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The impact of the visual concurrent swimming speed control on improving the economization of swimming

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background: The aim of this study was to determine the impact of the control of swimming velocity in real-time with the use of concurrent visual information on the economization of swimming.

Material/Methods: The study involved swimmers. During the research, two stress tests were performed, in which subjects swam 200m freestyle. In both trials, the participants' task was to swim the test distance as closely as possible to an individually pre-established set time. In the first test, subjects received no information on their swimming speed. In the second trial, subjects followed a beam of light at the bottom of the pool, which informed participants of the right swimming speed. The physiological cost of both efforts, which was an indicator of the economization of swimming, was estimated by the blood lactate (La).

Results: The difference in La obtained before and after the trial was statistically significantly lower ($p = 0.020$) while swimming with visual information. The time difference between the designated time and the achieved time was statistically significantly lower while swimming with visual information ($p = 0.015$).

Conclusions: Concurrent visual information delivered in real-time has enabled the control in swimming velocity and thus improves the economization of physical effort as marked by La.

Key words: swimming efficiency, pacing in swimming, visual information, concurrent information.

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INTRODUCTION

Over the years, optimization of techniques for faster and more economical swimming has been the subject of extensive scientific interest. New directions of research regarding more efficient swimming practices have been marked by numerous investigators [1, 2]. The essence of a swimming sports competition is to cover a distance in the shortest possible time [3]. To achieve a good result, it is important to use propulsive force as large as possible in order to overcome the water's resistance efficiently [4]. The use of variable propulsion forces and changeability variations in the resistance force cause changes in acceleration and, in turn, in the intracycle velocity variability [5]. Interaction between propulsive forces and resistance generates the intracycle velocity variability and variability of the mean velocity [6]. Additionally, the movement structure of all four swimming techniques enforces intracycle velocity variability which affects variability of the mean swimming velocity [7].

High variability in the intracycle velocity as well as changes in the swimming velocity over the entire distance are linked with an increase in the incurred energy costs. This is caused by a need to overcome the varying resistance force [8]. Stabilization of the changes in mean swimming velocity was recognized as an indicator for the increased effectiveness of swimming [9, 10]. Stabilization of the changes in swimming velocity mainly requires long-term training, which leads to a flawless technical movement. It is recognized that the so-called water sensation, or feeling of different stimuli, interpreting them and then adapting one's movements to a given experience helps in streamlining the action [11]. These features are developed when swimming at a particular speed. The acquisition of precise swimming skills is thus associated with participation in long-term training processes.

The stabilization of changes in the mean swimming velocity and its real-time control is an important element in training, which leads to effective preparation to competition. Due to such ability, the chance for faster adaptation to the desired effort is increased. An example of this is swimming at speed within indicated training zones; above or below the anaerobic threshold [12]. In the case of maintaining the established metabolic zones (intensity), such training helps to develop physiological traits [13]. In particular, young athletes are not able to maintain an adequate and stable speed when swimming. Thus, the control of swimming velocity in real time allows for a faster adaptation to the required effort. This enables one to achieve the training objectives at the early stages of preparation for competition. Another aspect of stabilizing the main swimming velocity is to improve the movement economization. The stabilization of swimming velocity results in a reduction of the effort of physiological exercise [14]. It is a common practice to form movements with the least physiological effort [15]. Control of swimming speed over a certain distance to stabilize the action can help minimize the energy needed to perform the effort.

Information on swim velocity/time is mainly passed on by a trainer by verbal communication. However, environmental conditions, i.e. the noise, disturb the process of information exchange. Over years, numerous methods have been created to improve the quality of information flow, including video recordings [16] and devices for wireless verbal communication [17]. However, none of the indicated methods have supplied information in real time, shaping a feeling of velocity. The means to stabilize the changes in the mean swimming

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velocity and its current control is through the use of a technical device called "Lider" (Kuca Ltd., PL). The light system "Lider" allows for the transmission of visual information to the swimmer on their swimming velocity in real time (concurrently) with a beam of light that moves across the bottom of the pool at the specified speed. As a result, the swimmer can stabilize the changes in mean swimming velocity and control it in real time. Concurrent information is continuous information that is conveyed during the performance of the motor activity [18].

