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OPTIMIZING SWIMMING START FROM BIOMECAHNICAL POINT OF VIEW

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Abstract
The presented work is a literature review of swim start strategies optimized from the biomechanical viewpoint. The goal of a competitive swim start is to generate high enough impulse in the minimum time. Literature points out that swim-start is single most crucial component and the determinant of overall performance as swimmer's body experiences the highest velocity in this phase. Swim-start is divided in four phases and during every phase the swimmer has to strike a series of compromises to ensure good efficiency. For instance, in block phase a high enough impulse should be created without increasing block time. For aerial phase, a parabolic trajectory recommended for long distance swimmers, accelerates body velocity as result of gravity but also increase the time spent in air as opposed to a flat trajectory which results in contrary. A common point to stress while choosing any strategy is to achieve aerial phases with a segmental alignment as swimmer’s body breaks the surface of the water. For entry and glide phase, the main purpose is to maintain body velocity without any propelling actions. Moreover an optimal depth to perform gliding and the optimum time to initiate underwater kicking is contingent on gliding velocity. The current study outlines strategies and trade-offs to achieve the desired aim of every phase. Apart from careful choices of strategies during different swim-start phases, individual characteristics also determine how each athlete will optimize the swim-start phase. Variability can therefore be contextualized as functional and there is no error with regard to deviation from the “only way” to achieve the best start. The existence of several start techniques and trade-offs discussed in the literature confirm the assumption that swimmers can improve performance of swim-start phase through proper training. Furthermore results outlined in this study can play a significant role in improving designs of swimming training programs.

Keywords Biomechanics, Swim-start, glide, performance.

Contents

Introduction

Since last decade, significant researchers have contributed towards biomechanical analysis of swimming techniques [1]. Based on literature review, Vilas et. al [2] categorized swimming as one of the most probed sports activity. Recently, the introduction of various new swimming techniques and new regulations in swimming competitions have inspired several avenues of research in this area. Especially, swim-start being considered as the most critical phase of swimming has become a significant subject of research. Maglischo [3] stated that swim start stage roughly constitutes 10% of the time in 50minutes sprint race and 5% in sprint race of 100minutes. Costill et al., [4] concluded that depending on the race, swim start phase can account for 0.8% and 26.1% of the total time and an optimized start can decrease the total race time by 0.1seconds. Moreover, a lot of new regulations have also been introduced for this phase. For instance, recently a new block called Omega OSB11 was authorized with a raised rear section to assist the track style start.

Figure 1:OSB11 Kickstart platform

Owing to the role played by swim start phase, it is important to understand that an optimized swim start, in line with principles of biomechanics has a potential to generate a high impulse magnitude and body velocity for swimmers (Lyttle and Blanksby) [5]. Swim-start is popularly divided in four phases, namely:

1- **Block Phase:** The block phase also termed as reaction time phase accounts for the time between starting signal to when the swimmer jumps off the block.
2- **Flight Phase:** Flight phase also termed as aerial phase in the literature accounts for the time between the feet leaving the block and the hands breaking the water surface.
3- **Gliding Phase:** Underwater phase also called the gliding phase spends underwater before starting swimming strokes.
4- **Stroke Phase:** Gliding phase is followed by stroke phase.

Using a good knowledge of biomechanics and fluid mechanics, a good efficiency can be ensured in each phase. Based on literature review, next section outlines various techniques useful to accomplish the aim.

Kinematic Analysis of Swimming start

Methodologies

Swimming start has been analysed majorly using Computational Fluid Dynamics approach and experimental trials involving professional and amateur swimmers. The trials are filmed using a digital camera perpendicular to the direction of motion of swimmer. Usually the kinematic analysis is compartmentalized in sequential phases namely block phase, flight phase, entry phase and underwater phase. Vantorre et al [6] used both fixed and underwater mobile cameras to qualitatively analyse the effect of various variables on the swimmer's motion. While the impulse generated on the block as the swimmer jumps in the pool is measured using custom built instruments (Benjanuvatra et al., Blanksby et al., Lee et al., Slawson et al., Vantorre et al, Vilas-Boas et al., West et al.,) [7,8,9,10,11,12,13,14] One of the few experimental setups (used in work of Elipot M et.al [15]) is shown in figure 2.

