related to development of the terrestrial basis motor patterns (3, 4). Some assessments were performed with electromyography and video analysis about lower limbs movements of young children (5) and some others about description of leg movements of children aged 3-20 months (6). Other authors assert that water experiences could improve specific skills (2).
The aim of this study was to understand if spontaneous swim movements of the child can evolve into an effective action, after a "keep doing" and a "free exploration" based methodological approach.

METHODS
This study involved 30 children divided into 3 groups (5 males and 5 females each), aged respectively 4-12 months (group A: age 10.8±1.8 months, weight 9.6±1.4 kg, height 74.7±4.44 cm), 12-24 months (group B: age 17.0±2.3 months, weight 11.8±1.7 kg, height 82.8±6.1 cm) and 24-36 months (group C: age 31.9±3.0 months, weight 13.7±1.6 kg, height 96.8±7.3 cm).
The study was performed with the same teacher, who proposed 10 lessons of 30 minutes each. The swimming pool had irregular edge, depth of 90 cm, Cl^- 0.6 p.p.m., pH 7-7.4, water temperature 33°-34° C, room temperature 29°-30° C.
The children experienced the water environment, freely playing. Several tools to increase their creativity and their imagination were placed in the water, such as mats, floating toys, slides, balls. No aids to floating, movement or programs to induce learning to swim were used.
The spontaneous behaviours of the children pre and post the period of free experience in the water were analyzed. The presence of the following six specific characteristic responses to the aquatic environment stimulation was observed and recorded by pictures and underwater videos: (I) a spontaneous submersion; (II) a balanced body inclination from 20 to 45 degrees; (III) a simultaneous action of the arms, (IV) an alternated action of the arms; (V) a simultaneous actions of the legs; (VI) an alternated action of the legs.
The criterion of scoring employed was: "0" when the characteristic was absent, "1" when it was present.
A comparison of the pre-post status within group and a comparison among the three groups for each characteristic observed, were conducted with a Mann-Whitney non-parametric Test, for $p<0.05$.

RESULTS
No significant differences ($p>0.05$) were found in the comparison between the pre and post experience analysis within group. On the contrary, in the comparison 4-12 versus 24-36 months, a significant differences ($p<0.05$) were found in all the characteristics evaluated, except in the spontaneous submersion action. In the comparison 12-24 versus 24-36 months, differences were found in the body position and in the arm movements (table 1).

Table 1. Comparison among groups with Mann-Whitney Test (= p<0.05; ** = p<0.01).*

Characteristics	4-12 Vs. 12-24 (months)	12-24 Vs. 24-36 (months)	4-12 Vs. 24-36 (months)
Submersion			
Inclined Body Position 20°-45°		*	*
Simultaneous arm movements		**	**
Alternated arm movements		**	**
Simultaneous leg movements			*
Alternated leg movements			**

DISCUSSION
From the results, it appears that no differences within group were noticed in the spontaneous motor actions observed. We can suppose that in young children aged 4 to 36 months, a free experience in the water environment does not produce effects in the aquatic motor behaviours considered.
On the contrary, variations appear in the comparison among groups. In the comparison of the children aged 12-24 versus 24-36 months differences were found in the body inclination and in the arm movements. The children aged 4-12 versus 24-36 months present differences in every aquatic motor behaviour observed, except in the spontaneous submersion action. Based on the data from the present study, we can suppose that, according to the literature (3), the aquatic motor development of the young children should depend mainly on age.

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VALIDATION OF A CABLE SPEEDOMETER FOR BUTTERFLY EVALUATION

Pedro Morouço[1,2], Antônio B. Lima[2,3], Pedro Semblano[4], Daniel Fernandes[4], Pedro Gonçalves[2], Filipa Sousa[2], Ricardo Fernandes[2], Tiago Barbosa[5], Miguel V. Correia[4], J. Paulo Vilas-Boas[2]
[1]Management and Technology College, Leiria, Portugal
[2]University of Porto, Faculty of Sport, Porto, Portugal
[3]Federal University of Ceará, Fortaleza, Brazil
[4]University of Porto, Faculty of Engineering, Porto, Portugal
[5]Department of Sports Sciences, Polytechnic Institute of Bragança, Portugal.

