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SCIENCE IN SWIMMING II

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INTRODUCTION

Meaning of water for a human organism cannot be overestimated. Swimming in water is connected with different environment and thus the necessity of performing different movements in it. We usually swim in water of temperature lower than the body temperature; this prevents getting a common cold and hardens the organism. Water has exceptionally beneficial influence over the condition of respiratory system. The special way of breathing in water, called the 'swimming breath', increases the force of respiratory muscles and enlarges lungs breathing capacity as compared to the body surface area. The position most frequently taken while swimming is horizontal position. In connection with almost total elimination of the gravitational force influence and reduction of the hydrostatic pressure influence, it provides the optimum conditions of even blood supply to all tissues. Cyclical movements performed while swimming result in overcoming water resistance with individual frequency and this allows for improving the muscle force of the swimmer. Strength exercises of this type are particularly recommended for children and people requiring body compensation.

Water and movement in water offer even further benefits positively affecting the widely understood human health. Only the major ones are presented here. At the same time, we do not even mention the utilitarian aspects of the swimming skill constituting a separate, extremely large area of knowledge.

For these reasons, numerous research programmes are conducted worldwide, of results which document the importance of activity in water, irrespective if it is undertaken for recreation, health, rehabilitation or sport reasons.

Researchers working in this field exchange their views at numerous seminars, conferences and congresses. Also, plentiful popular science and science works and studies on this subject are published all over the world. All the same, ordering and describing knowledge on swimming still requires extensive work. Thus, it seems that meetings of researchers studying various areas of swimming, held cyclically in Wrocław, may to some extent supplement the knowledge on the subject.

A monograph *Science in Swimming II* continues presentation of interesting results of research projects conducted in various research centres all over the world.

Since our last meeting, new research concepts have appeared; more modern methods and measuring instruments have been applied and new conclusions have been drawn based upon it. These conclusions will undoubtedly enrich knowledge and in many cases will become useful for all those dealing with implementing them in practice.

The monograph contains issues related to the Swimming Education. In this area, it is worth paying attention to the innovative educational concepts connected with kinaesthetic differentiation, kinaesthetic sensitivity, swimming education of seven-year-olds or teaching effectiveness as a result of applying trademark teaching programme in the form of instruction.

The next chapter – **Swimming Technique** – performs biomechanical analysis of young swimmers' technique as a result of training in water, studies the influence of the movement form on movement stability, the interconnection between the co-ordination abilities and the sports results of 11–12 years old swimmers and presents objective (mathematic) methods of assessing learning progress and improvement of the swimming technique.

Further research results are presented in the chapter about the issues connected with **Swimming Training**. It presents some interesting solutions, having influence, (as empirically documented), on the effectiveness of training. In this chapter it is worth paying attention to works on analysing selection of training exercise and results of 12-year-old swimmers, metabolic reaction to reducing breathing frequency during effort making, stabilization of lactate concentration while swimming with critical and maximum speed and frequencies of movement cycles, cyclical nature and selection of training exercises in preparing great class swimmers for competition, the relationship between the swimming pool length and assessment of critical speed of young swimmers in freestyle and finally the relationship between the swimming speed and the work performed on the swim ergometer.

The chapter entitled **External Factors Supplementing Swimming Training** covers some very interesting issues concerning factors crucial for choosing the swimming sport by children, the influence of the Fast-Skin swimwear on the results obtained by the elite Iranian swimmers, as well as the meaning of motivation factors in achieving sports success by young swimmers. The work in which its Author, upon scientific and philosophical deliberations writes about swimming – the human body and movement, is an interesting ending of this chapter.

The last chapter **Water Sports and History of Swimming** presents results of research conducted on various issues about the swimming sport. They comprise the influence of ribbing on fin's mechanical parameters, the influence of break on the match in the 'extra man' situation in water polo, the comparison of assessing sport results of Polish and German female juniors in 2004 and 2007, the overload of ankle joint during finswimming and its diagnosis as well as modelling the legs' movement and fin load in order to improve swimming speed.

Presenting our readers with the next monograph *Science in Swimming II*, we are convinced that the interesting research concepts it contains and their results shall inspire scientists involved in studying swimming to even more interesting ideas and ways of developing them

Krystyna Zatoń
Marcin Jaszczak

PART ONE

SWIMMING EDUCATION

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Differences in Level of Kinaesthetic Sense Between Swimmers and Non-Swimmers

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ABSTRACT:
Introduction: Kinaesthetic differentiation is one of the determinants of performance. It is a major factor stipulating rational usage of power during muscle contraction. The aim of this experiment was to estimate the changes of kinaesthetic differentiation ability as a result of incremental test in swimmers and non-swimmers.
Material and methods: The experiment involved 14 swimmers (9.8±0.8 years of training) mean±sd age 19.3±2.67 (yr), height 180.6±4.97 (cm), body mass 75.2±11.83 (kg) and 18 non-swimmers mean±sd age 20.8±0.65 (yr), height 181.1±6.79 (cm), body mass 78.74±10.33 (kg). Both groups performed an incremental test which was conducted in order to estimate performance level. Kinaesthetic sense was measured before and after the effort test. During the kinaesthetic trial subjects were obliged to make 10 identical force pushes following the first (model of force push) by the upper and lower limbs. Average force of push (F) and standard deviation of F (Fsd) measured before and after the test were compared using Student t-test.
Results: The differences in the level of performance between swimmers and non-swimmers are statistically significant ($p < 0.05$): swimmers/non-swimmers $\dot{V}O_{2max}$ 55.0±6.82/47.18±6.72 (ml/kg/min), total work (W_{tot}) 191.3±44.99/164.0±36.23 (kJ). Despite the higher W_{tot} made by swimmers, they committed fewer mistakes in pushing the right hand (forward and backward) and the left hand (forward) than non-swimmers both before and after the test. Statistical significance was set at $p < 0.05$.
Conclusions: There exists a dependence between kinaesthetic differentiation ability and the level of performance. Better kinaesthetic differentiation improves the economy of physical work.

KEY WORDS: kinaesthetic differentiation, work ergonomy, physical ability, swimmers

INTRODUCTION

Specific sequences of muscle co-ordination exist in movements in every sport. Sports involving repetitive movement patterns such as swimming depend more on specific co-ordination of muscle contraction sequencing in order to economize effort.

Kinaesthetic differentiation is one of the determinants of performance. It emerges on the basis of complex sense impressions. It allows one to percept and control the executed movement and feel consciously its power, speed and trajectory. Precision and timing of movement is a condition of efficient sport technique. Movement precision brings information about the efficiency of the central nervous system (CNS). The higher the CNS efficiency the proper movement execution (Djupsjobacka, Domkin 2005). The nervous system performance, including muscle and touch sense, has a crucial influence on the quality of the performed movement.

Skilled locomotor behavior requires information from various levels within the central nervous system (CNS). Each movement needs feedback information for its control. A sensory feedback from the muscle and skin mechanoreceptors and other sources is essential to capture eventual mismatches between predicted and actual sensory input to update relevant internal model of muscle tension (Nowak et al. 2003). The cerebellum plays an important role in a sensory – motor integration process. It obtains the information from the motor cortex about what kind of movement has been planned. It also receives proprioceptive information from the muscles, tendons and junctions and from the skin mechanoreceptors about the performed action. Proprioceptive information, especially from the muscle spindles is unconscious. The muscle spindles are responsible for modulating the spinal reflex excitability thus adjusting muscle tension. There is also a proprioceptive feedback to the sensory motor cortex and this part of information is conscious. The system of motor control decides about accuracy of execution of a motor task. It is responsible for a proper recruitment of motor units during each movement.

The level of kinaesthetic differentiation among others is determined by the level of the nervous system excitation, effort and motor fatigue. Fatigue is usually defined as a reduction in force generated by the muscles. It should not be forgotten that lack in repeatability of force generation can also characterize fatigue. One of the ways of measurement of kinaesthetic differentiation level is measurement of repetitiveness of muscle force generation.

The aim of this experiment was to estimate the changes in kinaesthetic differentiation ability as a result of the incremental test in swimmers and non-swimmers.

MATERIAL AND METHODS

The study comprised 32 subjects: 14 swimmers (9.8±0.8 years of training) and 18 non-swimmers (2nd year students at University School of Physical Education in Wrocław).

Both groups performed a graded incremental test to volitional exhaustion on a cycle ergometer. The test was discontinued with the occurrence of a decrease in oxygen consumption with a concurrent increase in ventilation and heart rate, or when the subject could no longer endure the effort. The subjects worked at a self-selected cadence but not less than 60 ($rev. \cdot min^{-1}$). Respiratory variables and heart rate (HR) were measured using the breath by breath K4b^2 analyzer (Cosmed Ltd, Italy) which was calibrated prior to each test according to the manufacturer's instructions. The data were averaged every 30 sec. In the third minute after the test, arterial blood samples were collected for determination of blood lactate concentration (LA) (mmol/l).

Kinaesthetic sense was measured before and after the test. During the kinaesthetic trial subjects were obliged to make 10 identical force pushes following the first (model of force) by the upper (push and pull) and the lower limbs. The upper limbs during measurements were bending in the elbow at an angle of 90°. The lower limbs were bending at the knee at an angle of 100° and the foot was placed at an angle of 90° in relation to the shank. Before beginning the trial, subjects had been instructed how to generate force of 10 kG.

All the tests were fully explained to the participants and were performed with their written consent.

The statistical analysis includes calculation of average force of 10 pushes (F) (kG) and standard deviation of F (Fsd) for each limb movement. Student t-test was calculated between the data measured before (rest) and after (post-effort) the incremental test for each movement and between swimmers and non-swimmers. The level of statistical significance was set at $p < 0.05$.

RESULTS

Both groups reveal a statistically significant difference in fitness level. Despite the almost the same Hb concentration, the swimmers have higher $\dot{V}O_{2max}$ in comparison to non-swimmers (Tab. 1). Swimmers manifest also statistically higher W_{tot} with lower lactate concentration. Blood lactate accumulation is significantly higher in non-swimmers and the difference between both groups equals 2 mmol/l (Tab. 2).

The results of kinesthetic sense measurements are shown in Table 3. Analyzing the results measured in the rest condition, one can see that average forces of 10 pushes (F) are overestimated about 1–2 kG in swimmers and 2–3 kG in non-swimmers. The comparison of the rest results in swimmers and non-swimmers shows statistically significant differences for F (URF), F (URB) and F (ULB).

TABLE 1. Physical characteristics – means (SD) – and t-test between both groups

Characteristics	Swimmers (*N* = 14)	Non-swimmers (*N* = 18)	Test-t
Age (years)	19.3 (2.7)	20.8 (0.6)	**0.01**
Weight (kg)	75.2 (11.8)	78.7 (10.3)	0.19
Height (cm)	180.6 (5.0)	181.1 (6.8)	0.42
BMI	23.0 (3.1)	24.0 (2.6)	0.17

TABLE 2. Fitness levels for swimmers and non-swimmers – means (SD) – and t-test between both groups

Characteristics	Swimmers (N = 14)	Non-swimmers (N = 18)	Test-t
Hb	14.45 (0.8)	14.6 (1.0)	0.36
LA (mmol/l)	10.8 (1.6)	12.8 (3.0)	**0.01**
$\dot{V}O_{2max}$ (l/min)	4.1 (0.5)	3.7 (0.5)	**0.02**
$\dot{V}O_{2max}$ (ml/kg/min)	55.0 (6.8)	47.2 (6.7)	**0.00**
W_{tot} (kJ)	191 (45)	164 (36)	**0.03**

Mistakes in repetition of model push (Fsd) measured during the rest are the same for whole limbs and directions of movements in both group, except the results of Fsd (URF). Fsd (URF) is statistically significant higher in non-swimmers.

Post-effort kinaesthetic sense parameters in the case of the upper right limb in both forward (URF) and backward (URB) movement are significantly worse in non-swimmers when compared to swimmers. Swimmers pushed closer to 10 kG force and made fewer mistakes (Fsd) (F(URF)/Fsd(URF) 10.45/0.90, F(URB)/Fsd(URB) 10.81/0.96) than non-swimmers (F(URF)/Fsd(URF) 13.11/1.13, F(URB)/Fsd(URB) 12.90/1.23).

