IDENTIFICATION AND THE CORRECTION OF INEFFICIENCIES DURING STARTS AND TURNS IN ELITE COMPETITIVE SWIMMERS

Bruce Mason and Colin Mackintosh

AppSen Company, Brogo. NSW, Australia

Olympic Games and World Championship swimming events are often not won by the fastest swimmer. In many events the free swimming speed of many of the competitors is almost identical, however it is the better starter in sprint events and the better turner in distance events who is victorious. The authors of this paper worked for over twenty years with analysis systems for starts and turns in elite swimming at the Australian Institute of Sport and over the last six years with the Kistler Company, that developed and installed in pools, a commercial swim start and turn analysis system to assess elite swimmer performances. This paper will discuss inefficiencies in the starts and turns that were found to be commonly identified in elite national swimmers and then state how these inefficiencies in performance may be rectified.

KEYWORDS: elite, swimming, starts, turns, performance enhancement

INTRODUCTION: Many coaches and swimmers believe that the performances of world champions and Olympic Games Gold medallists, during their starts and turns in competition, are almost perfectly executed. This belief is built on the incorrect assumption that to reach the level of world champion or Olympic Games medallist, the athlete must have an almost faultless execution in all aspects of their performance. Accordingly, everyday coaches and athletes attempt to emulate the start and turn techniques used by elite international swimmers. As such, any inefficiencies in the performances that age group swimmers learn may stay with them into the senior ranks. Continued practice of poor technique, that is not readily identified in training, will be difficult to rectify and as such is often displayed by international swimmers in competition. Kinetic and kinematic analysis of elite swimmers' starts and turns has identified many aspects of their technique that can be readily improved. One can go so far as to say that elite swimmers exhibit small technical inefficiencies in almost all aspects of their performance. Losing as little as 0.2 seconds to a competitor in a start for a sprinter or the equivalent loss of time during turns for a distance swimmer is difficult to overcome in the competition environment. However, identifying inefficiencies and practicing good technique will improve race time with generally no increase in energy expenditure on the part of the swimmer.
It is virtually impossible for a coach on pool deck to identify small technique inefficiencies during starts and turns using purely their regular above water vision of the performance. This is because the actions that occur are very rapid, because the bubbles in the water and the splashes in the air distort vision of the activity and because there are normally many swimmers in the squad for whom the coach is responsible. Hence many swimmers who have developed bad habits in starts and turns just reinforce these bad habits over many years of training without the faults being corrected. Some coaching squads have the benefit of additional staff who film the swimmers during training. This enables the coach to review the video footage of their athlete while performing starts and turns. Such video vision, particularly if it is from underwater, is indeed advantageous compared to the situation where the coach is on pool deck overlooking the training session. In such cases the athlete is usually present to hear the coach's view on the performance which normally occurs outside the training session. However, any gains for the athlete from such coaching judgements about performance enhancement, are strictly subjective and very dependent upon the coach's professional experience.
The most advantageous corrections to technique problems occur when a biomechanical analysis system is available to assess performance. Here, not only is vision of the performance available, but also actual numerical parameters are provided to quantify the various important characteristics of the performance, as well as possibly force profiles of the swimmer's dynamic interactions with the wall and starting block. It may be said that the first major step in the ability

to identify what is happening in an activity occurs when the kinematic and kinetic parameters are measured and provided along side a visual record of the performance for assessment.

