BIOMECHANICAL SUPPORT TO A NATIONAL SWIM PROGRAM AND RESEARCH REQUIRED TO PERFORM THAT SERVICE

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Swimming is a difficult sport in which to research and carry out support services in biomechanics. It occurs at the intersection between air and water, limiting kinematic analysis because visual images are hidden by splashes and bubbles. There is also a difficulty in obtaining kinetic analysis as a consequence of an inability to use force transducers which require attachment between the surfaces experiencing the force. Swimming does however provide one real advantage in that there are primarily only three areas that are needed to analyse performance. These are in the start, turn and relay changeover area, in the free swimming area and in competition analysis. This paper details the application of biomechanical servicing and research systems in swimming at the Australian Institute of Sport.

KEY WORDS: Competitive, Swimming, Kinematic, Kinetic, Analysis, Systems

INTRODUCTION: The Australian Institute of Sport (A.I.S.) has a specific unit that works with Biomechanics in Swimming and as a consequence has developed analysis systems to assist in research and serving in the sport. Swimming is indeed a difficult sport in which to apply biomechanics. The quality of kinematic analysis is indeed limited in that the visual image obtained using video and cinematography sources is often hidden or distorted by splashes above the water surface and by bubbles below the surface. Additional to this, there is also the problem of different refractive indexes for light in air and water, making any kinematic analysis having to be completed in air and water independently of one another. There is also a problem of using other kinematic electronic equipment systems that are generally used in air but which are unsuitable or easily damaged in an aquatic environment. An example of such a system is the Vicon analysis system. Nowadays, it is a common practice in biomechanics to perform automatic and immediate kinematic analysis of a sporting activity performed in a total air environment. However, such analysis has proved to be difficult in the sport of swimming as the performance occurs at the air/water interface. The Qualisys system attempts to find a solution to this problem, however the solution is very expensive. Kinetic analysis also poses a problem in swimming in that forces utilised by the swimmer to propel themself through the water occur as a consequence of interaction between the swimmer’s body and the surrounding water. Therefore force transducers are unable to be used as they need to be attached between the swimmers body and the surrounding water. Force transducers may however be used in activities that involve interaction of the swimmer with the pool’s structure in such activities as starts, turns and relay changeovers. As a consequence, biomechanical researchers have turned to using pressure transducers attached to such surfaces as the swimmer’s hands in an attempt to assess propelling forces. A problem with using pressure transducers is that pressure is not only affected by force application but is also affected by changes in the depth of the transducer in the water. There is also an additional difficulty in establishing the force direction when the force value is derived from a pressure transducer. Propulsive movement in swimming is dominated by two forces, swimmer propulsion and active drag. To biomechanically assess swim performance both these forces need to be accurately estimated. This paper will discus how the A.I.S. has established systems that enable analysis of swimming performance.

METHOD: Start & Turn Analysis: The A.I.S. completed the development of a start, turn and relay changeover analysis system named Wetplate (Mason, Mackintosh & al., 2012) in 2006 to assist in the performance enhancement of Australian elite swimmers. Wetplate is comprised of a starting block whose top surface is a modified 900mm by 600mm Kistler force platform. The force plate is angled, as per FINA regulations, down in the direction of the pool. Under the front edge of the platform is located a bar that is gripped by the swimmer's hands during starts. The bar is instrumented on either side of the handle so as to measure the grip force exerted by the hands during starts. There is also an inclined kick plate that sits on top of the start block force platform and this is used by the rear foot during starts. The inclined plate setup is compliant with FINA regulations. The inclined plate also is instrumented with 4 triaxial force transducers in the formation of a miniature force platform. The inclined plate is able to be moved along the starting block, to replicate its placement on a normal starting block. The turn wall is also a modified Kistler 900mm by 600mm force platform that fits into a section of the pool's end wall that is normally filled with a dummy plate. The front surface of the instrumented wall has a multitude of holes so as to minimise much of the force signal exerted by the wave which travels in front of the swimmer and therefore has much of the wave's force dissipated through the holes. All the force exerted by the hands and feet are measured directly on the turn wall. For backstroke starts there are handles that attach to the starting block. The force exerted by the hands and arms to raise the body out of the water during backstroke starts is measured by the force platform acting as the top surface of the starting block. The turn wall is utilised to measure the force exerted by the feet and legs during the backstroke start. Signals from all force transducers are transferred by way of cables to the computer via amplifiers and through an analogue to digital board.