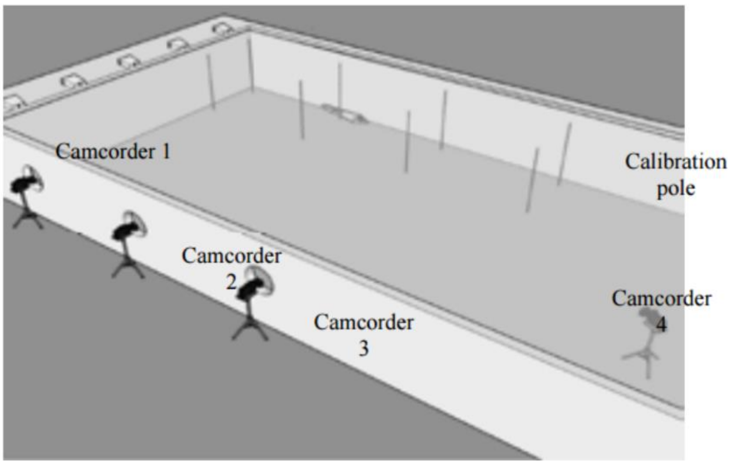


Figure 2: Experimental setup

Block Phase

In block phase, two distinct actions should be optimized with regards to reaction time after the whistle blows. Lyttle et al, [16] summarized that a compromise is needed to be struck between time spent on the block to create impulse and less time spent to minimize the time lag so the swimmer is not left at the start. These two distinct performance variables have a slight relation to the style of swim start (figure 3). Chuen Yu Lee et. al [17] have compared grab and tract swimming start techniques. Track takes longer duration and involves greater take off, entry angles and shorter distance. While grab start involves a flat trajectory and higher distance According to their study, in the track start technique, the centre of mass of the swimmer lies more toward the rear of the block and this start had a shorter block time. Although the grab start increased time on the block it did not increase flight distance. Apart from that no significant differences were found between the grab and track start in this study.

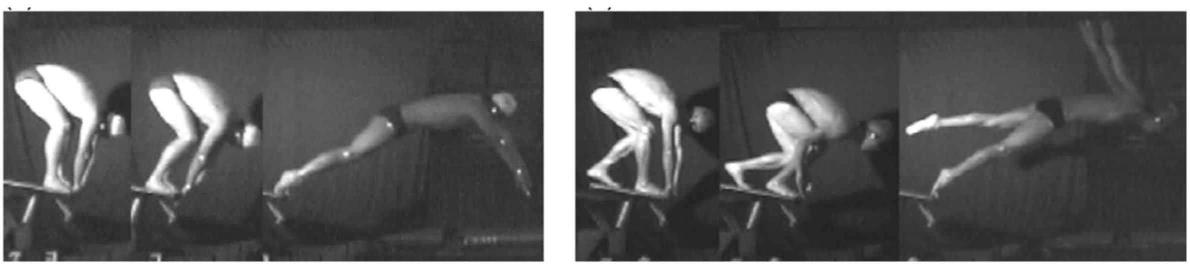


Figure 3:(a) The Grab start: Both feet at the front of the block and hands grabbing the front (b) In Track start one foot is in front of the other.

Flight phase

Flight phase is the duration starting from the jump from block to when hands enter the water surface. In flight phase the main objective is to travel the maximum distance using the velocity developed from the block phase. Another objective of flight phase is to accelerate the velocity using gravity. (Hubert et al., Sanders and Byatt-Smith) [18, 19]. The performance of flight phase is very much contingent the block phase as many researchers have termed the jump style as a part of block phase. As discussed before the track start increases the flight time but it also accelerates the velocity created from impulse using gravitational acceleration. While the grab start is aimed at quick entry in water. Mclean et al. [20] and Vantorre et al. [6], [11] showed from their study that swimmers should utilized least area of water to make a clean entry in water. Especially in track start movement of arms greatly influence the angular momentum. Backward arm swing increases the body's angular momentum and makes a clean start possible with minimum splashing. Moreover studies [21,23,13] have proved that other major factors such as hip angles (with water surface), shoulder angles (with water surface) should be customized to every swimmers physique , body mass index and gender.