Getting fast results from the evaluation of swimmers is one of the most important goals to achieve with technological development in the field. The purpose of this study was to validate a real-time velocimetric device (speedometer) through the comparison of their results with computer assisted videogrametry. The sample included 7 international level swimmers (3 females and 4 males). Each swimmer performed four 25m trials, two at 200m race pace and two at 50m race pace. For each trial, two stroke cycles were studied, resulting on a total of 28 cycles

analysed. Hip v(t) curves obtained from speedometer and videogrametry were compared, as well as the speedometer hip curve with the one of the centre of mass (CM). The higher mean correlation obtained was between v_{hip1} and v_{hip2} (0.955±0.028), followed by v_{hip1} with v_{CM} (0.920±0.049). The lower correlation was v_{hip2} vs. v_{CM} (0.878±0.053). It was concluded that the speedometer is a reliable, fast and interactive tool for training advice.

Key Words: swimming, biomechanics, velocity, speedometer, images processing.

INTRODUCTION

Swimming coaches intend to get better competitive results by improving swimmer's technique. There are several ways of doing so, and biomechanical analysis is, certainly, one of the most accurate and profitable solutions. Nevertheless, biomechanical analysis normally requires options rather expensive and time consuming for data analysis. Moreover, in Swimming, the biomechanical evaluation of the stroke technique is limited by original constraints related with the environment – air and water -, that do not exist in other sports: (i) the distortions of the swimmer's image produced by the water refraction, undulation and turbulence; (ii) the need of obtaining synchronized images in two elements of distinct density and (iii) the underwater visibility problems arising due to water aerisation [1]. Consequently, in this sport, biomechanical / technical evaluation is specially difficult, mainly if we intend to deliver results in a fast and useful time for swimmers and coaches. So, getting fast results from the biomechanical evaluation of swimmers is one of the most important goals to fulfil with technological developments related to swimming science.

In this domain, one of the most popular and rather informative evaluation procedures is the assessment of the intra-cycle speed fluctuation profile of the swimmer. The mean velocity of a given swimmer depends on the balance between propulsive and drag forces. During a swimming cycle, the intensities of both forces change constantly, once the motor actions are more or less discontinuous (reaching to his fullness in the simultaneous techniques), and the relative positions of the body segments are constantly changing [2]. So, in each stroke cycle, the speed of the swimmer's forward displacement suffers more or less pronounced modifications due to the positive and negative accelerations induced by the continuous variations of the resultant impulses.

There are two different ways of measuring the intra-cycle speed profile of the swimmer: (i) by getting the velocity variations of an anatomical point (usually the hip) or (ii) analysing the swimmers Centre of Mass (CM) speed profile [3]. A fixed anatomical landmark can be monitored directly using the so cold cable Speedometers or Swim-meters, or the propeller based Swim speed recorders. Radar solutions can also be attempted. Nevertheless, for the CM velocimetry, only image processing solutions can be used, with automatic digitizing routines seriously compromised due to the dual-media condition. Consequently, this procedures are to much time consuming and are characterized by a reduced interaction capacity with the training process.

The purpose of this study was to validate a real-time velocimetric device (speedometer) through the comparison of their results with those provided for the hip and the CM from computer assisted videogrametry.

METHODS

The sample included 7 swimmers (63.4±9.3kg; 171.9±12.7cm) from the Portuguese national team, being 3 females and 4 males. As a solution to facilitate images processing, the swimmers were marked with adhesive tape or ink black colour in the main anatomical landmarks to be digitalized. Starting in the water, each swimmer performed, two repetitions of 25 meters Butterfly: one at the corresponding velocity of a 200m race (V200m) and other at 50m race pace (V50m). The study included two cycles in each repetition, resulting on a total of 28 cycles studied.

