# THE EFFECT OF VISUAL SPEED SWIMMING CONTROL IN SWIMMERS' THRESHOLD TRAINING

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**Abstract** Controlling swimming speed is an important factor as far as accomplishing swimming training tasks is concerned. The aim of this study was to determine the importance of visual information about control of swimming speed in threshold training for swimmers. Six swimmers took part in this experiment. The study consisted of two exercise tests in which the participants swam 10 × 100 m. Individually designated task time corresponded to intensity of 95–100% of anaerobic threshold (AnT) intensity. AnT was determined in a progressive test prior to the experiment. In the first exercise test participants did not receive information regarding their swimming speed. In the second test visual information regarding their swimming speed was transmitted in real time using the Swimming Pace Control System device. The effect of visual control of swimming speed in threshold training for swimmers was determined by measuring the time needed to complete the test distances, heart rate and lactate concentration. Visual information used in swimming speed control in real-time statistically significantly reduces the differences between the assumed and actual time needed to complete the test distance ($p = 0.057$). Visual control of swimming speed resulted in an appropriate level achievement of intensity for threshold training, which was measured by swimming time (inaccuracy $\bar{x}$6.97 ±1.38 s), heart rate ($\bar{x}$162.7 ±15.9 beat/min), and lactate concentration ($\bar{x}$4.70 ±1.78 mmol/l). Comparing the increase in lactate concentration and exercise test with visual information, statistically significant differences are not observed ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards (4 to 5 mmol/l) of threshold training (8.85 mmol/l and 14.57 mmol/l). Additionally, value of standard deviations of lactate concentration after threshold training with visual information amounted to 37.87% mean of lactate concentration, and in the condition without information 84.00% mean of lactate concentration. The results indicate the need to use concurrent visual information provided in real-time allowing you to control the swimming speed in swimming training.

**Key words** controlling, swimming speed, visual information, threshold training

## Introduction

Speed control in sports training is a multi-faceted issue (Micklewright et al., 2012; Szczepan, Zatoń, Klarowicz, 2016). Speed measurement determines the absolute intensity of physical exercise. However, determining the relative intensity is dependent on the swimmer's current training level.

Speed control facilitates stabilization of an athlete's technique. This, in turn, lowers the physiological cost of physical exercise and improves exercise economy (Barbosa et al., 2005; Wilmore, Costill, Kenney, 2008). Speed stability allows the athlete to conserve the energy needed to perform the exercise and pass longer distances.

Maintaining a given speed is essential in improving athletes' technique during different exercise intensities, and high-intensity exercise in particular. High-intensity exercise often results in reduced motion precision, thus making it more difficult to perform with optimum technique.

Exercising with a given intensity determines the improvement of projected exercise capacity. This increases the chance for faster adaptation to the physical activity which is being performed (Costill et al., 1991; Bishop, Edge, Davis, Goodman, 2004; Glaister, 2005). Moving at a given speed within designated intensity zones, for example, above or below the anaerobic threshold, is used in the process of adaptation to appropriate lactate concentration (Pérez, Llana, Brizuela, Encarnación, 2009; Scruton et al., 2015). Inexperienced athletes often cannot maintain proper speed, thus failing to maintain proper intensity. In this case, speed control can help with precisely maintaining speed.

Controlling swimming speed allows the swimmer to accomplish a training task with a given intensity. Exercise intensity are categorized into five zones. The first and second training zones (aerobic) involves effort at speeds beneath the anaerobic threshold (AeT). The third training zone (aerobic/anaerobic) is performed at an intensity between the anaerobic threshold and maximum oxygen uptake ($VO_{2max}$). The fourth (anaerobic) training zone involves effort at $VO_{2max}$. The fifth (anaerobic) zone is above the $VO_{2max}$ (Bompa, Haff, 2009). Effort in last two zones produce significant concentrations of blood lactate, in which the threshold is termed as the onset of blood lactate accumulation (OBLA) (Bishop et al., 2004).

Threshold intensity is associated with the anaerobic threshold (AnT), which can be determined by ventilation or acidosis (Sharkey, Gaskill, 2013). Reaching the anaerobic threshold indicates the exercise intensity at which lactate utilization processes are slower than its production. Anaerobic threshold occurs during prolonged physical activity of increasing or variable intensity.