Glide Phase

Glide phase starts when head enters the water to when head breaks out the water surface. The objective of glide phase is to retain the velocity generated in the flight and impulse phase using streamline motion of the body. Hay [21] and Hay [22] concluded from their study that glide play the most viral role in starting phase of swimming as it makes 95% of the variance of the starting time. In this phase body position as well as surface area contributes to hydrodynamic drag against the body. For instance, (Bulgakova and Makarenko) [23] proved in their study that placing hands on top of each other decreases the drag coefficient by 7% as shown in figure 3.

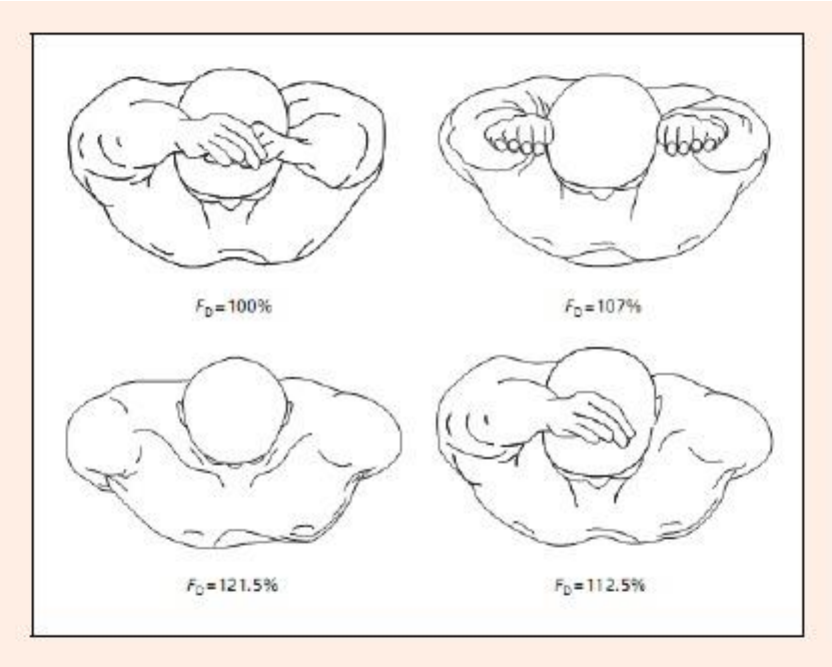
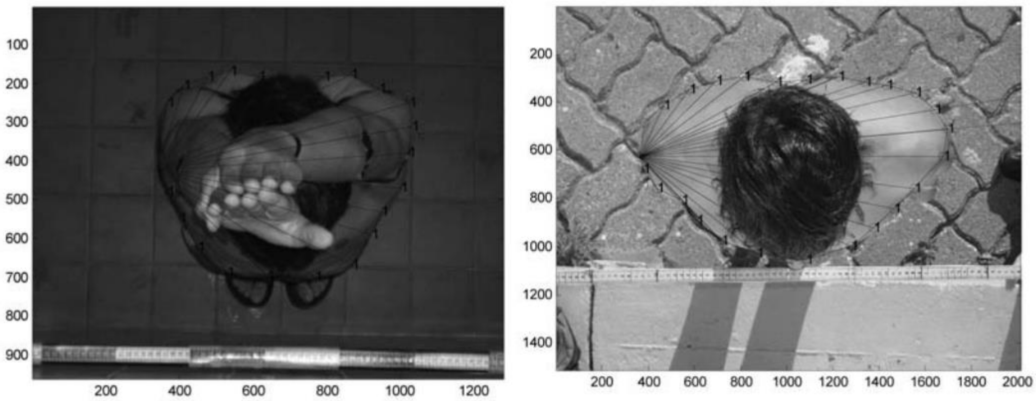


Figure 4:Impact of body shape on hydrodynamic resistance

Usually, researchers measures the efficiency in this phase using gliding factor. Glide factor, measured in meters is the distance covered by the swimmer as the body de accelerates from 2m/s to 1m/s. This factor takes into account the body posture, surrounding flow field, inertial and resistive characteristics of the motion. For instance in case of bra-stroke it is found by Seifert et al. [24] that the values of gliding factor for second glide position renders higher than for second glide position. These positions are illustrated in figure 5.