MATERIAL AND METHODS

PARTICIPANTS

The study involved men and women who actively participated in swimming training (n = 14) of age $\bar{x}$ 20.4 ±3.9 (years), body height of $\bar{x}$ 177.9 ±9.1 (cm), weight $\bar{x}$ 69.4 ±10.7 (kg), competitive swimming experience $\bar{x}$ 10.4 ±3.1 (years), and their personal record in the 200 freestyle of 2:12 (min:sec) $\bar{x}$ ±5.8 (sec). All participants belonged to the same academic swim team. The subjects were informed about the essence of the experiment and its circumstances. The participants gave their written consent to participate. The ethics committee accepted the grounds for and means of conducting the tests.

PROCEDURE

The experiment took place in a 25m long swimming pool. Before the experiment, swimming speed for each participant was calculated during both of the exercise tests. The Pensold Test für Schwimmer (Mesics GmbH, DE) computer software was used to determine the participants' intensity levels. Thus, the same relative exercise intensity for all the subjects was obtained. When determining the speed, the records from the current season in the 200m freestyle competition were used. The set speed to swim during the exercise tests corresponded to the third energy zone, which represents a range of intensity between the anaerobic threshold and the maximum oxygen uptake, where both aerobic and anaerobic metabolic systems are shaped [19].

Before each test, participants recorded their resting blood lactate concentration and heart rate. The participants then performed a warm-up in the water, which involved swimming 200m freestyle in the first energy zone. This corresponded to a slower speed than the speed of the aerobic threshold [19]. 2.5 minutes after the warm-up in the water for the second time, the blood lactate concentration and the heart rate were measured.

The main experiment consisted of two exercise tests. In each test subjects swam a distance of 200m freestyle and 2.5 minutes after swimming, the blood lactate concentration and the heart rate were measured again.

The beginning of each exercise test started in the water. In both trials the participants' task was to swim the test distances as closely as possible to the previously allotted times. In the first trial, the respondents completed the test distance without getting real-time information on their swimming speed. In the second attempt, subjects watched a beam of light moving across the bottom of the swimming pool, generated by the device "Lider", which informed them of their swimming speed. A beam of light covered the test distance at exactly the time established before the experiment.

The tests were performed at the same time on consecutive days. The trial with visual feedback was first performed by the participants. The subjects were also asked to maintain a normal diet and abstain from alcohol and caffeine [20].

Measurement

The concentration of lactate La (mmol·l^{-1}) in the arterial blood as determined by an enzymatic test manufactured by Sentinel (Italy) was collected from the participants' fingertip and immediately diluted with a cold isotonic solution containing NaF and NaCl. Samples taken after a warm-up were appropriately labeled La A and La C and a secondary sample after trials labelled respectively La B and La D (A – before test; B – after test (without visual information), C – before test; D – after test (with visual information). There were no differences between the pre-warm-up in lactate values.

Heart rates HR (beat·min^{-1}) were recorded using the recording device POLAR (Polar Electro, Finland). The measurement was performed on pool immediately before and after the test exercises were performed. There were no differences in the pre warm-up in hate rates.

The measurements of time to cover the 200m t(s) were taken electronically using the startup system: Colorado Time System (Colorado Time, USA) with an accuracy of 0.01 seconds.

Research tool

Visual information indicating the desired speed in the water was generated using a device known as "Lider" (Kuca Ltd., PL). The device sends light signals from electronically controlled LED's placed in a transparent hose laid at the bottom of the pool. Light signals move at the programmed speed (Fig. 1).