Speedometer

A low cost, house made speedometer was built (fig. 1). This instrument is based over a bobbin set in a tripod using a nylon line with almost no elasticity. This cable is fixed to the swimmer at the swimming suite, t a middle distance between the two hip joints.

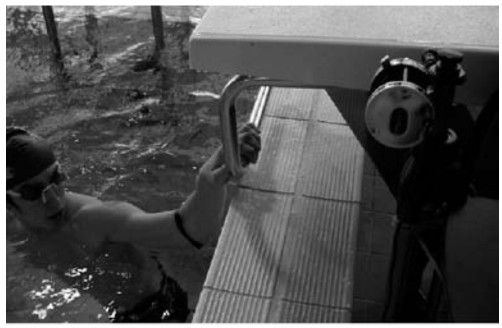

Figure 1. The speedometer

Fixed to the bobbin, a switch sends a signal to the computer, obtained at a 1000Hz frequency. This data is analysed by the computer that gives a graphic v/t in real time (fig. 2). These data can be exported from the software as ASCII and then be used in different analyses with basic software such as *Microsoft Excel*.

Figure 2. The graph v(t) obtained in real time

Images processing

Two video cameras were used (*JVC GR-SX1 SVHS* and a *JVC GR-SXM 25 SVHS*) in a special support with two shelves (fig. 3). A camera was 20cm below the water surface, inside a waterproof box (*Ikelite Underwater Systems*). The other one was

20cm above the water surface. The images obtained in the sagittal plan by the two cameras were synchronized in real time and mixed in a video mixing table (*Panasonic Digital AV Mixer WJ-AVE5*), originating a dual-media single image with corrected refraction, that was sent to a video recorder (*Panasonic AG-7350 SVHS*). The *Ariel Performance Analysis System*, from *Ariel Dynamic Inc.*, was used with Zatsiorsky model for centre of mass kinematical analysis.

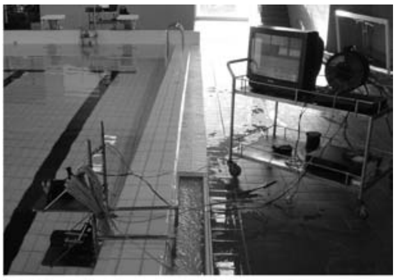

Figure 3. The dual-media image capture and mixing mechanism

Into the images obtained were digitized 24 anatomical points to get an accurate location of the centre of mass. Lately, results were filtered in x and y to eliminate possible errors from digitalization (*Digital Filter Algorithm* with a 5Hz frequency). After these procedures all the data were visualized, as shown in picture 4, both with the swimmer video image, the tick figure and the CM velocity graph.

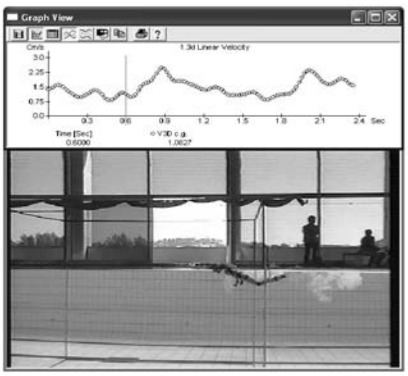

Figure 4. Data analysis

RESULTS AND DISCUSSION

The variables analysed were v_{hip1}, v_{hip2} and v_{CM}. The v_{hip1} stands for the velocity of the hip obtained by the images processing, v_{hip2} stands for the velocity of the hip assessed using the speedometer, and the v_{CM} stands for the velocity of the centre of mass of the swimmer. The kinematics of this last spot was taken as reference. An example of the v(t) curve for butterfly swimming, taken from one of the subjects of the sample is presented in Figure 5. To obtain this data was necessary to digitize, frame by frame, all the anatomical points. This took us a lot of time and it is, in fact, a procedure hardly available for the average swimming coach.

