A METHOD TO EVALUATE INTRACYCLE PROPULSIVE FORCE AND BODY VELOCITY CHANGES

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INTRODUCTION

The energy cost of swimming per unit distance at a given velocity varies to a large extent from one swimmer to another. This variation is thought to depend mainly on swimming skill (Toussaint, 1992).

Propulsive force in swimming show a periodical variation during each stroke. resulting in either acceleration or deceleration of the body. The greater the amplitude of speed fluctuation relative to the mean value, the greater the force consumption. Skilled swimmers conserve energy by allowing the motion established in one phase of the stroke to continue into the next phase. The optimal solution for a given work capacity, therefore, would be to swim at a constant velocity. Changes in velocity of 10% (for one stroke) result in an additional work demand of about 3% (Nigg, 1983).

Goldfuss and Nelson (1971). in a first attempt to gather force measurements in swimming and underwater filming, used a complete tethered swimming procedure. Swimming at zero velocity, due to the large turbulence created around the body, changes dramatically technical conditions, as was confirmed by Maglischo et al. (1984). Several measurement methodologies have been developed since then using cinematographic techniques with free swimming (Mason et al., 1992), devices that are sensitive to pressure gradient alterations and are small enough to be attached to the body, also in free swimming (Kent and Atha, 1975; Atha et al., 1985; Mainly and Atha, 1992; Hahn and Krug, 1992). or direct measurements of force and velocity in a semi-tethered condition, where movement patterns deviations to free swimming are not so important.

Bober and Czabanski (1975) developed a " photoelectric speedometer" to study the changes of body velocity in breaststroke, and Kornecki and Bober (1978) applied the same testing procedure to butterfly swimmers, establishing a biomechanical criterion to evaluate variations in swimmers' velocity. This criterion assumed that swimming techniques are more effecrive when the difference between instantaneous and mean velocities within the stroke cycle is minimal.

Craig and Pendergast (1979) conceived a "swim-meter" to monitor the swimmer's velocity in semi-tethered conditions. This device was later used by Costill et al. (1987) and D'Aquisto and al.. 1988, in combination with a video-computer analysis system to assess temporal information along the stroke cycle. To test the swimming-specific power, Costill et al., 1986, adapted the Swim Bench system for use during semi-tethered swimming, allowing direct measurement of power exerted by the swimmer in the several phases of the stroke.

The development of a computer-based system to measure force and velocity during semi-tethered swimming enables us to quantify intracycle variations and obtain an individual diagnosis of swimming proficiency. The objective of this paper is to present a direct force-velocity measurement system for swimmers to be used in testing and training situations. This procedure does not primarily aim at the quantitative acquisition of the overall velocity and force values, but at a qualitative evaluation of the intracycle fluctuations.

METHODOLOGY

The testing apparatus consists of a 3/4" shaft supported on radial bearings in which a 4" barrel is welded. The measurements were effectuated using 15 meters of stainless steel light cable coiled around the barrel, with its free end connected to a harness belt attached to the swimmer's waist. The force generated against the cable by the swimmer when moving away from the apparatus was sensed by a force transducer located between the harness belt and the cable, and converted to a proportional voltage output. The data is relayed to a computer through an a/d converter and processed to calculate force for each swimming stroke or for any given time period. Swimming velocity was measured based on the rotational velocity of the wheel. An adapted potentiometer was attached to an end of the shaft. The angle signal is also interfaced and converted to a digital signal. At the other end an electromagnetic brake was mounted, to prevent turning velocity of the. wheel to fluctuate due to its own inertia, keeping the cable always stretched. A constant force of 30 N was necessary to initiate the rolling of the barrel.

Force and velocity data acquisition were synchronised with video recording of the swimmer, to allow for technical analysis and feedback.

Typical testing situation is summarised in fig. 1

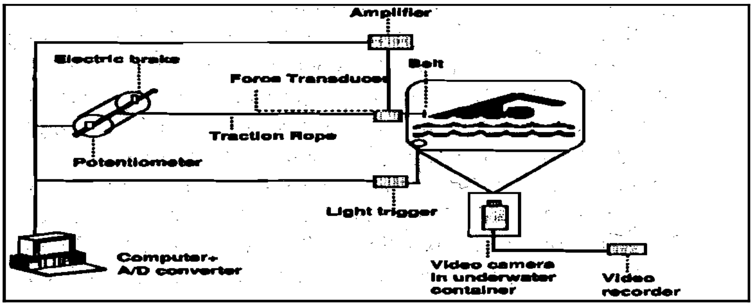

Fig.1 Schematic representation of the measuring system.

SYSTEM APPLICATION

The results that can be obtained by this force-velocity measurement system are illustrated in Fig. 2.

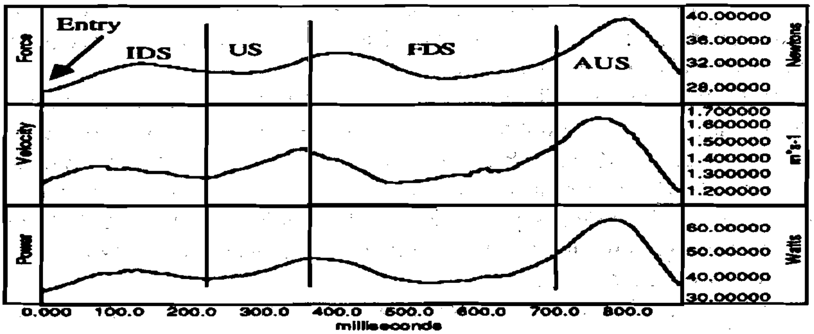

Fig 2 Force and velocity during an underwater arm stroke in backstroke. IDS - initial downsweep; US - upsweep; FDS - final downsweep; AUS - additional upsweep.

CONCLUSION

Success in elite swimming competitive performance may be determined primarily by technique rather than strength or general and specific endurance, on the supposition that organic adaptations are equally stressed to a level that is very near the individual limits. With the measurement of the intracycle velocity and acceleration pattern we can optimise the movement co-ordination of an individual swimmer during technique training.

The body velocity profiles can be very informative regarding the relative importance of each propulsive phase to the overall result, assessing the correction of the weak points of the stroke.

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