There is also a start button that is used by the starter who stands behind the starting block. The signal from this button is also transferred by an electrical pulse to the Wetplate computer via the analogue to digital board. A box which is located beside the starting block has a number of indicator lights for the visual indication of events that occur. These indicator LED lights are primarily there to display the instant of an event during the visual playback of the trial. The LED lights are an indication of events including: the start signal, when the swimmer leaves the block, when the front wall is touched in turns and when the relay touchpad has been activated by the incoming swimmer. The LED indicator receives its signal concerning the leave block time through the reconnection of an laser beam across the front of the start block. The swimmer's feet intercept the beam prior to the swimmer leaving the block.

Four Gig E Pulnix Machine vision cameras are used to provide visual feedback of a trial. All cameras are synchronised and run at 100 frames per second. The cameras cover the lateral or side view from behind the start block and out to the 15m mark from the wall. One camera films from above water to capture the above water activity during starts and turns. The other three cameras cover the entire underwater view from the turn wall out 15m from the wall. When viewing the visual display, all four cameras provide what appears to be a continuous image on the computer screen. There is both a magnetic timing system and a video camera timing system used to identify when the swimmer's head passes through the 5m, 7.5m, 10m, 15m and 20m marks from the wall.

Separate to the Wetplate analysis visual image from the four Gig E cameras, there is another image also provided. This image is captured by cameras that film from a moving trolley that travels along the side of the pool and which is powered by a golf buggy. The image stays level with the swimmer. This provides a split image that combines the view from two cameras, one above and one below the surface of the water. At the present time it provides analogue video signals which are combined to produce a single video image using an analogue video mixer. There is in addition to the side on footage, an image of the trial from above using another analogue camera. The analogue cameras are soon to be replaced with machine vision Gig E cameras.

Free Swim Analysis: The AIS developed an Assisted Tow Method analysis system (ATM) (Alcock, A. & Mason, B. 2007) which assists performance enhancement using a quantitative analysis of free swimming. The ATM relies on three assumptions being met; 1) that the swimmer exerted equal power in both the free swim condition and when being assisted, 2) that the swimmer maintained a consistent mean velocity through all trials and 3) that the swimmer maintains the same technique during all trials. The calculation of mean active drag is based upon the free swim velocity, the assisted tow velocity and the varying tow force. The ATM approach was based on similar assumptions as the velocity perturbation method (VPM) (Kolmogorov S. & Duplishcheva O.1992); however, the protocol involved assisting rather than resisting the swimmer. A powerful dynamometer is used to tow the swimmer at a constant velocity. A force platform, upon which the dynamometer is mounted, is used to measure the varying force profile required to tow the swimmer. As was the case of the VPM, the active drag of the swimmer could only be computed at the swimmer's maximum mean swim velocity. The trials are completed with the mean tow velocity approximately five-percent greater than the maximum mean free swim velocity. The trials are completed such as to allow normal swimming velocity fluctuations to occur (Mason et al., 2011). During each trial, continuous velocity data are captured from the dynamometer and continuous force data from the force platform. The captured data is processed to compute active drag profiles. Trials are simultaneously video recorded using three genlocked cameras at 50 Hz.