Threshold training is employed in a number of sports and used to develop many capacities. This training improves aerobic capacity, leading to greater efficiency (Larsen 2003; Diebel, Newhouse, Thompson, Johnson, 2017), developing cardio respiratory fitness through an increase in cardiac output and stroke volume (Hellsten, Nyberg 2015), an increase oxygen consumption, minute ventilation, and lung surface diffusion (Bassett, Howley, 2000). In addition, such training affects the development of slow-twitch fibres through an increase in the number of mitochondria and myoglobin concentration, and enhances the activity of oxidation enzymes (Ponsot et al., 2006). Such training helps in deferring the occurrence of anaerobic threshold in favour of higher muscle power (Rizzato et al., 2017).

During the threshold training, it is important to maintain a constant intensity that can be controlled using a predetermined time/speed. In addition, when speeding on a given distance, the speed should be constant. The stable threshold speed prevents excessive production of lactate in the blood and enables the implementation of the assumed goals of training.

The arguments raised suggest that using effective means of speed control during a swimming threshold workout is advisable. Hence, relaying information regarding elapsed time and swimming speed to athletes – that is, the intensity of their exercise – is a major role of the coach. This kind of information is often relayed verbally. However, it is not feasible in certain conditions. In an aquatic environment, interference in the process of information exchange occurs. Some examples are ambient noise, head submerged in the water, and swimming caps. They interfere with the exchange of information between coach and athlete.

Attempts to improve the flow of information between swimmer and coach have been undertaken. Zatoń, Szczepan (2014) showed a device for wireless verbal communication with a swimmer which employed radio waves. Turner, Smith, Coleman (2008) used an audio system which informed about swimming pace. Visual information, which also helps improve the performance of motor activities, has additionally been used (Anderson, Magill, Sekiya, Ryan, 2005; Andrieux, Proteau, 2016). Gonzalez et al. (2002) and Pérez et al. (2009) relayed information regarding elapsed time using a chronometer placed at the bottom of the pool. Zatoń, Kędrak, Rejman (2016) used a trolley with mirrors which moved along the edge of the swimming pool as a means of improving breaststroke.

The aim of this study was to determine the importance of visual information about control of swimming speed in threshold training for swimmers. It was assumed that visual control of swimming speed would allow an appropriate level of intensity for threshold training to be achieved, which was measured by swimming time, heart rate, and lactate concentration.

## Materials and research methods

### Participants

Six healthy swimmers – members of the University swimming team – took part in this experiment: age $\bar{x}$19.67 ±4.23 yo, height $\bar{x}$183.83 ±10.65 cm, weight $\bar{x}$69.83 ±9.87 kg, duration of training $\bar{x}$6.43 ±0.79 yr, 100 m freestyle personal best $\bar{x}$58.33 ±4.13 s. The relatively small size of the study group was associated with the pilot nature of this study. Each of the participants gave informed consent in writing. The Ethics Committee of the University approved the conduct of the study. Participants were asked to maintain a normal diet and avoid any strenuous physical activity during the study period (Thoma, Nelson, Silverman, 2015).

## Procedure

Before the main tests, participants performed a warm-up, swimming 200 m in an anaerobic threshold. Intensity and warm-up was supervised by an exterminator. 2.5 minutes after the warm-up in the water, the blood lactate concentration and heart rate were measured.

The study consisted of two main exercise tests that started 5 min after warm-up. The main exercise tests were performed at a 24-hour interval. In both trials a water start was used. In the first and second exercise test the participants performed threshold training.

Due to the numerous interpretations of the threshold training intensity, the work intensity was adjusted to 95–100% intensity of the anaerobic threshold (AnT). AnT was determined according to methodology of Binder's et al. (2008) in a progressive test performed prior to the experiment.

The flow time (corresponding to the flow velocity) during the test tests was calculated using the formula. In the applied threshold training, subjects flowed 10 × 100 m front crawl with a speed corresponding to 95–100% intensity AnT. Between the repetitions, a 60-second break was used.

The study participants were tasked with swimming all ten repetitions in a time as close as possible to the individually designated time determined prior to the experiment. In the first exercise test, those participating in the threshold training did not receive any information regarding their swimming speed. In the second exercise test, visual information regarding swimming speed was transmitted in real time.