METHODS: At the Australian Institute of Sport (AIS) an analysis system named Wetplate (Mason et al, 2012) was developed in 2006 and was housed in a 50m by 25m by 3m deep aquatics laboratory. The starting block had as its upper surface a 900mm by 600mm Kistler force platform which had an attachable instrumented inclined foot plate. The turn wall was a modified 900mm by 600mm Kistler force plate. The grab bar was also instrumented. The forces associated with starts and turns were able to be measured in association with the timing of the starting signal. A camera system behind underwater windows was used to obtain video images of each performance. A magnetic timing gate system was used to obtain the timing of the swimmer at various points from the wall. A complete analysis of the performance was able to be completed and feedback provided on pool deck when the swimmer left the water after a trial. This system was used by the AIS team on a continuous basis throughout the year from 2006 and for the Australian swim team periodically through from 2006 onwards. However, the Wetplate system was built into a specific analysis pool making it unable to be relocated. The Kistler company teamed up with the AppSen company to produce the KI-SWIM swim start and turn analysis system (Mason et al, 2017). The Kistler company was responsible for delivery of the hardware and the AppSen company for the software and analysis development. Although the hardware in the system was different to that of Wetplate, similar force parameters were provided. The camera system was available on fixtures attached to the pool wall. Due to the hardware differences, the analysis process was different to that in Wetplate but similar results were provided. The KI-SWIM system is capable of being located in most competition pools. Pools that presently use the KI-SWIM system are situated in Britain, Australia, the USA, in Switzerland and recently China. The force parameters in both systems are expressed as fractions of bodyweight (BW) so that comparisons between athletes of different mass may be readily observed. Measurement of power is in watts per kilogram of body mass. The recommendations provided in this paper have been derived from the experience of eight years working with Wetplate analysis for Australian elite swimmers and six years working with elite competitive swimmers in the countries in which the KI-SWIM system has been installed.

RESULTS: The Freestyle Start All the derived force signals for the start performance should be a constant value from before the starting signal through until approximately 0.15 to 0.2 sec after the start signal. The arm grab force should be a constant 0.2 to 0.3 BW up until this point and then should proceed through a uniform parabola with a maximum of slightly above 1 BW at approximately 0.3 sec after the start signal and then reduces to 0 BW at 0.5 sec after the start signal. This is the force that rotates the body off balance and into a position to achieve maximum thrust by the swimmer out from the start block.

The vertical force as disclosed in the analysis output should be a constant one BW up until just after the arm grab force begins to increase. It then generally experiences an unweighting prior to an increased value of over one BW prior to leaving the block. This is at about the same time in the starting action that the propulsive force reaches a maximum of approximately one BW.

The power curve gradually increases at a similar time to the arm grab force until it reaches a maximum value of about 70 watts per kg of body mass at approximately 0.2 sec prior to leaving the block. It then forms a bimodal curve by decreasing in value and exhibiting another minor increase about 0.1 sec before leaving the block, caused by the final leg thrust. Following this the power curve decreases to 0 watts per Kg of body mass after the swimmer leaves the block.

The angle that the swimmer’s CoG should leave the block is from 2 deg (upwards) to approximately -8 deg (downwards) from the horizontal. A common angle is about – 3 deg.

The athlete should enter the water a little further than 3m from the block through as small a hole as possible. Many athletes are able to pass through a hole as small as 0.5 m in diameter.

In general, the smaller the hole the swimmer enters the water, the less resistance the swimmer will experience on entry and hence the less velocity they will lose during the entry phase. The preferred angle that the swimmer's CoG should enter the water surface is at 45 degrees at a resultant velocity a little greater than 6.5 m/s.

It is at this point of the start, after entry, that the swimmer should retain a streamlined position and slowly move into a horizontal orientation in the water, slightly deeper than 1m below the surface. During this period the swimmer should continue to remain streamlined. Too many swimmers commence the kicking action far too early which in fact will tend to slow them down rather than increase underwater velocity. Dolphin kicking should only commence once the swimmer's streamlined glide velocity reaches a velocity equal to the swimmer's maximum underwater propulsive velocity. This is generally a little beyond 6m from the starting wall. Many elite swimmers begin their kicking actions far too early in the underwater trajectory (4m from the wall) when their velocity is still much higher than their normally attainable propulsive underwater swimming velocity and hence lose rather than gain velocity.

The swimmer generally reaches the lowest point of their trajectory at approximately 5 m from the wall. From this point on the swimmer should slowly ascend to reach the surface at somewhere between 12 and 14 m from the starting wall.

Breakout should occur with the head breaking the surface prior to any propulsive action by the arms. An early arm action while the head is under the water will only serve to slow the swimmer's velocity into the free swimming phase of the competition race.

Generally, butterfly swimmers are better at dolphin kicking and for this reason tend to descend a little deeper under the water, up to 1.5m below the surface, than do freestyle swimmers.

Breaststroke swimmers tend to leave the block at a higher angle of about -1 deg (downwards) to the horizontal than do free style swimmers, thus entering the water at a higher angle of entry at maybe 49 deg to the water surface so that they descend deeper than free style swimmers and predominantly use their ability to streamline and often breakout after 12 m from the wall.