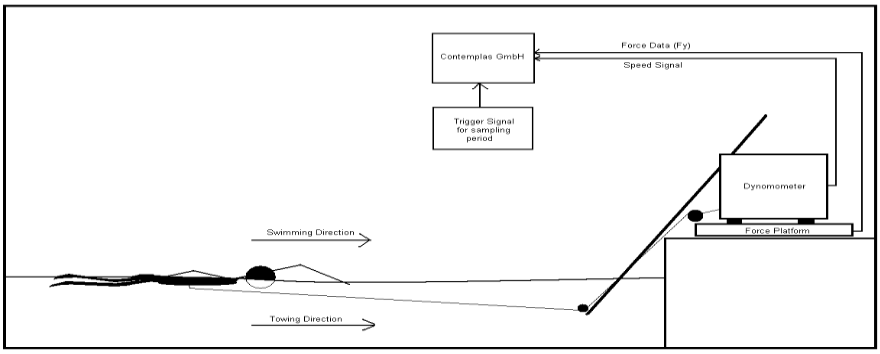


Figure 1: Assisted Towing Method set up

Computations:
v = Velocity Profile (a function of time) positive value.
A = Active Drag Profile (a function of time) negative value – As *P* and *A* directly oppose one another the *A* is considered a negative as velocity is positive in the direction of propulsion.
P = Propulsion Profile (a function of time) positive value.
m = Passive drag force (considered as equivalent to an inertial mass).
In the fluctuating velocity trials *v*, *A* and *P* all vary throughout the stroke cycle. However there is a relationship between all three.

$$v = \int \frac{P+A}{m} dt \ \therefore Propulsion = \frac{d}{dt}(mv) - A$$

Competition Analysis: The AIS has also developed a competition analysis system called Platypus. The system consists of 3 fixed synchronized GigE cameras that film directly across the pool's surface. These cameras are located high on the wall of the pool's building at the 12.5m, 25m and 37.5m distances from the end of the pool and film at 100 frames per second. There are calibration lines drawn across the image of the pool's surface filmed by each camera for the purpose of determining precisely when the swimmer's head passes each distance. These lines are located at the 15m and 25m distances from the start and at the 5m and 10m distances from both end walls. There is also a synchronised high resolution panning GigE camera that is used to film a swimmer in any lane. The camera can be quickly switched from lane to lane after each race. This camera is also located high on the pool wall and near the centre of the pool on a remote tilt and rotation device. The tilt is used to change lanes and the rotation and tilt to follow the swimmer down the lane. The panning movement of the camera is controlled by a computer to which is connected to an optical encoder with an attached handle to rotate it. The operator in a remote location uses the handle to keep the camera's image of the swimmer at the centre of the picture. This is done by watching the camera's image on the computer screen. The computer keeps track of where in metres the panning camera is pointing down the lane. There is also a press button finger trigger to indicate when each swim stroke occurs and a foot trigger to denote each wall touch by the swimmer. The start signal as well as split times are automatically received from the official competition timing system by the computer controlling the panning camera. Several of these panning cameras may be used in the analysis setup.

CONCLUSION: Start & Turn Analysis: The Wetplate computer provides the completed analysis within minutes of the trial being conducted. The computed analysis data is usually presented on a large plasma screen with the analysis being controlled by a laptop computer on the pool deck. At the same time, the Wetplate capture computer may be collecting information from another trial, enabling several swimmers to be tested during the one session. When viewing the Wetplate analysis, the visual information from the machine vision Gig E cameras is always available to be displayed. Other kinetic and kinematic analysis information can also be provided by way of switching it on or off via a selection tab.

Free Swim Analysis: The ATM produced an active drag profile that varied throughout the stroke. From the active drag profile a propulsive force profile (Mason, Sacilotto et al., 2012) is computed. An active drag profile, a propulsive force profile and a resultant force profile of the swimmer in conjunction with a synchronised video image of the performance is provided in the analysis. This is able to be used to assist the coach in stroke correction.

Platypus Competition Analysis: High quality panned video footage zoomed in on the swimmer's performance is available for the coach to review. Associated with this footage is the start time, turn times and finish time as well as the stroke lengths and stroke frequencies in the free swimming phases of the race. This information is available immediately after the times are checked and obtained as the swimmer's head passes through the distance markers. This is very much an automatic process that is completed quite quickly and easily.

DISCUSSION: Generally the competition analysis system is used to identify problems with a swimmer's race performance. The coach is then able to concentrate on refining the swimmer's technique using the Wetplate Analysis System for starts, turns and relay changeovers and drag analysis for free swim analysis.