In this test the participants followed a beam of light moving across the bottom of the swimming pool, which was emitted by the Swimming Pace Control System (SPCS) (Creosiv, PL) device (Figure 1). SPCS device enables delivery of visual information about swimming speed in real time. System submerged at the bottom of the pool is equipped with LEDs and software informing the swimmer of the appropriate distance and swimming speed. A beam of light from the SPCS device covered the distance precisely within the time which had been designated for each participant prior to the experiment. A validation test of SPCS was completed with an accuracy of ±200 ms (Szczepan, Zatoń, 2017).

**Figure 1.** Swimming Pace Control System (SPCS) device before installation at the bottom of the swimming pool

## Measurement

Measurements of time/speed, heart rate and lactate concentration were taken.

Measurement of time t(s) needed to complete the test distances was performed electronically, with an accuracy of 0.01 seconds. The Colorado start system (Colorado Time System, USA) was used for this purpose. After each test, time differences between the time designated for a given test subject and the actual time needed to complete the test distance in both variants (with visual speed control and without) were calculated.

Lactate concentration La (mmol/l) was determined using the enzymatic method (Hydrex, Italy). Arterialised fingertip blood was used in this assessment. Blood was diluted with a cold isotonic solution containing NaCl and NaF. Lactate concentration during the research tests was measured three times: (A) before the test – 2.5 min after the warm-up, (B) midway – halfway through the test and (C) after the test – 3 min after completing the test when the lactate concentration had a maximum value (Goodwin, Harris, Hernández, Gladden, 2017).

Heart rate Hr (beat/min) was recorded before (resting) and after (post-exercise) each test using POLAR sport tester (Polar Electro, Finland).

### Statistical analyses

The statistical analyses used Student's T-test for paired values. Statistical analyses were performed in Statistica 9.0 (StatSoft, USA). Using t-test was a proper way to determine differences between variables (Thoma et al., 2015). To check whether a given distribution of the quantitative variable is normal, the difference between the observed distribution and the ideal one was checked. An insignificant result ($p > 0.05$) allowed assuming that the observed distribution has a normal shape.The absolute value (accuracy) between the assumed and actual time needed to complete the test distance in both situations (with visual speed control and without) was analysed.

The significance of the increase in lactate concentration prior to the test (A), midway (B), and after the test (C) in two condition was also calculated.

Additionally, the significance in the increase of lactate was calculated as well.

## Results

In condition with visual information performed task was significantly more accurate in time ($p = 0.057$) compared to the condition without information, as evidenced by a decrease in the time difference.

It is interesting that after summing up all the differences in time for ten replications, the subjects obtained an inaccuracy equal to Σ = 41.80s (with visual information) and Σ = 89.70s (without visual information). Inaccuracy in time was a measure of sum of absolute values of differences between the scheduled time and elapsed time (Table 1).

**Table 1.** Inaccuracy in time in two conditions (with and without visual information)

| | visual speed control $\Delta t$ (s) | no visual speed control $\Delta t$ (s) |
|---|---|---|
| | sum of inaccuracies | |
| | 7.90 | 23.70 |
| | 6.10 | 7.40 |
| | 7.00 | 7.20 |
| | 9.20 | 23.20 |
| | 6.10 | 21.90 |
| | 5.50 | 6.30 |
| $\bar{x}$ | 6.97 | 14.95 |
| ± | 1.38 | 8.77 |

Table 2 contains change in lactate (La) concentration in the research test with and without visual information. In order to determine changes in lactate concentration between test tests A, B, C for two conditions, a difference test was performed. In the test with visual information lactate concentration between research test A and B was statistically significant ($p = 0.019$). Between the test A, and C also statistically significant ($p = 0.014$). There were no significant differences between research test B and C ($p = 0.830$). In the sample without visual information lactate concentration between research test A and B was statistically significant ($p = 0.051$). Between research test A and C ($p = 0.069$) and between research test B and C no significant differences were observed ($p = 0.611$). The results show that in exercise test with visual information, the changes in lactate concentration in blood were more significant compared to exercise test without information.

In contrast, no statistically significant differences ($p = 0.710$) were observed between exercise test with visual information and without information. Similarly, there was no difference in increase in lactate concentration ΔLa A-C ($p = 0.947$).