The upper limb post-effort results in swimmers are slightly better than rest results but the changes are not significant. For legs the incremental test on cycle ergometer results in higher mean force of 10 pushes (F) and less repeatability of generating forces (Fsd). For F(LR) differences between rest and post-effort measurement are statistically significant.

Effort improved non-swimmers level of kinaesthetic differentiation in forward movement of both hands: Fsd(URF) rest/post-effort 1.42/1.13 and Fsd(ULF) 1.06/0.83. In the case of legs the parameters of kinaesthetic sense increased which spots worsening of kinaesthetic differentiation level and for Fsd(LR) this change is statistically significant.

Despite the higher W_{tot} made by swimmers they committed fewer mistakes in pushing the right hand (forward and backward) and the left hand (forward) than non-swimmers both before and after the test. Statistical significance was set at $p < 0.05$.

DISCUSSION

It is well known that the ability of a human to make judgments of generated force deteriorates with muscle fatigued growing. Fatigue slows muscle fiber conduction velocity, prolongs twitch duration (Chin 2005), and increases the neural activation required to produce a given force (Carson et al. 2002). It is evidenced that fatigue can affect motor performance in skilled activities. Jones and Hunter (1983), Carson et al. (2002) found that during fatigue subjects are unable to estimate accurately the force

TABLE 3. Values of kinaesthetic sense parameters and t-test for rest results, post-effort results, swimmers and non-swimmers – mean (SD)

	Swimmers (rest)	Non-swimmers (rest)	t-test	Swimmers (post-effort)	Non--swimmers (post-effort)	t-test	t-test swimmers	t-test non--swimmers
Fsd(URF)	1.01 (0.28)	1.42 (0.52)	**0.01**	0.90 (0.28)	1.13 (0.36)	**0.03**	0.16	**0.03**
F(URF)	10.30 (1.44)	12.38 (1.54)	**0.00**	10.45 (1.44)	13.11 (1.62)	**0.00**	0.40	0.09
Fsd(URB)	1.25 (0.61)	1.17 (0.24)	0.30	0.96 (0.33)	1.23 (0.41)	**0.03**	0.07	0.29
F(URB)	11.38 (1.59)	12.54 (1.47)	**0.02**	10.81 (2.02)	12.90 (1.73)	**0.00**	0.21	0.25
Fsd(ULF)	0.97 (0.31)	1.06 (0.38)	0.23	1.01 (0.24)	0.83 (0.32)	**0.05**	0.35	**0.03**
F(ULF)	12.07 (1.91)	11.81 (1.21)	0.31	11.80 (1.97)	11.55 (1.38)	0.34	0.36	0.28
Fsd(ULB)	1.06 (0.43)	1.13 (0.42)	0.32	0.90 (0.25)	1.05 (0.32)	0.08	0.12	0.26
F(ULB)	11.87 (2.08)	12.96 (1.33)	**0.04**	11.33 (1.91)	12.38 (1.67)	0.06	0.25	0.13
Fsd(LR)	1.85 (0.66)	1.82 (0.83)	0.46	2.00 (1.03)	2.34 (0.84)	0.17	0.32	**0.04**
F(LR)	12.63 (2.47)	13.52 (3.01)	0.19	13.95 (1.45)	13.51 (2.92)	0.31	**0.05**	0.50
Fsd(LL)	1.95 (0.56)	1.99 (0.99)	0.44	1.94 (0.78)	2.42 (1.06)	0.09	0.48	0.11
F(LL)	12.00 (2.07)	13.50 (3.15)	0.07	12.69 (1.87)	14.58 (3.21)	0.03	0.19	0.16

F – mean force of 10 pushes, Fsd – standard deviation of F, URF – upper right limb movement forward, URB – upper right limb movement backward, ULF – upper left limb movement forward, ULB – upper left limb movement backward, LR – lower right limb, LL – lower left limb. Level of statistical significance set at $p < 0.05$

of contraction. Walsh et al. (2004) suggest that exercising to fatigue leads to proprioceptive disturbance. Perhaps proprioceptive disturbance results in less precise movements during effort which may decrease correct movement execution and work economy.

Fatigue does not seem to really change kinaesthetic differentiation. Słonina (1998) has reported that low and medium intense exercise improves the ability of kinaesthetic differentiation and high intensive work reduces it. In our research we found out that the level of kinaesthetic differentiation measured as a standard deviation of generated force (Fsd) did not change in swimmers after maximal incremental test in comparison with rest results (Tab. 2). In swimmers kinaesthetic sense of the upper limbs increased insignificantly. However, in non-swimmers a significant improvement can be seen in forward movement for both hands (Fsd(URF) and Fsd(ULF)). This could be a result of post-exercise nervous system excitation. Improvement in forward movements in non-swimmers can be explained by the fact that most of daily life movements are related to forward hand motion. In swimmers a better improvement in backward movement was observed which can be explained as a result of a swimming technique where propulsion force is backward pull.

The values of mean force of 10 pushes (F) (kG) did not change significantly in both swimmers and non-swimmers. The differences which appeared between rest and post-effort results in F(LR) and F(LL) show the direction of transitions in muscle sense after eccentric exercise. In both groups the post-effort results were worse than rest results, and in swimmers the change in F(LR) is statistically significant. Overestimation of force after eccentric contractions was observed also by Carson et al. (2002) and Walsh et al. (2004). Gregory et al. (2002, 2004) found in an animal model that fatigue and muscle damage after eccentric exercise did not disturb responsiveness of the muscle spindles and tendon organs. Imprecision in force scaling after effort can be more an effect of metabolic changes than disturbance responsiveness of proprioreceptors (Carson et al. 2002; Walsh et al. 2004). It is also well known also that exercise with domination of eccentric contractions, like cycling, gives rise to an accumulation of metabolic products and often leads to muscle damage (Proske, Morgan 2001). These metabolic changes cause direct disturbance in muscle work and indirect by alteration in the discharge rates of groups III and IV afferents. Excited free nerve endings III and IV afferents are blocking α-motoneurons which results in a decrease in muscle excitation with progressing of fatigue. Despite the metabolic changes and rise of discharge III and IV afferents, the F was greater in post-effort in comparison to rest results. This can be a result of post-exercise nervous system excitation (Walsh et al. 2004).

Our research shows that swimmers have better level of kinaesthetic sense than non-swimmers before and after the effort. It is also supported by results of incremental test which was performed by swimmers. Work done W_{tot} is statistically significantly higher than in non-swimmers (swimmers/non-swimmers 191/164 kJ) with less lactate accumulation (10.8/12.8 mmol/l). Better kinaesthetic sense can be an effect of years of training which is in agreement with the previous study (Albiński et al. 2006; Jastrzębska et al. 2006).

Concluding, we can say that there exist a slight dependence between kinaesthetic differentiation ability and the level of performance. Swimmers manifest a better level of kinaesthetic sense than non-swimmers before and after the effort which can be explained by years of training. Better kinaesthetic differentiation improves the economy of physical work. Improvements of kinaesthetic sense of the upper limbs after legs cycle ergometer test can be an effect of the nervous system excitation. An improvement in forward pushes in non-swimmers and backward pulls in swimmers can result from dominant movement direction in daily life (non-swimmers) and backward pull in swim techniques (swimmers).

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Differences in Conscious Reception of Stimuli from Water Environment in School Children

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ABSTRACT: One of the key factors conditioning smooth movement of a human being in water is the ability to differentiate force. The feeling of water resistance and reaction to this effect is connected with individual level of kinaesthetic differentiation ability. Throughout the last few decades, many definitions of kinaesthetic differentiation have been offered. It was frequently defined as a subtle differentiation of proprioceptive stimuli produced by the limb movement in the water environment or sensing water resistance, based on cooperation of two analysers: motor analyser and skin analyser (Starosta 1997). According to the this definition, these are co-ordination abilities that enable one full adaptation to the water environment and moving in it rationally with the minimum consumption of energy. This study describes the analysis of the value of force, as an indicator specifying the sensitivity to stimuli coming from the water environment. It will also present the results of the study, which prove the relationship between the subjects' swimming fitness and the level of perception of stimuli from the water environment. This study aims at proving that the level of kinaesthetic differentiation ability as measured in water depends not only on the precision of the force applied but also on its value and duration. The study was carried out with the use of kinaesthesiometer, which was specially designed to record repeatability of force in water.

The data obtained during the study allowed us to conclude the following:

1. The maximum force (FM) is correlated on the level of 0.98 with the swimming fitness.
2. In the water environment the subjects differentiate the force the most precisely at the rate of 61% of the maximum force.

KEY WORDS: swimming, water environment, motor activity, kinaesthetics

INTRODUCTION

Teaching the ability of motor performance in water environment is a complex and difficult process – bringing about stressful situations arising due to the specific character of this environment. The following difficulties mark only the beginning of problems that the teacher and the students have to overcome while working in the water environment: difficulty in breathing – the basic need of each human being, prompt loss of heat and lack of full visual control of the surrounding. Still, orientation in space gets disturbed most of all in the water environment. In the initial phase perceiving direction of movement, amplitude and muscle tone become significantly distorted. It happens very often that in the first lesson the students are not able to maintain erect body position, make a few steps or spin around their cephalocaudal axis without the teacher's help. Additionally, sensitivity to temperature and sensitivity to light skin touch are also altered. Orientation in space conditions proper functioning of a human in the surrounding reality. This ability is also required in each school lesson, not only in swimming classes.

Since our birth, we have been learning how to understand our living space because this is the only way to control it and satisfy all our needs. Exploring the space is so deeply set in our experiences that we do not percept it consciously. The key role in learning to understand the space is played by the following factors: cognitive processes, stock of concepts, knowledge of the body scheme, space representations and handling the relation of distance and time (Kwapisz, Kwapisz 1990). Exploring the new space of water environment is a complex and long-term process. The space is experienced directly, when we look at it, and most of all, when we move in it. While moving from one place to another, a human being acquires the sense of direction (Yi-Fu 1987). As we move in the space, we go through various experiences and make various observations; this provides us with the data on the space and the ability to 'handle it'. Only its thorough exploration guarantees smooth movement and realizing our abilities. Orientation in space is shaped by the body movement, gestures, touch and observing the effects of moving in the space. These experiences must be accompanied by appropriate verbalising of the person's feelings, doings and perceptions. Still, the words may not replace the experiences of exploring the space. A child must by himself live, feel, as well as notice and name his experiences (Gruszczyk-Kolczyńska et al. 1992). Verbalising experiences, matching them with particular words, is the next stage in exploring water environment and in creating the so called body image (comprehending the body in the space) (Przyrowski 2001).

One of the key factors conditioning smooth movement of a human being in water is the ability to differentiate force. The feeling of water resistance and reaction to this effect is connected with the individual level of kinaesthetic differentiation ability. Throughout the last few decades, many definitions of kinaesthetic differentiation have been offered. It was frequently defined as a subtle differentiation of proprioceptive stimuli produced by the limb movement in the water environment or sensing water resistance, based on cooperation of two analyzers: motor analyzer and skin analyzer. According to the latest definition, these are co-ordination abilities that enable one full adaptation to the water environment and moving in it rationally with the minimum consumption of energy. This study describes the analysis of the value of force, as an indicator specifying the sensitivity to stimuli coming from the water environment. It will also present the results of the study, which prove the relationship between the subjects’ swimming fitness and the level of perception of stimuli from the water environment.

OBJECTIVE AND HYPOTHESIS OF THE STUDY

This study aims at proving that the level of kinaesthetic differentiation ability as measured in water depends not only on the precision of the force applied but also on its value and duration. The hypothesis of the study: Students presenting higher level of swimming fitness have better ability to differentiate force in water.

SUBJECT OF THE STUDY

The study involved a group of 30 children aged between 9 and 12. They attended a course in sports swimming, which at this stage is aimed at teaching the standard level swimming techniques. The classes took place in the 25-metre-long swimming pool at the University School of Physical Education in Wrocław. Altogether 150 training units were completed in the water environment, which intended to improve motor and co-ordination skills of children.