REFERENCES:

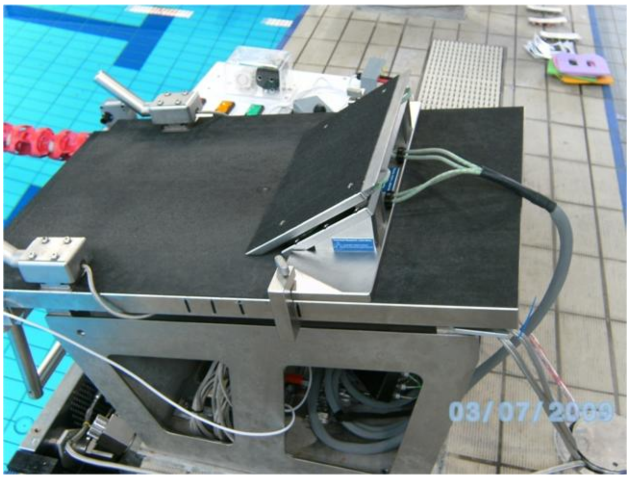
Alcock, A., & Mason, B. (2007). Biomechanical analysis of active drag in swimming. Paper presented at the 25th International Society of Biomechanics in Sports Annual Conference, Brazil, 212-215

Kolmogorov, S. V., & Duplishcheva, O. A. (1992). Active drag, useful mechanical power output and hydrodynamic force coefficient in different swimming strokes at maximal velocity. *Journal of Biomechanics, 25*(3), 311-318.

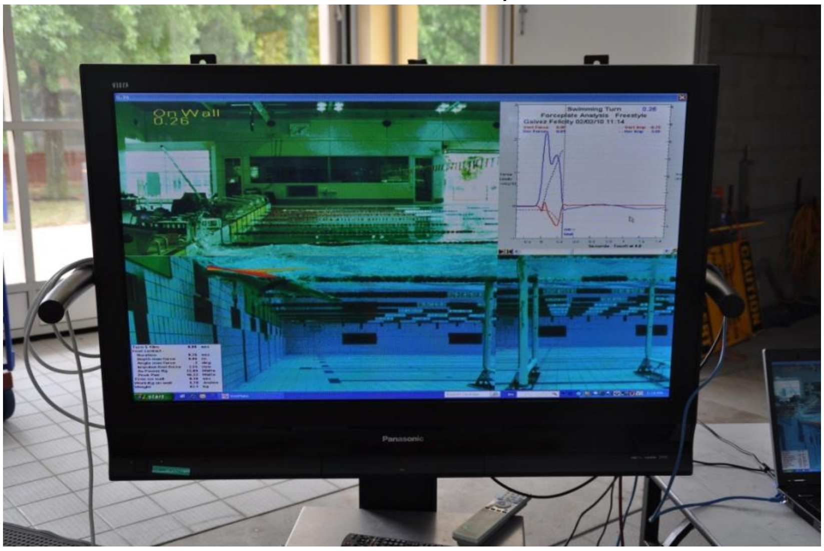
Mason, B., Mackintosh, C., & Pease, D. (2012). The Development of an Analysis System to Assist in the Correction of Inefficiencies in Starts and Turns for Elite Competitive Swimming. Paper Presented at the 30th International Society of Biomechanics in Sports Annual Conference, Melbourne, 249- 252

Mason, B., Sacilotto, G., & Menzies, T. (2011). Estimation of of active drag using an assisted tow of higher than max swim velocity that allows fluctuating velocity and varying tow force. Paper presented at the 29th International Society of Biomechanics in Sports Annual Conference, Portugal, 327-330

Mason, B., Sacilotto, G., & Dingley, A. (2012). Computation of a Swimmer's Propulsive Force Profile from Active Drag Parameters with Fluctuating Velocity in Assisted Towing. Paper Presented at the 30th International Society of Biomechanics in Sports Annual Conference, Melbourne, 244- 24



Wetplate Starting Block with top surface as a Kistler force platform and inclined kick plate as a miniature force platform.



Wetplate Feedback plasma screen showing Footage from the 4 GigE cameras of a turn analysis with the associated force curve of swimmer's interaction with the wall.

Filming trolley pulled by modified golf cart using two filming cameras (1 above & 1 below water surface).