**Table 2.** Change in lactate (La) concentration in the test with and without visual information

| | Visual speed control | | | | | | No visual speed control | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | La before the test (mmol/l) | La in the middle of the test (mmol/l) | La after the test (mmol/l) | Δ La | Δ La | Δ La | La before the test (mmol/l) | La in the middle of the test (mmol/l) | La after the test (mmol/l) | Δ La | Δ La | Δ La |
| | A | B | C | A–B | A–C | B–C | A | B | C | A–B | A–C | B–C |
| | 2.11 | 3.53 | 4.28 | 1.42 | 2.17 | 0.75 | 3.20 | 9.85 | 8.85 | 6.65 | 5.65 | –1.00 |
| | 1.01 | 8.09 | 7.23 | 7.08 | 6.22 | –0.86 | 5.78 | 6.74 | 14.57 | 0.96 | 7.79 | 7.83 |
| | 0.92 | 4.50 | 4.83 | 3.58 | 3.91 | 0.33 | 1.70 | 3.52 | 1.98 | 1.82 | 0.28 | –1.54 |
| | 1.46 | 4.49 | 4.09 | 3.03 | 2.63 | –0.40 | 1.51 | 2.81 | 2.35 | 1.30 | 0.84 | –0.46 |
| | 1.64 | 4.60 | 5.85 | 2.96 | 4.21 | 1.25 | 1.59 | 5.70 | 5.55 | 4.11 | 3.96 | –0.15 |
| | 1.95 | 2.55 | 1.94 | 0.60 | –0.01 | –0.61 | 2.14 | 2.36 | 2.33 | 0.22 | 0.19 | –0.03 |
| $\bar{x}$ | 1.52 | 4.63 | 4.70 | 3.11 | 3.19 | 0.08 | 2.65 | 5.16 | 5.94 | 2.51 | 3.28 | 0.78 |
| ± | 0.48 | 1.87 | 1.78 | 2.24 | 2.11 | 0.83 | 1.65 | 2.86 | 4.99 | 2.42 | 3.49 | 3.50 |

## Discussion

Swimming speed control is important aspect of training. First, in an effort to increase the chance of a more rapid adaptation to a performance during swimming training (Costill et al., 1991). Second, is to improve the economization of the movement as a result of stabilizing the swimming speed. The stabilization of swimming speed results in a reduction in the cost of physiological exercise (Barbosa et al., 2005). Third is to improve swimming technique during high-intensity exercise. Proper selection of training loads, in particular the intensity of the swimming exercise is an important factor enabling the mastery of a sport's technique used at a given speed of swimming. Fourth is to optimize the kinematic parameters of the cycle of swimming, for example; stroke length and stroke rate. The swimming stroke length is the distance of the horizontal displacement of the swimmer during one movement cycle (Hay, 2002). For these reasons, using control of speed of swimming is an important factor in the process of optimizing sports training (Chinnasamy, St Clair Gibson, Micklewright, 2013).

It is worth noting that there are numerous communication barriers in the aquatic environment. Communication barriers are created most often by the sound of water, head submerged in the water, swimming cap, and poor acoustics at the swimming pool. In these conditions, transfer of any information at all is difficult (Zatoń, Szczepan, 2014). Many authors have concluded that visual information is an important information medium, particularly in an environment where interference in communication occurs (Andrieux, Proteau, 2016). Visual information is beginning to be used in teaching swimming (Zaton, Kędrak, Rejman, 2016), improving technique (Zaton, Szczepan, 2014) and the swimming training process (Vezos et al., 2007). Additionally, it should be noted that in terms of time, as a criterion of information quality, immediate (in real time) transmission is considered the most effective form of information passed on to people performing motor activities by many authors (Lee, Swinnen, Serrien 1994; Schmidt, Lee, 2013).

The aim of this study was to determine the importance of visual control of swimming speed in threshold training for swimmers. The main findings of the work were to prove that visual information about flow rate control improves the accuracy of the training task. Test subjects floating with visual information obtained a smaller inaccuracy in time compared to the condition without information. The sum of differences in the time of overcoming ten repetitions with visual information was $\Sigma = 41.80$s, while without information $\Sigma = 89.70$s. Differences in inaccuracy in time of execution were statistically significant ($p = 0.057$). However, it was exhibited important parameters. Some participants maintained the designated speed without visual control. On the other hand, other people could not keep the indicated swimming without being in control, swimming or too fast. Therefore, one can conclude at the same time. More experienced swimmers are not bothered by speed control, while the less advanced swimmers are clearly helped by it. The obtained results correspond with the studies of Szczepan et al. (2016), in which also improved visual information accuracy during the flow.

