. Proceedings from SPIN '13: <i>Sport Innovation Summit</i>. Calgary, Canada.</li> <li>3. Atkison, R., <b>Dragunas, A.</b>, Nolte, V. Dickey, J.P. (2012). The importance of sagittal kick symmetry for underwater dolphin kick performance. Proceedings from the SPIN '12: <i>Sport Innovation Summit</i>. Vancouver, Canada. <u>Winner of the Young Investigator Award.</u></li> <li>4. <b>Dragunas, A.</b>, Bartoch, J., Dickey, J.P. Omega OSB11 starting block replica for swimming start analysis and training. Annual Ontario Biomechanics Conference meeting, Barrie, Ontario, March, 2011. (<i>poster presentation</i>)</li> <li>5. <b>Dragunas, A.</b>, Nolte, V., Dickey, J.P. The Effect of Drag Suit Training on 50-M Freestyle Performance. 16th biannual meeting of the Canadian Society for Biomechanics, Kingston, Ontario, June 9-12, 2010. (<i>poster presentation</i>)</li> <li>6. <b>Dragunas, A.</b>, Nolte, V., Dickey, J.P. The Effect of Drag Suit Training on 50-M Freestyle Performance. Annual Ontario Biomechanics Conference meeting, Barrie,</li> </ol>	

Ontario, March, 2011. ( <i>oral presentation</i> )	
<b>Professional Experience</b>	
<b>Assistant Swimming Coach</b> Senior Age Group, London Aquatic Club (LAC)	<b>Sep 2013 - Aug 2015</b>
<b>Assistant Swimming Coach</b> Varsity Swimming, <i>The University of Western Ontario</i> , London, Ontario	<b>Sep. 2007 - May 2011</b>
<b>Race Analyst</b> Racetek Systems, Calgary, Alberta	<b>Jan 2006 - present</b>
<b>Swimming Camp Director</b> Pointe-Claire Swim Club, Pointe-Claire, Quebec	<b>Aug 2007, 2008, &amp; 2009</b>
<b>Swimming Coach</b> Pointe-Claire Swim Club, Pointe-Claire, Quebec	<b>May 2006 - Aug 2007</b>