METHOD

The study was carried out with the use of kinaesthesiometer, which was specially designed to record repeatability of force in water. The accuracy of measurement reached 0.23 N and the impulse frequency record amounted to 500 Hz, a tensometric amplifier and a computer processing and recording the changes taking place in water were additionally used. The device records the results of processes taking part in the human organism, which aim at conscious differentiation of force in water. Each movement made by the subjects in water is controlled by their consciousness; the task is easy ‘repeat each movement applying the same force’. The volume of force with which the body interacts with the tensometric platform under the influence of the movement of the left and right upper limb is registered with the frequency of 500 times per second (Klarowicz et al. 2006). The exemplary record of the value of force in time is presented in Figure 1.

RESULTS OF THE STUDY

This simple record allowed us to gather a values reflecting numerically the phenomena of conscious differentiation of force in water. The obtained data was divided into two groups. The criterion of division was the verbal message given to the stu-

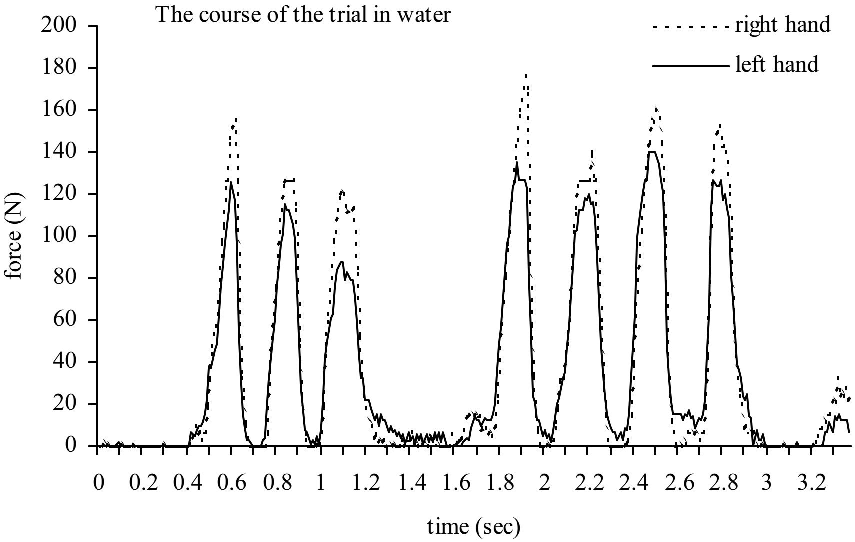

FIGURE 1. The exemplary record of measurement in water

dents prior to the recording. The first one was: 'make the rowing movements applying the same strength each time', the second group performed the task: 'make the most forceful rowing movement with your arms'. For the easier reference purposes, the first group was marked FD (force precision) and the second one FM (maximum force). The FM values ranged between 16 N and 331 N, presented in Figure 2.

Specifying the value of FM allowed us to calculate the percentage of FD it contained. It is the second ratio that enables us to notice a relation appearing in the ability of conscious reception of the kinaesthetic stimuli from the water environment. FD presented in Figure 2 constitutes on average 61% of the FM value.

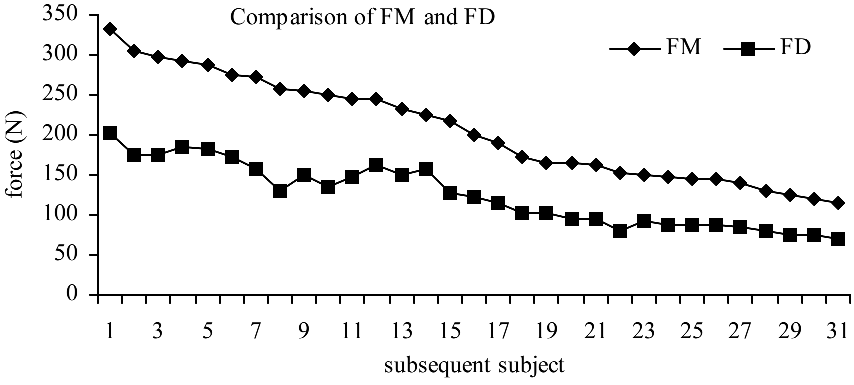

FIGURE 2. The maximum and precise force recorded for individual subjects

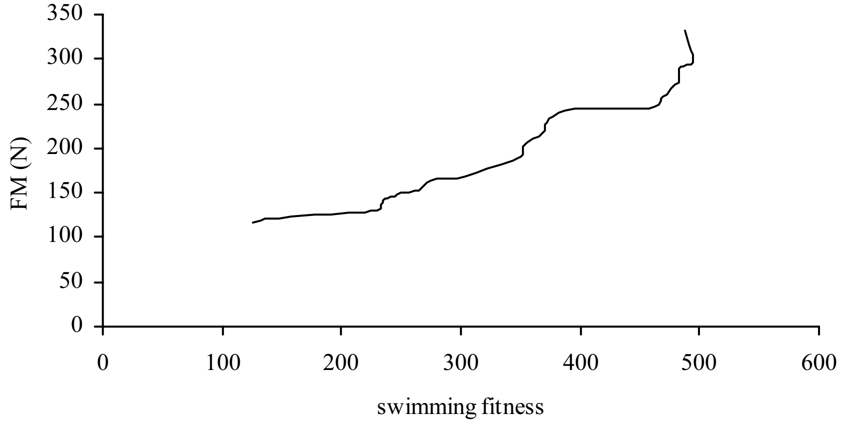

FIGURE 3. The function of the relationship between FM and the swimming fitness

The comparison of FM value and the level of swimming fitness displayed by the subjects is given in Figure 3. The level of the swimming fitness was established based on the amount of multi-discipline points obtained by each subject after the time they needed to swim 50 m freestyle was measured. The results have been presented as a function that might be considered a linear function. The higher the FM level, the higher the swimming fitness of the subjects.

CONCLUSIONS

The data obtained during the study allowed us to conclude the following:

a) The maximum force (FM) is correlated on the level of 0.98 with the swimming fitness.
b) In the water environment the subjects differentiate the force most precisely at the rate of 61% of the maximum force.

DISCUSSION

Swimming requires from children lengthy stay in the water environment. Doing motor activities in such a surrounding is to some extend hindered or even limited. Breathing co-ordination, tone of particular groups of muscles, body positioning and appropriate force application are conditioned by additional factors like water density, temperature and hydrostatic pressure. According to researchers, 'The ability to differentiate movement is displayed on the basis of kinaesthetic sensations'. These sensations may be specific and non-specific. The first ones take place while making movements typical for a given discipline, which are perfected while they are frequently repeated. Under a long and systematic training they reach a high level of perfection enabling particularly precise differentiation of amplitude, movement speed and muscle tone, i.e., precision of motor activities (Starosta 1997).

The data collected in the study allowed us to establish the average value of force with which the conscious movements in water are made. The value of this force was determined on the level of 61% of the maximum force. Despite numerous publications on determining the level of kinaesthetic differentiation ability (Zatoń 1981; Starosta 1997; Wołk, Zatoń 1998; Zatoń, Klarowicz 2001), no material describing the changes of these abilities directly in the water environment was found. The most frequent indicator specifying differentiation was the value of the average mathematical error (standard deviation). The measurement of the value of force coming as a result of conscious reception of stimuli from the water environment seems to be a pioneer concept. Would it be possible to find a correlation between the speed of swimming and the information passed on to the students by the teacher, its content and form? This question is waiting to be answered. Few studies written on the theory of the school physical education try to solve this problem. The method applied in the studies specifies the results of the conscious performance of a human in the water environment. We are not able to record the human thought but we can measure its effects and draw conclusions that in the future would give a more detailed knowledge on the teaching process of learning of the movement activities.

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The Effectiveness of the Process of Learning Swimming Skills in 7-year-old Children

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ABSTRACT: This study is an attempt to evaluate the effectiveness of the process of learning and teaching swimming in children at the age of seven with respect to their fittnes and body built. The results of the study show that subject's sex has no effect on children's swimming skills. The frequency of movements has the greatest influence on mastering the sports abilities in boys and balance among girls. Additionally, it was noticed that body weight strongly influences the process of acquiring swimming skills.

KEY WORDS: swimming, fitness, process of learning

INTRODUCTION

The process of motor learning causes permanent changes in the amount and level of motor skills. Learning complex motor activities, such as sports technique involwes both energetic and cognitive action. The process learning consists of exercising, thinking, decision making and emotional engagement.

The effectiveness of the process of learning how to swim appears to be very complex. The learning rate of swimming is influenced mostly by: motor abilities, level of physical development, instructor's personality, emotional state (fears of a child), and appropriate methodology.

A precise specification of sports technique leads to the best results in learning. It is also possible thanks to the appropriate teaching methods. The greater the teacher's knowledge about the process of learning, the better results in performance. The precise choice of the aim and task will allow for the teaching results evaluation. The differences between results and aims indicate the progress. The progress positively influences motivation to further effort. However, one should be aware that evaluation of results should not be performed only at the end of the whole process but also during it. This should help to improve its effectiveness.

Co-ordination abilities also play an important role in the effectiveness of the process of learning. The speed and quality of motor learning as well as the perfection and stabilization of motor skills are greatly influenced by co-ordination abilities (Raczek et al. 2002).

Raczek et al. (2002) showed that the process of acquiring new motor abilities skills in children relies on multilevel and coordinative stimulation. He also stated that together with improvement in sports performance the level of co-ordination abilities also improves. There is an observable relationship between technical preparation and the level of co-ordination abilities.

The aim of this study was to evaluate of the effectiveness of learning process of swimming skills in 7-year-old children. The following research questions were formulated:

1. What is the effectiveness of the process of learning of swimming skills?
2. Are there any differences between swimming skills and motor abilities due to the differences in sex?
3. Do the relationships between the level of swimming skills and motor fitness exist?
4. Do somatic features of the examined group influence the level of acquiried swimming skills?

MATERIAL AND METHODS

The research was conducted on 57 children from primary school. There were 28 girls and 29 boys between them. They were at the age of 7. During the school year they participated, once a week in 30 lessons of swimming. In the first semester of the program the children were learning basic swimming skills: backstroke and legs-down water jumps. The second semester included learning of freestyle and head-down water jumps. Specific swimming skills were evaluated by means of the 15 m swim test (Dybińska 2002, 2004).

The swimming technique was assessed by means of a score system. It was evaluated in the following manner:

1. front slide-up to 3 meters, 0–3 points,
2. back slide-up to 3 meters, 0–3 points,
3. water exhalation (5), 0–3 points,
4. legs-down water jumps, 0–3 points,
5. legs movement in backstroke – up to 15 meters, 0–3 points,
6. legs movement in freestyle – up to 15 meters, 0–3 points,
7. backstroke – the distance of 15 meters, 0–10 points.

Each correct performance was awarded with points. Pupils could obtain 0 to 3 points for the basic swimming skills and jumps (depending on the technique), and 0 to 5 points for legs movements while swimming (2 additional points were given for 15 m swim). The highest scores (0–10), were given for swimming 15 m backstroke and freestyle, other evaluated skills were the following: position of body on the water, steady legs movements, knees joint angle during performance, foot position, over-water arm movement, hand positioning, breathing, co-ordination of movements. For each properly performed technical element there was 1 point to be obtained, while for 15 m swim – 2 points.

The tests results allowed distinguishing following fitness groups:

0–8 points – poor level, the fitness group – '1',

9–16 points – average level, the agility group – '2',

17–24 points – good level, the agility group – '3',

25–32 points – very good level, the agility group – '4'.

The evaluation of the motor fitness level was made by means of 8 agility tests evaluating chosen motor abilities.

The tests concerned:

1. dexterity – putting legs over a dash,
2. ability of quick reaction – running after forward bending,
3. differentiation of movements – ball control test,
4. static balance – beam standing test,
5. dynamic balance – bench spins,
6. ability of high frequency of movements – both feet over-bench jumps,
7. locomotor dexterity – slalom run,
8. flexibility – bending forward.

Additionally motor fitness tests were used in the research (Raczek et al. 2003), the locomotion dexterity (Mynarski 1995) and the flexibility test by Zuchora's (Drabik 1992).

We also measured body weight and height. The achieved empirical data was used in further analysis.

The statistical analysis included:

1. Descriptive statistics.
2. Analysis of variance ANOVA and *post hoc* HSD Tukey test.
3. The Spearman's rank correlation was used for the evaluation of the relationship between motor fitness and swimming skills as well as motor fitness and somatic features.