Achieving the right time/speed for the respondents in the research test with visual information resulted in maintaining the intensity of the training threshold. Level of intensity for threshold training, measured by heart rate, and lactate concentration. Heart rate achieved after the threshold of training corresponded to $\bar{x}$162.7 ±15.9 beat/min. In contrast, lactate concentration was $\bar{x}$4.70 ±1.78 mmol/l, which was the purpose of the threshold training. This means that the subjects achieved the characteristic value of the anaerobic threshold of the lactate value of 4 to 5 mmol/l, which subject to the training objective. Without speed control participants after threshold training also achieved a similar level of appropriate intensity (Hr $\bar{x}$160 ±21.3, La $\bar{x}$5.94 ±4.99 mmol/l). When interpreting the results of increase in lactate concentration we may conclude that there was no significant difference between the increase in lactate concentration when visual control was used and when it was not ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards (namely 4 to 5 mmol/l) of threshold training (8.85 mmol/l and 14.57 mmol/l). Even though the mean values of lactate concentration in the blood did not differ significantly in both conditions, it did not prove that the physiological costs for each swimmer were similar. The value of standard lactate concentration after the training in both cases was different. With visual information, the standard deviation of lactate concentration was ±1.78, which was 37.87% of the mean lactate concentration 4.70 mmol/l. On the other hand, in the condition without information, the standard deviation of lactate concentration was ±4.99, which was 84.00% of the mean lactate concentration 5.94 mmol/l. The lower variation of the standard deviation in the condition with visual information indicates the need to use visual control of the swimming speed.

In the present experiment, the Swimming Pace Control System (SPCS) device (Creosiv, PL) was used to provide visual information about the flow velocity in real-time (online) (Szczepan, Zatoń, 2017). In the past, devices such as Lap Track (Finis, USA) have been used for the same purpose and are displayed on the pool wall, or a hand chronometer (SportCount Chrono, USA). Also a visual means for the transmission of information via a timer submerged at the bottom of the pool has been used (Gonzalez et al., 2002; Perez et al., 2009). Other devices such as Lider (Kuca, PL) (Szczepan et al., 2016), GBK-Pacer (GBK-Electronics, PT), Pace2Swim (FADEUP Porto, PT), and SwimLead (Synerte, PL) report the speed of swimming in real time, using a beam of light moving along the swimming pool were used as well.

The presented research results should be interpreted carefully due to several limitations. It was not assessed whether the intervals between repetitions of pressures were sufficient to eliminate fatigue that could affect the results. The results could also have been influenced by experience, hence it is not known how visual control can affect children, and how on very advanced players. Similarly, the sex of respondents who can otherwise receive visual information. In addition, due to the pilot nature of the research, the number of respondents was small. In future studies, the emphasized restrictions should be taken into account.

To sum up, swimming with a given speed helps maintaining the desired intensity of physical exercise. This is important in such situations as when threshold training with multiple repetitions is performed. Real-time (online) swimming speed control using visual information emitted from the SPCS device facilitates achieving an appropriate level of intensity for threshold training, which was measured by swimming time, heart rate, and lactate concentration. Visual control is a method that can be used during various types of swimming training, and for many training groups, which constitutes the application value of the presented results.

## Conclusions

Visual information used in controlling of swimming speed in real-time statistic significantly reduces the differences between the assumed and actual time needed to complete the test distance ($p = 0.057$). That means that the accuracy of threshold training performance increases, which allows for accomplishing training objectives in a more precise manner. Visual control of swimming speed resulted in achieving an appropriate level of intensity for threshold training, which was measured by swimming time (inaccuracy $\bar{x}$ 6.97 ±1.38 s), heart rate ($\bar{x}$ 162.7 ±15.9 beat/min), and lactate concentration ($\bar{x}$ 4.70±1.78 mmol/l). Comparing the increase in lactate concentration and exercise test with visual information, significantly statistical differences are not observed ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards of threshold training. Additionally, value of standard deviations of lactate concentration after threshold training with visual information amounted to 37.87% mean of lactate concentration, and in the condition without information 84.00% mean of lactate concentration. The lower variation of the standard deviation in the condition with visual information and the indicated results indicate the need to use concurrent visual information transmitted in real-time enabling control of swimming speed in swimming training.

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