The important start feature of backstrokers is their ability to thrust themselves out over the water without trailing their legs in the water. To do this the backstrokers need to get their upper body horizontal to the water surface while extending the legs on leaving the wall. They should not be in a sitting position during this leg extension thrust. Backstrokers may use a more round arm action, rather than an above arm action during the arm recovery. Newton's 3rd law applies here – for every action there is an equal and opposite reaction. As the arms recover above the body there is an equal and opposite movement of the body downward toward the water. This is not desirable. A round arm action does not result in such a downward movement of the body.

The Freestyle TumbleTurn Swimmers need to adapt as they approach the wall by modifying their stroke pattern on observation of the T on the pool floor. This is done so they have an appropriate body position and location from the wall to commence the turning action.

Once their rotation begins the swimmer should retain a tight tuck. As the feet come over toward the wall the legs should be extended to actively make contact with the wall about 0.15m below the water surface. A fault many swimmers display is to allow the rotation to continue so that the legs over rotate and their feet make contact low on the wall. Generally, when swimmers have this fault their action is first to place and steady their feet on the wall before commencing the push away from the wall. This fault is easily identified by a double peak in the force curve exerted on the wall. A better turner will hit high on the wall and by extending the feet to hit and push in a single action will have a single rather than a double force curve. In this case because of the position of the body, the body thrust will be at an angle of approximately 20 degrees downward. This technique will also reduce the time on the wall by approximately 0.1 sec, providing a time advantage. Time on the wall is generally between 0.25 sec and 0.35 sec.

When a swimmer makes contact high on the wall their legs will act to push them in an outward and downward direction which is what they want to occur. When the feet are placed low on the wall their legs will act to push them outwards and upwards toward the water surface. The swimmer in this situation then needs to change their body attack angle to go deeper in the water. This movement direction change will result in a retardation in the swimmer's velocity.

It is important that the swimmer maximises the pushing action off the wall and for this reason the swimmer should not attempt to rotate their body back into the free style swimming orientation until well off the wall. Some freestyle swimmers in turns remain completely on their backs until they approach the surface, well after the actual turning action has been completed.

There is an actual mechanical advantage to remain under the water for as far as is possible. Wave drag is a serious consideration here. There is an 8% to 24% decrease in drag at speeds of 1.9 m/s when swimming 0.5 m to 1 m below the surface of the water (Tor, 2017). Therefore, there is a trade off between depth and drag – deep enough to reduce drag but shallow enough to maintain horizontal velocity after entry. The principles to observe at this part of the underwater phase after leaving the wall are very similar to the biomechanical principles that exist for starts. Generally, the swimmers reach a depth of just over a metre under the water with the maximum depth occurring just over 6m from the wall. Good turners will have a breakout between 12m and 14m from the wall.

DISCUSSION: In analysing the performance, before providing feedback to the athlete, it is important to consider all aspects of the start/turn analysis information, including the visual movement of the athlete as per the video record, the movement parameters as well as the force parameters. It should be noted, that there is not a particular set way the swimmer should perform their starts and turns. The information provided in the results section of this paper will only provide an overall indication of the start and turn parameters and may be used as a guide to identify inefficiencies. It should not dictate how a start or turn should be performed. A few principles should exist before providing feedback to a swimmer. Firstly, the feedback should be provided by the coach rather than a biomechanist. However, it is the biomechanist's role, apart from conducting the technique testing, to ensure the coach fully understands the analysis of the performance prior to providing any feedback. The coach should be familiar with the analysis results, the units used in the biomechanical analysis output, and should understand the implications of altering any feature of the swimmer's technique. No more than two major inefficiencies of the swimmer's start or turn technique should be earmarked to the swimmer for change at any one time. Those that are earmarked should be the most serious inefficiencies disclosed by the analysis. The swimmer should then practice the start or turn with the coach correcting the inefficiencies, prior to retesting. The biomechanical testing should not take place as part of a regular training session but rather should be performed with just the coach and athlete present at a technique session. The coach must ensure that the swimmer puts into practice during all training session all that has been learnt from the technique analysis. For any technique change to be effectively implemented by the swimmer into their race performances, all the changes made need be automatically performed which can only occur when the skill is executed correctly many times during multiple training sessions.

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