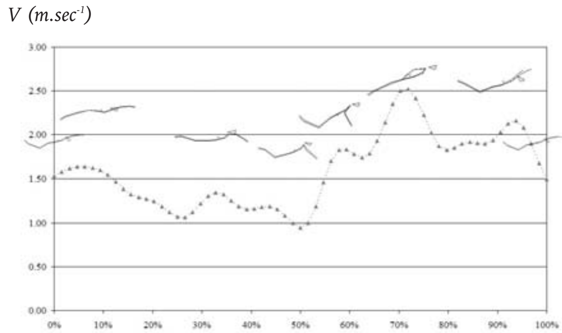

Figure 5. Butterfly intra-cycle velocity variation profiles of v_{CM} from a swimmer during a stroke cycle.

Using our home made speedometer we were able to obtain, in real time, the results presented in Figure 6. There it can be seen the successive cycles performed along the 25m distance, their intra-individual variability, the effect of fatigue associated with de decline of the mean velocity, and the intra-cycle variation of velocity (and their kinetics along the test duration). So, immediately after the test, the swimmer and the coach can have a set of very relevant biomechanical parameters associated with the butterfly technique performed just before. In the figure, between the vertical lines, a stroke cycle is defined.

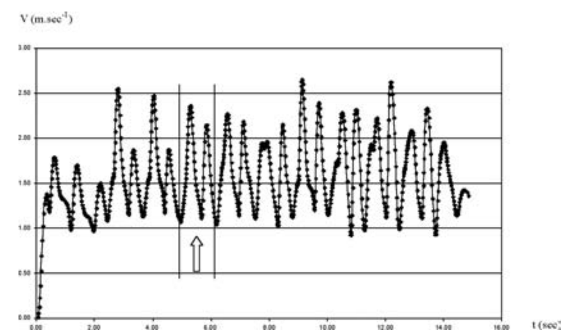

Figure 6. Speed profiles of v_{hip2} from a swimmer during a 25 meter Butterfly set.

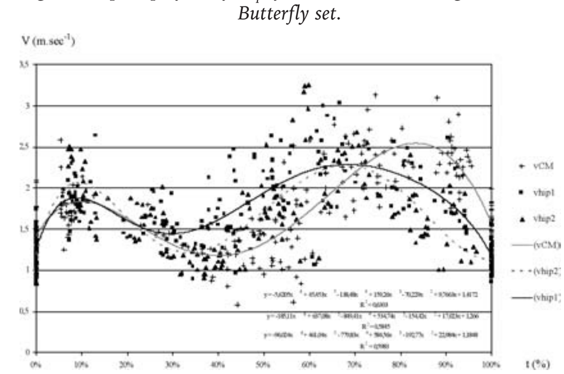

Figure 7. Velocity profiles obtained for the pooled data for v_{hip1}, v_{hip2} and v_{CM} during a stroke cycle.

The Pearson correlation coefficient computed for each swimmer between the variables analysed (v_{hip1}, v_{hip2}, and v_{CM}) was statistical significant in all cases ($p\leq 0{,}01$). The higher mean value of the obtained individual r values was found between v_{hip1} and v_{hip2} (0.955±0.028), followed by v_{hip1} with v_{CM} (0.920±0.049). The lower mean value for r was obtained between v_{hip2} vs. v_{CM} (0.878±0.053). After normalizing to the time duration for the period of a cycle we were able to create the Figure 6 scattergram and v(t) polynomial fluctuations best fitted to each distribution (v_{hip1}, v_{hip2}, and v_{CM}).

CONCLUSIONS

From these results we can assume that the study of a swimmer intra-cycle velocity profile assessed through the speedometer is reliable with the profile described for the same anatomical point but obtained through image processing biomechanical videogrametry. It is also very strongly correlated with the CM kinematical profile, despite some function discrepancies associated, mainly, to the effect over the CM of the simultaneous forward recovery of the arms. So we are strongly convinced that this artefact may be of extreme relevance for training evaluation and advice, allowing a number of practical applications to the performance enhancement of swimmers without major equipments, and time 8and money) costly analysis.