RESULTS

The evaluation of the effectiveness of swimming training was made by means of swimming skills test composed of 7 trials. The results (Tab. 1) shows that the level of the subjects swimming abilities mastery was diversified. 43% of girls represented the highest level – very good ('4') and good ('3') as well as poor, and only 7% of girls reached the average level ('2') as well as the poor level ('1'). The results of boys

TABLE 1. Numbers of investigated subjects in the aspect of obtained swimming skills

Level of skills	Girls		Boys		Together (girls and boys)	
	mumber	%	number	%	number	%
‘1’	2	7	0	0	2	4
‘2’	2	7	6	21	8	14
‘3’	12	43	11	38	23	40
‘4’	12	43	12	41	24	42

show that they mastered swimming better than poorly – level (‘1’). The highest level (‘4’) was reached by 42% of boys, good (‘3’) – 40%, while 21% mastered the skills of swimming on the average level (‘2’).The girls and boys together scored the following results: very good level (‘4’) of the swimming results obtained 43%, good (‘3’) – 40%, and average (‘2’) – 14% of the examined children.

The differences in the swimming fitness profiles between girls and boys were not significant (Fig. 1).

The analysis of results showed that girls mastered slides better, as well as footwork in backstroke and backstroke as whole technique, whereas boys dominated during water exhalations, legs-down water jumps and during legs movements in freestyle. However the differences between boys and girls in the level of swimming skills were statistically insignificant.

The examined children differed in somatic and motor profiles (Fig. 2). Boys dominated in co-ordination abilities: speed of reaction, kinesthetic differentiation of movements, dynamic balance and locomotion dexterity, they were also taller than girls. Girls obtained better results in overall dexterity, flexibility, static balance and movement frequency. However, statistically significant differences in the level of motor fitness concerned only: kinesthetic differentiation of movements, flexibility, movements frequency and locomotion dexterity.

The study finds the answer to the question if motor efficiency was significant in mastering swimming skills at the first stage of learning. Spearman’s rank correlation indicates motor abilities that significantly influence swimming skills mastery. Among girls only static balance significantly influenced learning of swimming skills (Fig. 3). This ability correlated with legs movements’ skill in backstroke and freestyle. The results of boys were different. In their case, movement frequency and whole body dexterity were the abilities that significantly influenced learning of swimming skills (Fig. 4). We observed correlations between the following swimming skills: back water slide, movement of legs in backstroke and freestyle and backstroke swimming technique. Locomotion dexterity was closely related to the water exhalation and to the backstroke swimming technique. It can be stated that the greatest influence on the process of swimming skills learning in boys had movement frequency and dynamic balance in girls.

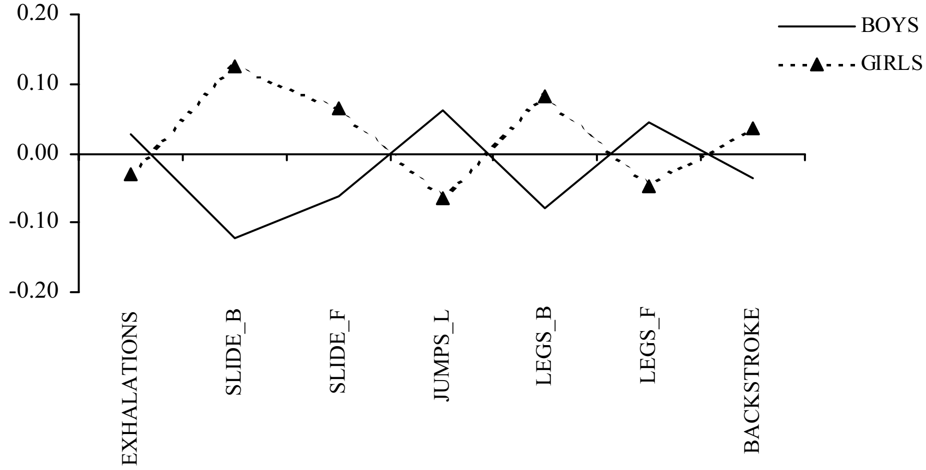

FIGURE 1. Swimming fitness profiles

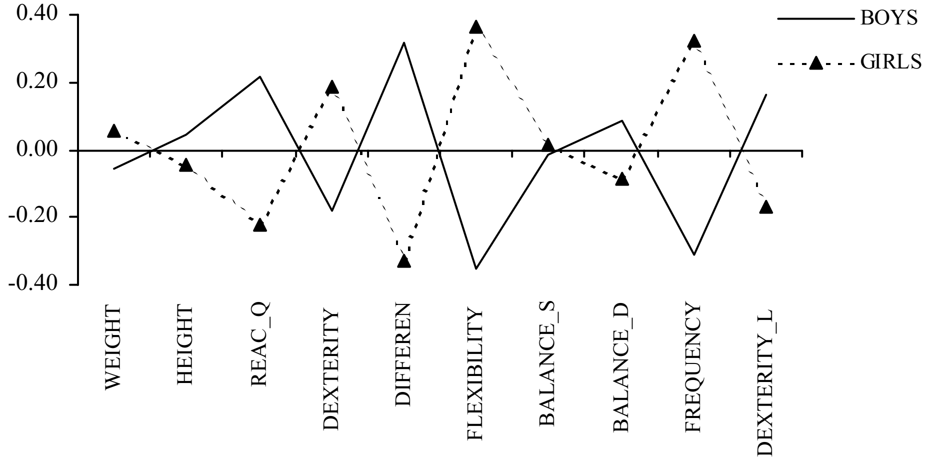

FIGURE 2. Motor and somatic profiles

Another discussed aspect was the influence of somatic features on mastering swimming skills. The only swimming skills that correlated with swimming fitness were the following: legs movement in backstroke and freestyle (Fig. 5). Additionally, body height in boys significantly correlated with back water-slide (Fig. 6). Body mass in boys significantly correlated with: efficiency of water exhalations, front water-slide, legs movement in freestyle and the skill of backstroke (Fig. 7). Back water-slide skill and legs movement skill in freestyle were significantly influenced by body height in boys. An interesting observation is that body mass affected swimming skills more than body height.

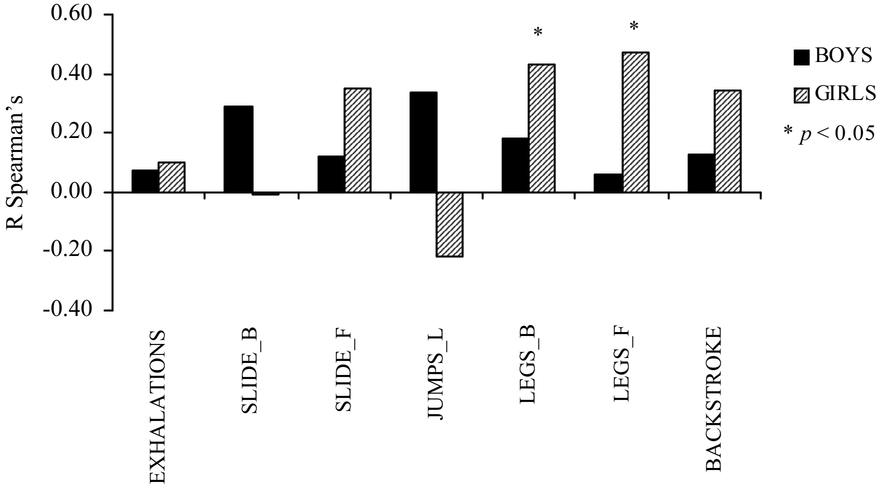

FIGURE 3. Correlations of swimming efficiency and static balance

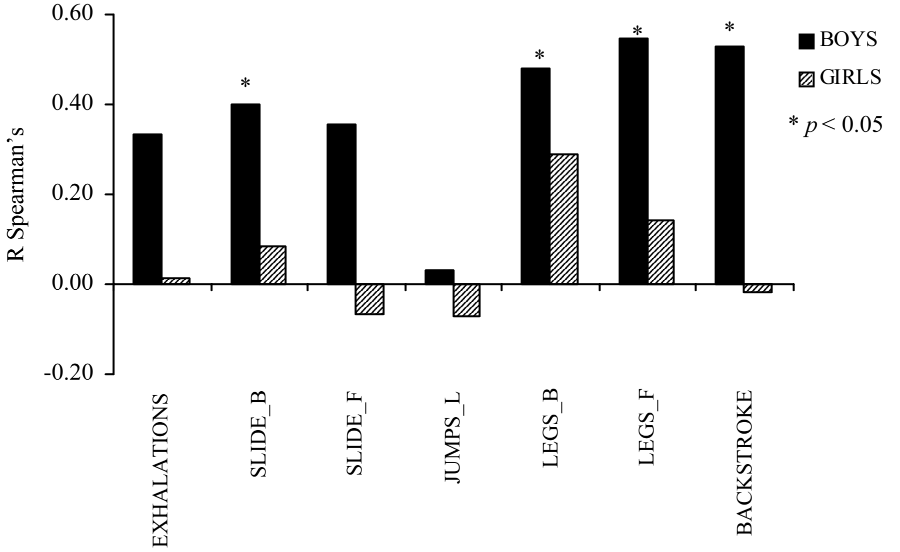

FIGURE 4. Correlations of swimming efficiency and frequency of movements

DISCUSSION

The achieved empirical data allows one to conclude that motor fitness and somatic features of the subjects mark their influence on the acquirement of new swimming skills. There is a certain parallel to previous studies. Raczek (1989) demonstrated a close connection between the level of co-ordination abilities and the process

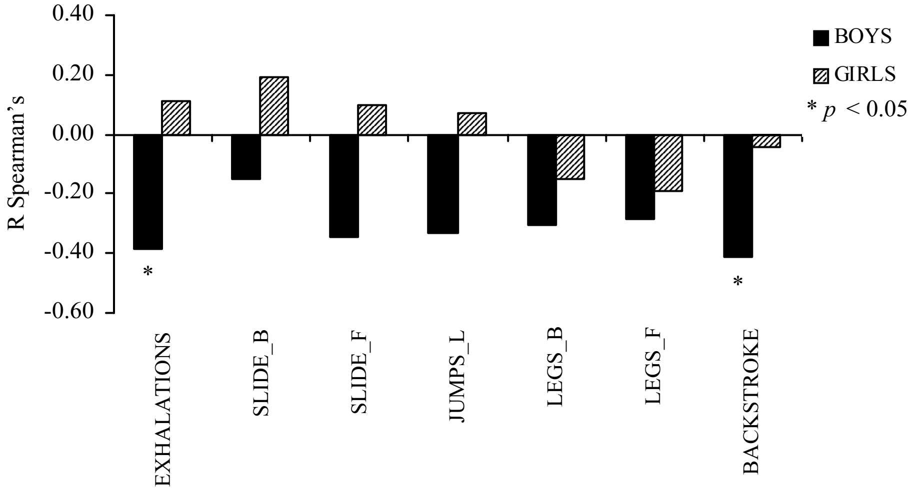

FIGURE 5. Correlations of swimming fitness and locomotion dexterity

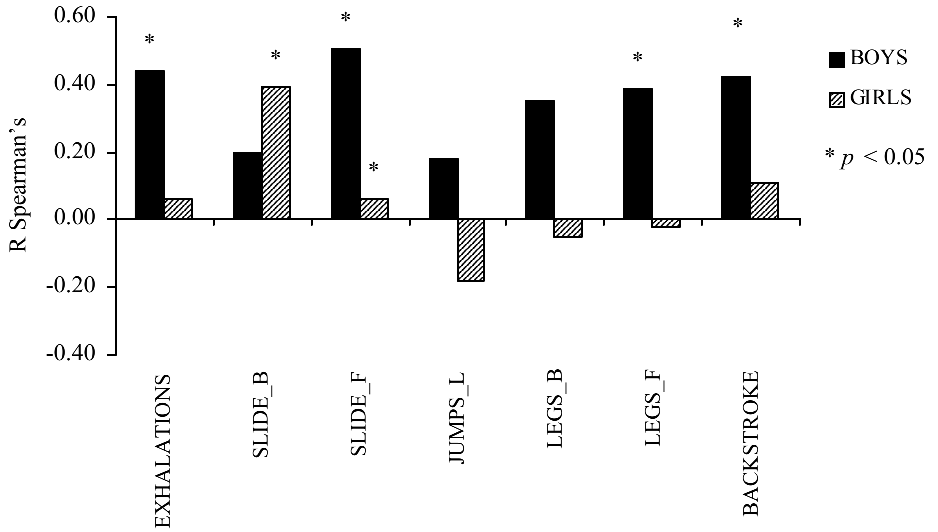

FIGURE 6. Correlations of swimming fitness and body weight

of motor learning (sport games, gymnastics, athletics). Szczepanik and Szopa (1993) had similar observations in volleyball, and Zimmermann (1984) in handball. Czabański (1998) and Dybińska (2004) reported a close relationship between the level of co-ordination abilities and the efficiency of motor learning. Bartkowiak (1997) and Czabański (1991) agree that there is an influence of somatic features on the efficiency of learning and swimming scores, especially at the first stage of learning.