A B

Figure 5:A - First gliding position B- Second gliding position

Underwater propulsion

According to FINA rules, swim-start is not restricted to block and aerial phase only, instead the phase continues up to 5-m mark until the swimmer re-surfaces swim stroking (Elipot et al., Maglischo, Vantorre et al.,) [15, 3, 6] .Quite a number of researchers have analyzed the underwater phase (Arellano et al., Cossor and Mason, Guimaraes and Hay; Vilas-Boas et al.) [27, 28, 2, 29]. Cossor and Mason [27] suggest that to achieve high swim velocity, value of velocity should be high in underwater phase because of negative correlation (r = -0.734) between the underwater velocity and the 15-m start time in 100-m backstroke. Although significant researchers have focused on underwater phase but very few have focused on underwater propulsion (Blanksby et al., 2002; Clothier et al.; Elipot et al, Lyttle et al. , Takeda et al.,) [8, 25, 15, 16, 26] as underwater phase time very important in achieving effective swim-start (Sanders, Vilas-Boas et al, Vilas-Boas et al.). During underwater phase, legs are used for all strokes except breaststroke. Several authors have worked on analyzing the propulsive and gliding actions and concluded that during this phase a common problem demonstrated by many swimmers is negative superposition of leg propulsion with arm recovery at the pull-out phase, which is resolved at the first swim stroke. These researchers also argue that swimmers don’t achieve optimal arm-leg coordination because of high velocity which restricts adaptive variability. Elipot et al. [15] emphasize that to maintain the velocity acquired by diving start, gliding and underwater kicking coordination is very important. (Vantorre et al.) [12] explained underwater phase as composed of a leg kicking phase and also counted the number of leg undulations which helped the authors to distinguish gliding from leg propulsion in terms of relative duration and quantity and pointed to the challenging transitions with regard to the respective parameters.

Conclusion

In the present study a comprehensive biomechanical analysis of swimming start is done. Swimming start is divided in four phases. Each phase is studied from biomechanical point of view and recommendations for increased swimming performance are listed out. Following are the recommendations concluded in this study.

1- In block phase, the tradeoff should be set between the time spent on the block to generate impulse and reaction time. For Long distance swimmers a more time on block and grab style of start is recommended. For sprint swimmers less reaction time with track start is recommended Moreover swimmers toes should be pointing forward as he/she dives in.
2- In flight phase a lot of components play in such as shoulder angle, hip angle etc. It has been proved from studies that these factors should be customized for every swimmer. Moreover in case of grab start enough angular momentum should be generated in the body to make a ´clean´ start.
3- In glide phase apart from the body´s frontal surface area, shape of the body contributes in drag as well. Its has been proved in studies that placing hands on top of each other decreases the drag by 7%. In bra-stroke swimming second gliding position is more hydrodynamic.
4- In underwater phase, except breaststroke legs are used for all strokes and the phase time is very important in achieving effective swim-start. In this phase, value of velocity should be kept high in order to achieve high underwater velocity. A

common problem in this phase is negative superposition of leg propulsion with arm recovery at the pull-out phase, which is resolved at the first swim stroke.

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31. BIOMECHANICAL ANALYSIS OF THE GRAB AND TRACK SWIMMING STARTS Chueh-Yu Lee1 , Chen-Fu Huang1 and Ching-Wen Lee2 Department of Physical Education, National Taiwan Normal University, Taipei, Taiwan1 Division of Physical Education, National Taipei University, Taipei, Taiwan 2