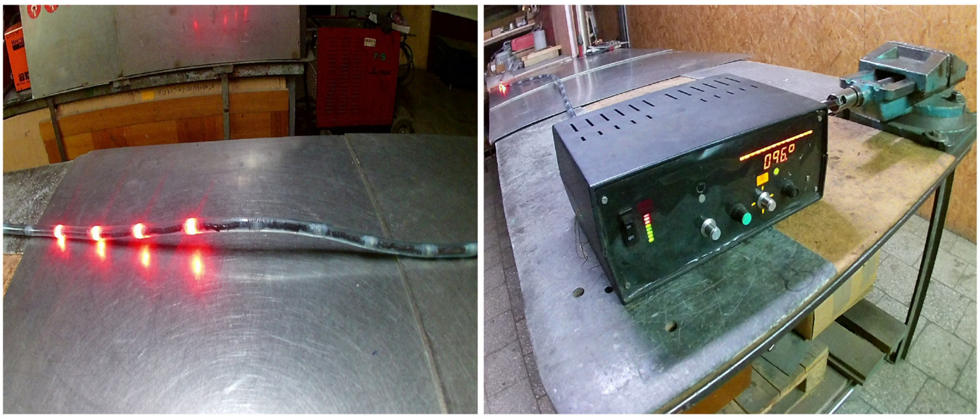

Fig. 1. The device "Lider" (Kuca Ltd., PL), consisting of a controller and polyvinyl chloride tube, (which includes LEDs) before installation at the bottom of the pool

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Statistical analysis

Statistical analysis was performed using the Statistica 9.0 software (StatSoft, USA). To determine statistical differences between Δt(s), ΔLa, and ΔHR, a t-test was used for the paired samples. A value of $p \leq 0.05$ was adopted as the level of statistical significance.

Results

Tables 1 and 2 contain values of the dependent variables as analyzed before and after the tests and the absolute value of the difference Δ in two conditions (with and without visual information on swimming speed).

The resulting swim time was significantly longer during the attempt with visual information ($p = 0.015$). The time difference between the designated time and the achieved time was statistically significantly lower while swimming with visual information ($p = 0.015$). This means that with visual information the respondents obtained a significantly closer swim times to the times designated before the experiment. Swimming speed was significantly slower when attempting to visual information ($p = 0.015$). The difference in lactate concentration obtained before and after the sample was statistically significantly lower during the attempt with visual information ($p = 0.020$). This means that with visual information the swimmers performed the test at lower physiological cost. There were no statistically significant differences in the HR ($p = 0.319$) (Table 3).

Table 1. Values of dependent variables analyzed before and after tests without visual information

	t (s) design-ated time	t (s) achieved time	Δ t (s)	V ($m \cdot s^{-1}$)	La A ($mmol \cdot l^{-1}$) before test	La B ($mmol \cdot l^{-1}$) after test	Δ La ($mmol \cdot l^{-1}$)	HR A ($beat \cdot min^{-1}$) before test	HR B ($beat \cdot min^{-1}$) after test	Δ HR ($beat \cdot min^{-1}$)
$\bar{x}$	153.71	149.86	3.86	1.34	2.02	6.61	4.59	94.3	153.0	58.7
±	9.14	9.33	4.28	0.09	0.58	2.49	2.33	26.0	15.9	19.3

Δ means the absolute value of the difference

Table 2. Values of dependent variables analyzed before and after tests using visual information

	t (s) design-ated time	t (s) achieved time	Δ t (s)	V ($m \cdot s^{-1}$)	La A ($mmol \cdot l^{-1}$) before test	La B ($mmol \cdot l^{-1}$) after test	Δ La ($mmol \cdot l^{-1}$)	HR A ($beat \cdot min^{-1}$) before test	HR B ($beat \cdot min^{-1}$) after test	Δ HR ($beat \cdot min^{-1}$)
$\bar{x}$	153.71	153.29	0.43	1.31	2.49	5.96	3.47	83.6	149.6	66.0
±	9.14	8.93	0.65	0.08	0.86	2.28	2.13	18.3	15.9	26.2