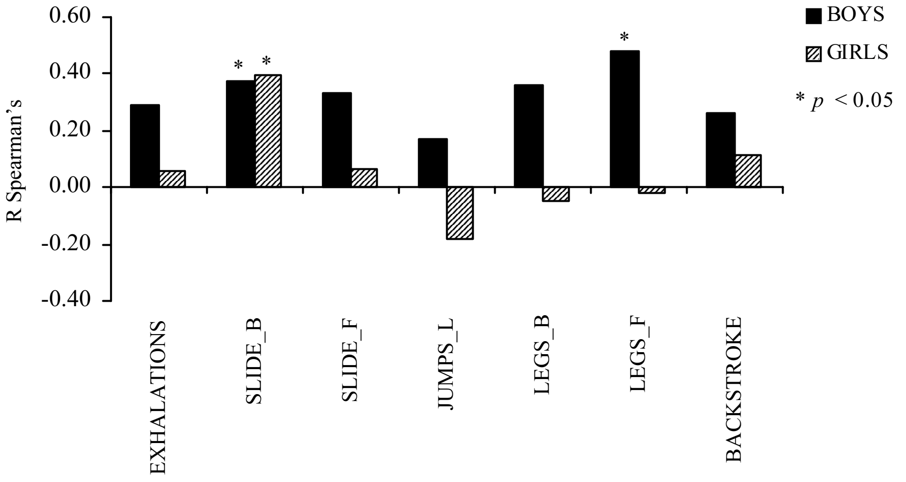

FIGURE 7. Correlations of swimming fitness and body height

CONCLUSIONS

The study reveals that:

1. The sex does not influence the process of learning swimming skills.
2. Boys did master swimming skills at the level higher than poor.
3. The majority of pupils could perform on the very good and good level.
4. The body weight determines greatly the acquirement of swimming skills.
5. The process of mastering skills in swimming is not very much affected by motor fitness.

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Construction and Verification of Progressive Educational Strategies in Swimming Instruction

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ABSTRACT: When educating either students in physical education or leading athletes in their sports training, it is essential to keep the educational process in continuity with preferred methodological conceptions. Thus, the main purpose of this research was to verify an influence of newly conceived progressive methods and strategies on students in settings of swimming instruction. The sample consisted of 26 secondary school students aged 11 to 12 years. Results show that the application of the progressive educational process affects positively the acquisition of swimming motor skills. The efficiency of the application manifested itself, above all, in differences between input and output levels of the motor skills. We can claim that the progressive teaching method was also useful to meet challenging cognitive objectives. When comparing progressive and habitual lessons from a view of students' evaluation, the progressive lessons were continuously better evaluated.

KEY WORDS: educational strategy, teaching methods, pedagogical experiment, swimming, role of student

INTRODUCTION

Generally, education in sports should be a dynamic and living process that aims not only at educating athletes/students (i.e. 'educants') but also at activating them meaningfully. Presently, the educational process in swimming is still rather performance-oriented, even in the youngest age categories.

The choice of educational strategies in the educational process should follow out from a preferred conception of the educational process, induce its efficiency and respect all main elements and other factors of the educational process in their interaction. Didactic approaches based on creativity, individualization, openness, activity, and cooperation of students (i.e. highlighting the 'role of a student') are typical of the so-called progressive educational strategies.

For promoting modern educational trends, it is important to generate specific educational strategies fulfilling both cognitive purposes and requirements for individual pace, creativity and experience etc. These requirements are feasible with progressive teaching methods and strategies.

The purpose of progressive approaches is not to memorize information, but to comprehend connections and cause-effect relationships between phenomena, leading to creative cognition of a piece of work or art (although predominantly in a subjective sense). Thus, in addition to the advancement of cognitive and formative processes, a productive or critical cogitation (especially divergent thinking) is emphasized.

The main principle of the progressive approaches is their orientation towards the 'educant' who is interrogative, critical, independent in thinking, passionate for his/her tasks, compatible and cooperative, able to work independently in line with his/her own talents, which he/she is aware of, and who is not willing to automatically admit things based only on claiming and opinions of authorities.

As the progressive approaches include and combine a large number of methods and approaches, we can apply the term 'blended learning', although it has been known in the context of e-learning (Valiathan 2002). From this point of view, the progressive approaches combine the above mentioned and determined types of teaching and learning (Fig. 1) into modern (progressive) methodological principles:

- Principle of self-reliance and openness in the educational process.
- Principle of individual and optimal pace of education.
- Principle of divergent thinking.
- Principle of support (but not forcing), imagination, fluency and originality in the educational process.
- Principle of freedom, deciding of the activity and increased role of the 'educant'.
- Principle of enjoyment, experience and emotionality in the educational process.
- Principle of a free choice of a partner and cooperation in the educational process.
- Principle of choice of strenuousness of educational content in compliance with individual predispositions and educational conditions.

A systemic approach of the progressive teaching methods is shown in Figure 1.

OBJECTIVES

The primary aim of the research is to support forming of grounds for a theory of progressive approaches, to form and verify conditions for a more effective promotion of modern conceptions of the educational process in swimming instruction. Secondary aims:

- To construct and verify progressive teaching methods in swimming instruction.
- To find out efficiency of applying progressive teaching methods within motor learning of swimming styles, knowledge on the technique of swimming styles and assessment of the efficiency of applying these methods to swimming performance.

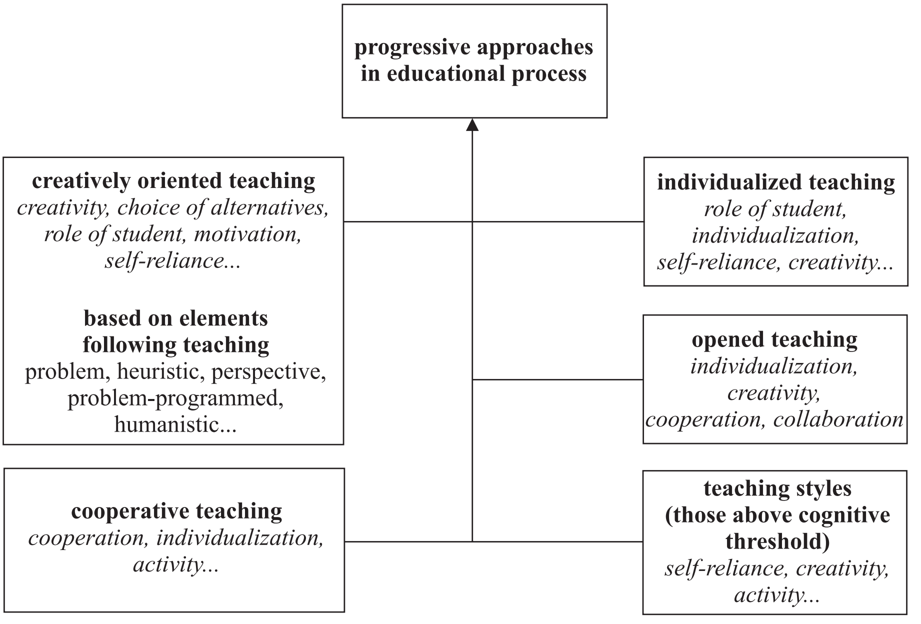

FIGURE 1. Factors of the progressive approaches in the educational process (Svozil 2005)

- To assess the relationship of students towards the progressive teaching methods and progressive lessons of swimming.

RESEARCH QUESTIONS

- How will the use of the progressive methodological constructs in the educational process influence the process of acquiring swimming motor skills?
- How will the use of the progressive methodological constructs in the educational process influence the process of acquiring knowledge on motor skills?
- Will the use of the progressive methodological constructs in the educational process influence motor performance?

MATERIAL AND METHODS

The conception of this experiment is in line with the thesis that an experiment is a practical action and purposefully induced process, which is immediately focused on the recognition of reality (Cizek 1974). It is an intentional, planned and repeated exploration under controlled conditions at intentionally evoked changes.

In inter-group experiments, we differentiated:

- Independent variable comprised verified teaching methods.
- Dependent variable comprised the level of motor skills, the level of knowledge on the acquired motor skill, the level of monitored motor performances, and the attitude of the examined persons towards PE lessons.
- Settings in which the educational process is carried out.

In the present study we used a strategy of progressive teaching method of front crawl swimming.

The sample consisted of 26 secondary school students (10 girls and 16 boys) aged 11 to 12 years, who participated in a course for advanced swimmers in Olomouc. The experimental group (*N* = 13; 8 boys and 5 girls) acted upon a constructed individualized teaching method for front-crawl swimming (a complex method) in eight lessons. The control group (*N* = 13; 8 boys and 5 girls) acted upon a programmed teaching method for front crawl swimming (analytic-synthetic method).

All the subjects were able to perform fundamental swimming skills and swimming style breaststroke. The teacher and the curriculum were the same. The lessons differed in the way of supervision. The supervision of progressive (individualized) lessons was focused on individual solving of problems, autonomous selection of additional drills and tools, individual use of individualized educational means (individual cards of the constructed teaching method) etc. From the structural aspect, the educational strategy was based on the 'complex teaching method', i.e. without decomposing of a concrete front crawl motor skill into partial swimming skills (Fig. 2). On the other hand, the controls (programmed teaching method) progressed by the 'analytic-synthetic method', which is focused on decomposing of the general motor skill into partial skills. These partial skills are exercised separately (analysis) and consecutively combined (synthesis) into one entity (co-ordination of pulling and kicking action together with the whole body motions and breathing).

The following items were assessed in pretest and posttest:

- Swimming skills: by constructed and verified rating scales for front crawl (Svozil, Gajda 1997).
- Knowledge on the technique of the swimming style: by a front crawl knowledge test.
- Swimming performance: actual swimming performance was assessed in all the participating students at 40-m distance by two referees with the accuracy of a tenth of a second. An average value of the two measures was recorded.

In the process of the experiment we monitored:

- The attitude of the students towards the lessons with a standardized questionnaire for diagnosing PE lessons (Frömel et al. 1999). The questionnaire contains 24 dichotomized questions divided into six dimensions (cognitive, emotional, health, social, relational, and creative) and one complementary dimension ('role of student').

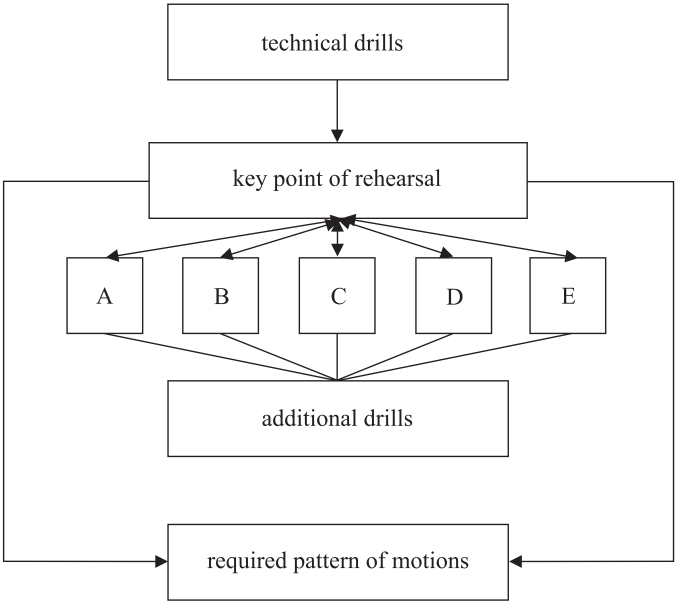

FIGURE 2. The strategy of the progressive (individualized) teaching method for front-crawl swimming

In the described experiments, an analysis of covariance (ANCOVA) was used as a primary method for processing the statistical data. In the case of statistical significance of F-value of ANCOVA, we applied Duncan's test for detecting differences between groups. For additional statistical processing, we used pair t-test for dependent samples, Wilcoxon's matched pairs test, t-test for difference of two relative values and basic descriptive statistics. We also applied an analysis of variance (ANOVA – a value of Kruskal-Wallis test) in some experiments. All the data was processed by Statistica 6 (StatSoft, Inc., USA).