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ESTIMATION THE LAP-TIME OF 200M FREESTYLE FROM AGE AND THE EVENT TIME

Teruo Nomura

Kyoto Institute of Technology, Kyoto, Japan.

This investigation aimed at the estimation of the lap time of 200m freestyle races from age and event time on national level swimmers. Subjects were 1759 swimmers that selected by D'Agostino-Pearson test of each age from 1857 swimmers that participated in 200m freestyle of the Japanese national level competitions in 2002. The lap time in every 50m and the event time were used for analysis. Exponential function approximation of the event time by aging was carried out. Furthermore, the linear regression between a lap time and event time for every age was calculated respectively. It seems that the competitive time of 200m freestyle reach the maturity about 20 years old for men and/or 18 years old for women. The estimation formula applied to international level swimmer has high validity (0.904 to 0.987, n=118 and 86) on condition that the age factor should fix at 22 for over 22 years old male swimmer and/or at 21 for over 21 years old female swimmer.

Key words: lap-time, age, event time.

INTRODUCTION

The performance of 200m freestyle improves with aging in the period of growth. The contents of race change with grades of development of many physical fitness factors. The competitive record shows synthetic performance. On the other hand, the lap times are the composition elements of the swimming performance. It is not discussed by details about these development tendencies until now. This investigation aimed at the estimation of the lap time of 200m freestyle races from age and event time on national level swimmers. This investigation aimed at the estimation of the lap time of 200m freestyle races from age and event time on national level swimmers.

METHODS

Subjects were 1857 swimmers (men: 935, women: 922) that participated in 200m freestyle of the Japanese national level competitions in 2002. These subjects included from 10 to 22 years old.

The normal distribution of subjects is required for the parametric presumption. Therefore, the data arranged in order of the event time for every age respectively. The D'Agostino-Pearson test (ZAR 1999) which authorizes the normal distribution from coefficient of skewness and kuytosis was used. The swimmer which the normal distribution was not held as probability < 0.1 excepted. The lap time in every 50m and the event time were used for analysis. It was obtained permission of these data use from the Japan Amateur Swimming Federation Information System Committee. Exponential function approximation of the event time (TIME) by aging (AGE) was carried out. The time constant (TC) was decided as a correlation of TIME and a presumed value became the highest. The estimation formula of TIME from AGE was as follow:

$$TIME=a\left((TIME_{max}-TIME_{min})\cdot\exp\left(-\frac{(AGE\text{-}10)}{TC}\right)\right)+b \qquad \text{(Eq. 1)}$$

Furthermore, the linear regression between a lap time (LAP) and TIME for every age was calculated respectively. The linear regression coefficients were smoothed with 3rd order polynomial regression. The estimation formula that calculated the LAP from AGE and TIME was as follow:

$$LAP=(a_1AGE^3+a_2AGE^2+a_3AGE^3+c_1)TIME+(b_1AGE^3+b_2AGE^2+b_3AGE+c_2) \qquad \text{(Eq. 2)}$$

RESULTS AND DISCUSSION

The 908 men's and 851 women's swimmers were selected by D'Agostino-Pearson test applied to the event time. Figure1 showed the case of 15 years old boys, 15 slower swimmers were cut from 137 swimmers. The critical point was at 132.75sec.

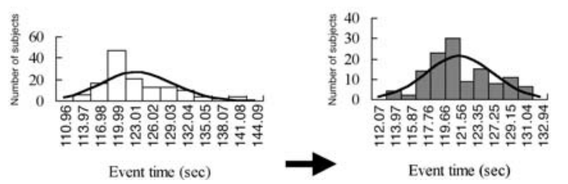

Figure1. Sample selected for the normal distribution by D'Agostino-Pearson test.

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Endereço para correspondência
Revista Portuguesa de Ciências do Desporto
Faculdade de Desporto da Universidade do Porto
Rua Dr. Plácido Costa, 91
4200.450 Porto · Portugal
Tel: +351–225074700; Fax: +351–225500689
www.fcdef.up.pt – expediente@fcdef.up.pt

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