Δ means the absolute value of the difference

Table 3. Statistical analysis of changes in the measured parameters

Parameter	Δ t (s)	v ($m \cdot s^{-1}$)	ΔLa ($mmol \cdot l^{-1}$)	Δ HR ($beat \cdot min^{-1}$)
without visual information	$\bar{x}$ 3.86 ±4.28	$\bar{x}$ 1.34 ±0.09	$\bar{x}$ 4.59 ±2.33	$\bar{x}$ 58.7 ±19.3
with visual information	$\bar{x}$ 0.43 ±0.65	$\bar{x}$ 1.31 ±0.08	$\bar{x}$ 3.47 ±2.13	$\bar{x}$ 66.0 ±26.2
value of t-test for paired values	0.015*	0.015*	0.020*	0.319

**statistical significance p ≤ 0.05*

Δ t = time – time achieved

ΔLa = La B – La A or La D – La C

ΔHR = HR B – HR A or HR D – HR C

DISCUSSION

Physiological costs were a predictive measure for economization of swimming, and this was evaluated by physiological parameters, such as lactate concentration in blood, amount of lactate in the system La (mmol·l^{-1}), and participants' heart rates HR (beat·min^{-1}) [20, 21]. The assumed hypothesis of improved economization of movement has been confirmed. The use of concurrent visual information leads to a decrease in physiological costs and improves the economization of swimming. Visual information yielded a statistically significant lower concentration of lactate ($p = 0.020$). The results of this study indirectly correspond to the results of the studies by Perez et al. [22]. In this study, swimming speed was controlled by a swimming chronometer which was submerged at the bottom of the pool. Their results showed that the swimming rate is determined by the speed (aerobic or anaerobic intensity of exercise) and the length of the pool (25m, 50m). Therefore, one's ability to maintain a stable swimming velocity over a set distance in any swimming technique is determined by the efficiency of the effort and reflects the athlete's level. Perhaps, with the change of effort intensity into a higher zone, the resulting significance may be more pronounced. Increasing the intensity reduces control of the performed movement [23] and, as such in this case, the use of "Lider" might be more desirable.

Although stabilization of the changes in swimming velocity, with the aid of concurrent visual information, can reduce the cost incurred during physiological exercise (as assessed by lactate concentration), there was no significant difference in the heart rate ($p = 0.319$). Heart rate is dependent not only on the intensity of effort, but also on several other factors, for example, emotions. Participation of a larger number of subjects could also have allowed for the observation of statistically significant changes in the heart rate. Swimming training is a dynamic process that requires an individual approach to the trainee's body. Achieving better results often requires finding new and diverse training methods. One of these is the use of visual information. In practice, swimming while receiving real-time information on one's swimming speed is essential in order to achieve the training objectives. Swimming at a certain speed, imposed by the moving beam of light along the bottom of the pool, allows one to control the established intensity and to improve one's given exercise capacity. As a result, the swimmer has an opportunity to pursue the training objective. The term individual swimming speed which will be carried out during the workout, together with its concurrent control, increases the chance of rapid adaptation to the effort. In the presented study, the subjects obtained a significantly lower speed in the test swim with visual information, rather than when they were swimming without it ($p = 0.015$). Therefore, when the goal of training is, for example, swimming at the speed corresponding to changes in the aerobic threshold, the use of visual information helps the swimmer perform the work with the desired intensity. "Lider" was used in the study in an attempt to obtain a significantly closer swim times to those times appointed before the experiment ($p = 0.015$). Although "Lider" is a technical device, it can be used in swimming training without restricting the movements of swimmers, which could favorably affect their achievement.

CONSLUSION

Concurrent visual information delivered in real-time has enabled control of swimming velocity and in this way, the effort is performed in a designated training zone. Maintaining a proper velocity caused a reduced physiological effort, as marked by blood lactate concentration.

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