RESULTS AND DISCUSSION

The results (Tab. 1) indicate that influenced by the instruction, a significant pretest/posttest difference between the levels of the front-crawl technique was present in both groups. The inter-group differences were not statistically significant. In initial lessons, the students had problems with a different way of supervision, which they had never met before. The teacher had to regulate the lessons more frequently and coordinate activities of the students to a certain extent. After four lessons, the majority of students worked autonomously. In particular, the teacher facilitated work of some students helping them to choose adequate additional drills. In this experiment,

TABLE 1. Efficiency of the individualized teaching method on acquiring front crawl motor skills

Variable	Group	*N*	*Mdn*		SD		T	*p*	χ^2
			Pretest	Posttest	Pretest	Posttest			
Scale (points)	E	12	4	6	2.99	2.12	2.24*	0.01	0.33
	C	12	2	6	2.26	2.14	3.06*	0.00	

Scale – evaluation of skills by the evaluation scale for front crawl; E – experimental group of the secondary school students learning under the individualized teaching method for front crawl; C – control group of the secondary school students learning under the programmed teaching method for front crawl; *N* – number of students; *Mdn* – median value; SD – standard deviation; T – testing criterion of Wilcoxon's test; *p* – level of statistical significance; χ^2 – ANOVA (Kruskal-Wallis test); statistically significant values ($p \leq 0.05$) denoted as (*)

wide differences appeared between individuals. On the other hand, this experiment proved again that it is more suitable to realize the instruction of one swimming style in a larger extent (10 to 12 lessons).

The efficiency of the individualized teaching method on the knowledge presents Table 2. In students of both groups, their knowledge level remained the same (or even decreased in controls). Moreover, we neither registered any significant differences between the pretest and posttest nor between the groups. One of the causes of this finding is that the students did not fully understand the phenomena described in the knowledge test. That is why the knowledge test appeared to be too complicated for students of the mentioned age group.

The swimming performance improved in both groups (Tab. 3). The difference between the input and output performances was even significant in controls. In the

TABLE 2. Efficiency of the individualized teaching method on the knowledge on the technique of the front-crawl swimming style

Variable	Group	*N*	*Mdn*		SD		T	*p*	χ^2
			Pretest	Posttest	Pretest	Posttest			
Knowl. test (points)	E	12	4	4	1.38	1.58	1.02	0.31	0.01
	C	12	4	3	1.47	2.10	1.37	0.17	

Knowl. test – evaluation of knowledge by the knowledge test for front crawl swimming style; E – experimental group of the secondary school students learning under the individualized teaching method for front crawl; C – control group of the secondary school students learning under the programmed teaching method for front crawl; *N* – number of students; *Mdn* – median value; SD – standard deviation; T – testing criterion of Wilcoxon's test; *p* – level of statistical significance; χ^2 – ANOVA (Kruskal-Wallis test); statistically significant values ($p \leq 0.05$) marked as (*)

TABLE 3. Efficiency of the individualized teaching method on the front crawl swimming performance

Variable	Group	N	M		SD		t	p	F
			Pretest	Posttest	Pretest	Posttest			
Result (sec)	E	12	48.62	45.15	11.33	7.1	1.88	0.06	0.43
	C	12	46.74	43.81	8.6	7.95	3.04*	0.00	

Result (sec) – performance of students in 40 m front crawl event; E – experimental group of the secondary school students learning under the individualized teaching method for front crawl; C – control group of the secondary school students learning under the programmed teaching method for front crawl; N – number of students; M – mean; SD – standard deviation; t – testing criterion of pair t-test; p – level of statistical significance; F – testing criterion of analysis of covariance (ANCOVA); statistically significant values ($p \leq 0.05$) marked as (*)

experimental group, the improvement was very close to the level of statistical significance. The inter-group differences were not statistically significant. The improved swimming technique was efficient also for the improvement of the performance. Despite of the mentioned problems with the application of the progressive educational approaches, we can claim the improvement of the swimming performance. In this age category it is necessary to adjust the individualized approaches to cognitive level and habitual leadership of lessons.

The attitude of the students towards PE lessons was tested twice. Considering the course of the instruction, values of positive points are surprisingly high in both groups (Fig. 3). Statistically and logically significant differences were found in creative and relational dimensions, complementary dimension 'role of student' and also in gen-

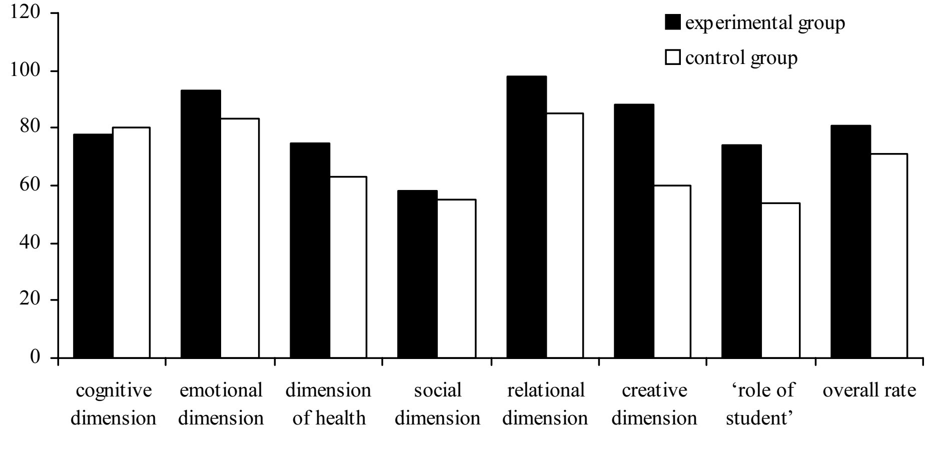

FIGURE 3. The evaluation of the questionnaire dimensions for diagnostics of the relationship of the secondary school students (N = 48) towards individualized PE lessons

eral evaluation. The students valued positively possibilities to solve autonomously some task; they would like to participate in similar lessons once again; they did not feel like being conducted by the teacher. In this case, the teacher proved his ability to be flexible in reacting to individual problems of students arising during the instruction, without forcing the creativity and self-reliance by all means.

CONCLUSIONS

- We succeeded in constructing and verifying the progressive teaching method of the front crawl swimming.
- The results show that the use of the progressive educational process influences positively the acquisition of swimming motor skills. Particularly, the efficiency of the use showed between the input and output levels of the motor skills. In the inter-group comparison, the level of skills was minimally equal to the motor skills in controls. We can claim that the progressive teaching method was also useful to meet challenging cognitive objectives.
- The results did not fully prove significant differences between the pretest and posttest in the acquisition of knowledge on the swimming technique. This experiment was conducted in 11-to-12-year-old children. That is why the individualized approaches should be adjusted to cognitive level and habits to leadership of lessons. The insignificant differences followed out also from some misunderstanding of the knowledge tests, which were not constructed for this age category. For these younger categories, the knowledge tests should be simplified and verified.
- Surprisingly, the improvement of the swimming performance was observed in both groups. We assumed that orientation and number of the lessons (eight) will be insufficient for the performance improvement. For demonstrable improvement in swimming performance, we recommend to organize twelve lessons.
- Relation of 'educants' towards progressive (individualized) teaching methods and progressive lessons was very positive and statistically verifiable in the majority of cases.
- Constructed and verified progressive teaching methods are in compliance with modern trends of education and can be a convenient aid for improving the quality of PE teacher education and also improving the practice of teachers within intentions of the new conception of the educational process.

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Swimming Education – the Area of Interest and Methodological Basis

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ABSTRACT: This work aims at presenting the process of swimming teaching and learning as the all-round physical education, widely understood as the physical upbringing. Thus understood swimming education is the process of the teacher's profound impact upon a student's personality by leading to acquiring new swimming skills and shaping the student's prosocial attitude and attitude connected with motor activity in water. Apart from swimming teaching and learning, the algorithm of the educational activities understood in this way comprises above all understanding the sense and values derived from the swimming skill, applying these skills into the 'better life' strategies, getting acquainted with the learning and improvement methods, as well as the methods of self-discipline, self-assessment and self-rescue in water, understanding and following the legal standards and safety principles during water activities. Is there a science comprising research conducted in connection to the swimming education? The theory of physical education describes the methodological basis of the swimming education. A man performing motor activities in the water environment is the subject of the research on the swimming education, whereas its object is physical culture. The conceptual apparatus enabling us its description and explanation is praxeology, pedagogy and biology forming the science of swimming. The applied research methods are typical of the physical education theory – experiment, observation, specific tests and auxiliary methods.

KEY WORDS: swimming, education, axiology

INTRODUCTION

The present literature on swimming and swimming teaching methods have adopted a stance that swimming teaching-learning is related solely to the human corporeality (Dybińska, Wójcicki 1996; Bartkowiak 1997; Karpiński 2000; Waade 2003; Pietrusik 2005; Laughlin, Delves 2006). These works are predominated by the issues of the biomechanical analysis of the swimming technique, the elements of the swimming training and competitive swimming, as well as the methods of achieving sports championship (Counsilman 1977; Maglischo 1993; Płatonow 1997; Bartkowiak 1999). Swimming as a water sport is supplemented by other types of swimming such as water rescue, swimming for health and swimming helping to maintain fitness of the body (Bartkowiak, Witkowski 1986; Czabański et al. 2003; Waade 2003). Most frequently, the methodological works describe a man in the water environment more as a biological entity rather than a psychologically complex and socially active being. From the methodical perspective the teaching objective analysis defined by the sports technique of swimming predominates strongly over the analysis of the process of learning the complex motor activities. Modification of this perspective appears in the works by Czabański who emphasizes the educational and psychological aspect of the swimming teaching process (Czabański 1977, 2000) as well as Zatoń, Kwaśna and Wiesner (Zatoń et al. 2005).

Swimming skills together with the process of acquiring them should be ascribed to the quality of the universal educational path for a human person. The process of swimming teaching and learning begins with understanding the sense and values resulting from swimming skills, continued by the application of the acquired knowledge and skills into the 'better life' strategies (Wiesner 1999, 2007). This work aims at presenting the process of swimming teaching and learning as an important area of physical education, understood as the physical upbringing and schooling (Grabowski 1997). This work is an excerpt from a deeper and more extensive discussion. The presented part only specifies the swimming education area of interest and the research trends desired for this process.

SCOPE OF SWIMMING EDUCATION

Education denotes all educational processes understood as a broadly defined educational activity, it comprises schooling and upbringing (Grabowski 1997). Education is a consciously organized human activity, aiming at introducing changes into the entire human personality, including the part expressing one's attitude towards values (Okoń 1987). The educational process is directed at comprehensive development of personality which should guarantee preparing the educatee properly to effective participation in social life. In this sense, effective educational activities should train a human being to influence their own development (self-creation). Education requires conscious undertaking of learning[1] and teaching[2]. The basis of the didactic activity is activeness of the learning subject. No educational assumptions can be reached without this activeness. Thus, *teaching* cannot exist without *learning*. As intentional activity, the teaching process is foremost about inducing the student to learn (Okoń 1987). The learning subject may alone reach the desired objectives, even without the teacher's participation. 'A human is able to learn many things by self-study, however, learning is faster, more precise and shows better retention if aided by a good teacher' (Czabański 2000).

Pedagogy goes beyond the school premises. It functions successfully in the family, in sports, aids the education of adults and development of the disabled. In practice, the word 'pedagogue' means an educator. Most frequently it is a teacher but also people playing educational roles in the extraschool situations, equipping students with the system of values, attitudes and beliefs, with knowledge and capacities. Any educational activity always takes into account the generally understood well-being and happiness of a man.

Physical education, as a widely understood physical upbringing, is the intentional transfer of models, values and behaviours related to the human body (Grabowski 1997). The physical education (physical upbringing) process strives for shaping the prosomatic and prosocial attitudes for teaching movement and body improvement. Moreover, it influences the intellectual development, the aesthetic development or the moral attitude. We support the views of Grabowski (1997) who claims that in practice it is impossible to differentiate between physical schooling[3] and physical upbringing[4]. Taking care of the student's physical development influences positively development of his personality as a whole. There is also a reverse relationship. Reaching the physical upbringing objectives is supported by the remaining spheres of the educational endeavours – moral education, intellectual education or aesthetic education.

Swimming education should be perceived as the process of the teacher's profound impact upon a student's personality, leading to acquiring new swimming skills and shaping the student's prosocial attitude and attitude connected with motor activity in water (Wiesner 2007). The scope of thus understood swimming education comprises multilateral educational activities engaging the student's entire personality. Swimming education may not only be limited to applying measures connected with water and swimming. Moreover, the effects of educational activities connected with swimming are more versatile than acquiring the sport technique of swimming. It is an excellent educational path for a human.

EDUCATIONAL ACTIVITIES IN SWIMMING[5]

1. Teaching and learning of the swimming technique at the elementary and standard level;
2. Motivating students to learning by understanding their own needs and values obtained thanks to the swimming skill;
3. Getting to know the swimming learning methods, as well as self-control and self-assessment of the learning results, also outside the organized process of swimming teaching;
4. Making the students aware of various risks to be met in the water environment and learning the methods of risk assessment;
5. Learning the basic self-rescue skills;
6. Learning and understanding legal norms and safety principles binding by the water;

7. Teaching safe and responsible life saving activities in water, including first aid;
8. Incorporating swimming, self-rescue and life saving skills into the 'better life' strategies:
   - multilateral development of personality;
   - numerous of vocational qualifications;
   - attractive forms of leisure and recreation;
   - healthy lifestyle;
   - safe water recreation.

ISSUES SUPPORTING SWIMMING EDUCATION

Although swimming education is the pedagogical domain, it overlaps with other sciences because the accompanying phenomena are of psychological, sociological, axiological, biomechanical, medical, legal, economic, ecological and even political nature.

1. Swimming education is the **pedagogical** domain because it comprises issues related to education, schooling, teaching, caring and organizing free time. The area of interest relates to children, also disabled children (special education), adults (andragogy), as well as teachers and teaching instructors (pedeutology). The basic field of pedagogy is didactics[6], i.e. the science of teaching and learning, the two integral parts of the educational process[7]. The general didactics is the basis for the teaching methods[8] of particular school subjects and other areas of knowledge, called the methodology.
2. Swimming education from the **pedeutological** perspective is the issue aimed at training the EDUCATOR, the efficient swimming teacher. The teacher induces learning, controls its course and if necessary, corrects this process. The subject of the swimming education process is both the learner and the teacher. Subjectivity of the teacher and students emphasizes their rank in the pedagogic process. It is expressed by the autonomy enjoyed with relation to the possibilities of influencing the defined objectives and educational tasks and the selection of teaching methods and means. Both subjects have a mutual, partner-type share in shaping their own personalities. The activity of the learning subject is frequently independent from the teacher's operations. It should persuade the teacher to diagnose the course of the learning process. Thanks to the perception of the information from the student, the teacher acquires knowledge allowing him to plan the teaching process properly and react successfully to the obtained results of teaching and learning. What is the optimal model of competencies and personality for such a teacher? How should he be trained?
3. Swimming education from the **axiological** perspective classifies the world of values giving sense to the human life. The water environment arouses re-

flections about the value of the human life defence of which, is the absolute value. Also the ethical, agonistic and hedonistic values acquire significance in the swimming education (Zatoń et al. 2005; Pawłucki 2007).

4. Swimming education from the **psychological** perspective relates most of all to the achievements psychology of learning – diagnosing personality of the students undergoing schooling and education and explaining phenomena accompanying swimming learning and teaching. The most frequently solved problems are the fear of water, motivation processes and enforcement applied in the educational process.
5. Swimming education from the **sociological** perspective allows for placing the issues connected with the human activity in the water environment on the social level. The answer to the basic question about the social rank of this education begins to take on significance. What is the level of social acceptance of the general swimming education? And in the context of searching for the socialization methods it is significant to answer the important social question to what extent does the swimming education prevent social pathologies?
6. The task of the swimming education from the **medical** perspective is emphasizing its health-oriented properties. The role of medical sciences consists in searching for educational paths providing excellent lifelong state of health, containing information about life and health risks to be encountered while staying in the water environment and allowing one to avoid these risks. The common level for the medical swimming education is preparation for giving first aid to people injured in water.
7. Swimming education from the **economic** perspective shows in a very pragmatic way the expenses and benefits connected with the general swimming education. The economic issues allow one to simulate the benefit and expenses balance in various situations connected with the human activity in the water environment. This may be, for example, the balance of costs of providing security measures connected with the recreation on the water, as opposed to the costs of life saving operation and the effects of the accident on the water.
8. Legal education consists in making the students aware of the law and its value. For swimming education from the **legal** perspective it is more important to understand the sense of the given legal regulation than suffering severe punishment and other social consequences. For example, rigorous swimming ban imposed over the water tempting to swim takes on a different value, if one knows its meaning and conditions of imposing the ban (including the mechanism of effects for health). The penal consequences have some meaning but of secondary type. Legal education in swimming also covers legal liability of teachers and persons obliged to provide the pedagogic care.
9. From the **sport theory** perspective, swimming education is aimed at the sports results and success. At present, it is most probably the most attractive educational

trend. It is confirmed by the generally dominating teaching aim, i.e. acquiring the technique of sport swimming (crawl, back crawl, breaststroke and butterfly stroke). Also the applied forms of classes (water competition, elements of swimming training, swimming competition regulations) display the sport-oriented character, as well as the structure of the swimming facilities (swimming pools with lanes and marking for the swimming race, with starting blocks, turn flags, etc.).

10. Swimming education from the **biomechanical** perspective comes as a consequence of the sport education. Examination of the movement mechanics in water is the necessary condition of searching for the best technique of sports swimming[9]. The extra sports movement tasks in water do not thus require precise and expensive research tools.
11. Swimming education from the **aesthetic** perspective is too rarely emphasized in the swimming teaching process. Most frequently it comes down to becoming sensitive to the beauty of the swimmer's body proportions and harmony of his movements, aesthetics of the swimsuits, water environment and beauty of the surrounding landscape. However, it is necessary to emphasize that in the swimming education there is also some space for the artistic expression, for creating and expressing one's own aesthetic needs. This area consists of synchronized swimming, water jumping, various forms of water fitness, free diving, aquatic park facilities etc.
12. Swimming education from the **ecological** perspective is the task for those who prefer swimming in the natural environment. Including the ecological demands into the swimming education will allow one to enlarge the group of people understanding the meaning of clean natural environment in their own best interest.

METHODOLOGICAL BASIS OF RESEARCH CARRIED OUT IN CONNECTION WITH SWIMMING EDUCATION

The theory of physical education describes the methodological basis of swimming education. The applied research methods are typical of physical education theory – experiment, observation, specific tests and auxiliary methods (Osiński 1996). A man performing motor activities in the water environment is the subject of research on swimming education, whereas its object is physical culture (Pawłucki 2007). The conceptual apparatus enabling the scientific description and explanation is facilitated by praxeology, pedagogy and biology. They constitute the basis for the potential science of swimming (Osiński 1996).

Methodological foundations of physical education can be explained as follows: 'The theory of physical education due to human corporeality as the subject of interest is the field of study directly superior to the physical upbringing theory; whereas due to the motives of these interests – it is pedagogy. The first one provides the axiological premises for the physical ubpringing process, the other – teleological' (Grabowski

1997). The process of learning the regularities to be found in learning and teaching is the subject of didactic research (Okoń 1987). Physical education didactics which as the scientific practice and theory deals with the movement teaching, is based on the general didactics and physical ubringing theory[10] (Czabański 2000).

Physical education 'would be empty in the axiological sense, if together with other fields of education, it would not prepare for life in the society and for the society' (Grabowski 1997). The pedagogic research, independent of fulfilling the scientific cognitive function, most of all serves for the pedagogic practice (Palka 1989; Osiński 1996; Grabowski 1997; Łobocki 1999). It is even more explicitly emphasized by Zaczyński who claims that 'the teaching practice constitutes the object of didactic research and the didactics separated from practice becomes a pointless discipline' (Zaczyński 1988). The same view is expressed by Łobocki who calls the pedagogic theories *valueless*, if they are not supported by the pedagogic practice (Łobocki 1999).

CONCLUSION

The general conclusion to be drawn from the presented discussion is that the process of swimming teaching should not only be limited to the human corporeality but also encompass the swimming education understood as the universal educational path for a human. The inspiration for any theoretical investigations and formulating of the scientific problems in the area of swimming education should be searched for in the practical experience. Also the criterion of pedagogic theory assessment should be researched into.

NOTES

[1] Learning is the process of generating new forms of human behaviour (or modifying the earlier ones), as a result of gaining experience and going through the cognitive process (Okoń 1987).
[2] Teaching is a planned and systematic introduction of changes into a student's knowledge, skills, capacities and entire personality by the teacher, as a result of learning (Okoń 1987).
[3] Physical schooling is constituted by the processes of teaching and physical improvement (Grabowski 1997).
[4] Physical upbringing comprises shaping of the prosocial and prosomatic attitudes (Grabowski 1997).
[5] The detailed characteristics of the educational activities connected with swimming is the subject of a separate work, to be found in the materials for the 14th Tatra Scientific Seminar 'The Education of Tomorrow', held June 22nd–25th, 2008.
[6] Didactics is the science of the educational process (learning and teaching), its objectives, methods, means, organization and contents (Okoń 1987).
[7] Education comprises learning and teaching enabling one to develop the knowledge and capacities (Okoń 1987).
[8] Methodology as pedagogic science deals with the analysis of teaching and learning of the specific area of knowledge, e.g. methodology of mathematics, history, physical education, methodology of swimming and also methodology of water rescue.

[9] Between 1981–1985, the connection between teaching and biomechanics, resulted in the series of 5 international scientific conferences organized by Professor Bober and Professor Czabański 'The School of Biomechanics and Teaching of Sports Technique' (Bober 1986).

[10] Czabański uses the notion 'movement' understood as the 'movement activity'.

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PART TWO

SWIMMING TECHNIQUE

Biomechanical Effects of Application of the Technique Exercises in Young Swimmer Training

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ABSTRACT: The aim of the study was to assess the changes in biomechanical parameters of crawl swimming after 4 weeks of special technique exercises program. Six girls (12.83 yrs ± 0.6) and 6 boys (13.62 yrs ± 0.5) participated in the experiment. Within 4 weeks the girls were taking comprehensive aerobic training with 20% of technique exercises oriented to freestyle. Boys were going through the same sort of training but without technique tasks. During the next 4 weeks, the training program was reversed. Three tests of 100 m freestyle with maximal speed were carried out. Changes in boys' velocity were statistically significant in the third test ($p < 0.05$). Their results in control tests were significantly better than girls' ($p < 0.05$). Stroke length did not differentiate the sex, while stroke rate did.

KEY WORDS: swimming, training, technique, young swimmers

INTRODUCTION

Planning workouts for children at the age of 12–13 must consider all the mental and physical transmutations that accompany their adolescence. This age group demands special interest because of huge variations in physical growth. Some boys and girls may begin their adolescence period at this time, while the others are still in their childhood. Differences in height and body proportions may occur fast. Some authors say that pre-pubertal boys and girls are sufficiently similar in physical characteristics. They may differ in stature, but not in aerobic power (Blanksby et al. 1986; Borms 1986). Achievements in competitive swimming in the early adolescence period are correlated more with physical growth and technical accuracy of movements rather than with endurance and strength. For endurance improvements, an emphasis on the techniques of performance is more beneficial than the programming of assumed physiological stimulations of training.

Thus, a training program for swimmers at the age of 12–13 should be particularly focused on aerobic-based tasks and technical exercises. Anaerobic loads are also applied in this period, but its amount is dependent on swimmers' proficiency. Although young athletes can accept heavier training loads in this period, these loads should be applied rationally. Technique training should be performed precisely because of its long-term effects. Watanabe and Takai's (2005) experiment showed that stroke technique was the most effective parameter for explaining swimming performance throughout adolescence. In older groups this correlation was less evident. The older the swimmer, the greater influence of body size on sports result, the authors suggest. Other conclusions come from Norwegian studies (Kjendlie et al. 2004). Adult swimmers (21.4 yrs old) had lower stroke rate in submaximal and maximal front crawl swimming than pre-pubertal swimmers (11.7 yrs old). The authors say that the causes could not be attribute to differences in body size, but probably the propelling size and swimming technique make adults more effective swimmers. Swimming technique and swimmer's posture was the subject of an experiment done by Jurimae team (2007). The purpose of this study was to examine the influence of the energy cost of swimming, body composition, and technical parameters on swimming performance in young swimmers (aged 12–14). The results suggest that the stroke index (velocity times stroke length) and arm span appear to be major determinants of front crawl performance in young male swimmers.

An analysis of the swimming technique on top level is often supported by electronic devices like underwater cameras and special computer programs. Coaches who work with age groups can hardly afford this kind of equipment, yet in everyday training simple biomechanical measurements can be done with a stopwatch and some calculations.

MATERIAL AND METHODS

The aim of the study was to evaluate the changes in biomechanical parameters of crawl swimming after 4 weeks of special technique exercises program. The research questions were as follows:

1. Were there any significant changes in values of velocity, stroke length, stroke rate in boys and girls groups?
2. Did these parameters differentiate boys and girls?

The experiment was carried out on the group of 6 girls (12.83 yrs ± 0.6) and 6 boys (13.62 yrs ± 0.5). They had practised swimming for 3 years in Orka Sport Club in Chełmno.

The experiment started 2 weeks after winter holidays in February 2007. In the first test, boys and girls had to swim 100m freestyle with maximal velocity (start from the edge of the pool). The measurements were taken in the central part of a 25 m pool. Calculations were made according to the following formulas (Klajman, Makar 2003):

$SR=60 \times 3/tSR$, SR – stroke rate, tSR – time of 3 cycles

$V=S/t$, V – velocity, S – distance, t – time

$SL=V \times 60/SR$, SL – stroke length

Girls participated in the experiment within 4 weeks after the first test. They underwent a comprehensive aerobic training with 20% of special exercises, improving freestyle technique (e.g. swimming with shoulder rotation, high elbow, fists, swimming with snorkel). The average capacity of training sessions was 1600 m, three times per week. In this time, boys had the same training program, but without technique exercises. After four weeks, the subjects participated in the second test of 100 m freestyle. The procedure was the same as in the first test. Then, for another 4 weeks the training program was reversed between genders. After that, the third 100 m freestyle test was conducted.

Statistical calculations (mean, standard deviation, Wilcoxon test for small samples, Fisher-Pitman test, Spearman's rank correlation) were made based on Statistica 7.1 program (StatSoft Power Solution, USA).

RESULTS

The changes in mean values of velocity in girls' tests are presented in Figure 1. After four weeks of technique exercises, velocity increased only in three cases (SB, PG, AP). The third test revealed improvement in velocity in most cases. The comparison between the results of all the tests did not show any statistical differences in the Wilcoxon test. It seems that training loads (including technique exercises) were more effective for girls of less confidence in swimming, because they improved velocity in each successive test.

Stroke rate variations in girls' 100 m freestyle tests are shown in Figure 2. The most distinct differences in stroke rate after a 4-week technique program were pre-

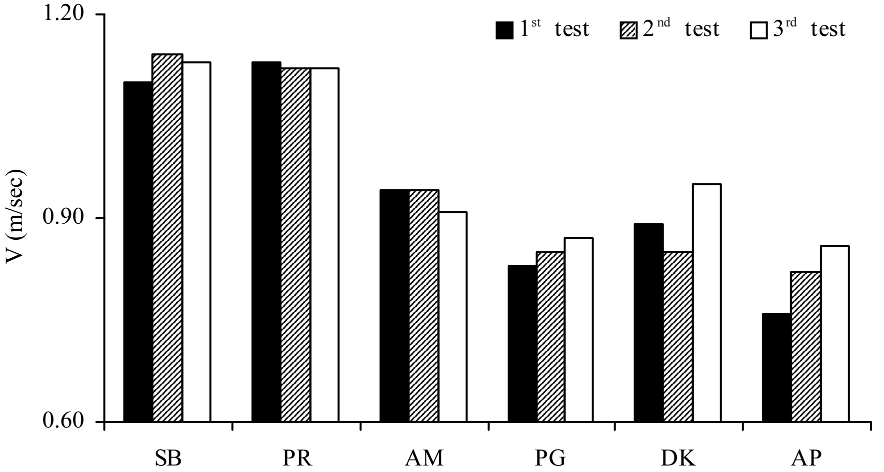

FIGURE 1. Mean velocity in 100 m freestyle tests – girls

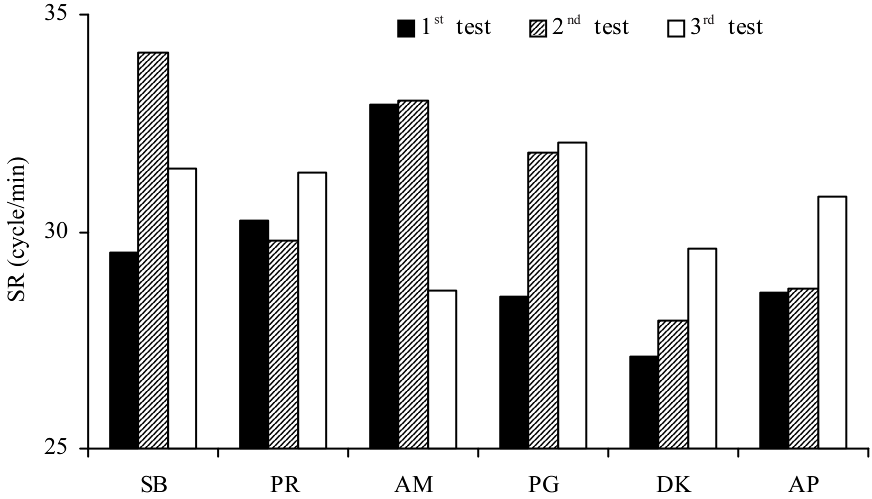

FIGURE 2. Mean stroke rate in 100 m freestyle tests – girls

sented by SB and PG. In one case only (PR) stroke rate values decreased slightly. After another 4 weeks, when girls did not do technique exercises, stroke rate increased in less-confident athletes (PG, DK, AP) and in PR. Statistical differences between measurements were not essential according to the Wilcoxon test.

The four-week technique training brought a slight improvement of stroke length in three girls. In the third test, four girls decreased their stroke length in contrast with the first test. The results among the successive test did not vary essentially. The correlations among velocity, stroke rate and stroke length were not strong.

Individual changes in biomechanical parameters are clearly visible. SB and PR achieved a very similar value of velocity in the second test but in the SB case this achievement was due to a higher stroke rate and in the PR case to a higher stroke length. The conclusion is that PR swam the second test with more effective technique.

Velocity values in boys' tests are presented in Figure 3. In every case velocity increased in each successive test. These changes were statistically significant only between the first and the third test, which is shown beneath (Tab. 1). The most dynamic changes were observed in the KT case.

Stroke rate variations were not so evident (Fig. 4). All the boys improved their stroke rate after 4 weeks of technique exercises, except PP. In the 2nd and 3rd test, his stroke rate values decreased in contrast with the first test. After technique training, stroke rate varied in the whole group from 29 (PP) to 40 (PS) cycles per minute, but these changes were not essential ($p > 0.05$). Only the differences between 1st test and 3rd test were statistically significant ($p < 0.05$). It seems that the increase in the stroke rate was caused by total training loads rather than by special technique exercises.

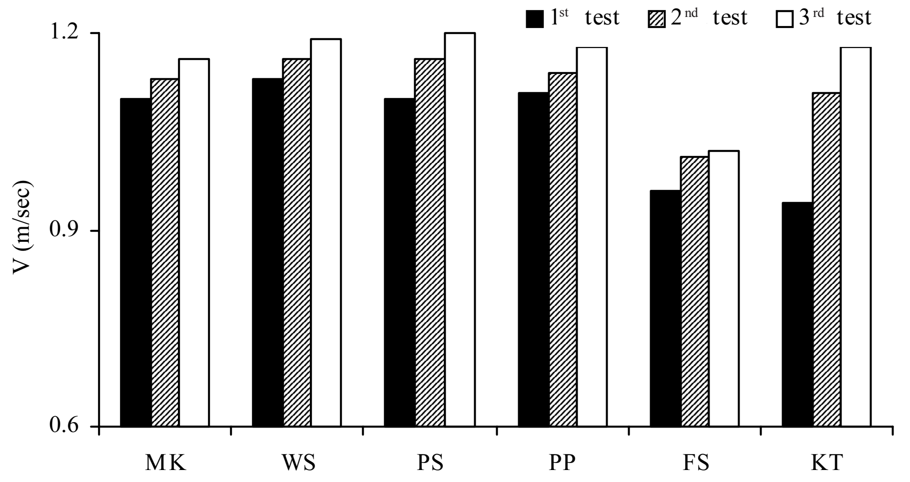

FIGURE 3. Mean velocity in 100 m freestyle tests – boys

TABLE 1. Differences in boys' velocity in 100 m freestyle tests according to the Wilcoxon test

Tests	1st/2nd	2nd/3rd	1st/3rd
V (m/sec)	1.06/1.11	1.11/1.15	1.06/1.15
p (Wilcoxon test)	0.0931	0.1894	0.0335

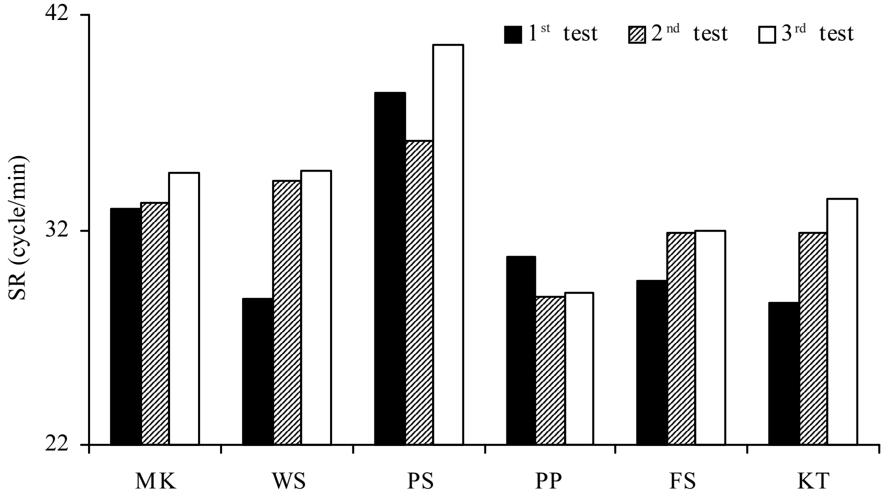

FIGURE 4. Mean stroke rate in 100 m freestyle tests – boys

Stroke length changes in boys' tests are shown in Figure 5. Mostly stroke length values decreased a little or remained still after the 4-week technique program. There were no significant differences in stroke length among the successive tests, according to the Wilcoxon test. Individual variations in biomechanical parameters are clearly visible. Swimmers PS and PP gained almost the same velocity in 3rd tests (1.20 m/sec vs 1.18 m/sec). In that test, PS's stroke length was 1.75 m, while PP's stroke length was 2.43 m. The conclusion is obvious: PS had to put more effort to achieve this result by performing more movement cycles. WS, the third athlete with similar velocity (1.19 m/sec), had the highest SL value in the first test (2.35 m). Four weeks of non-specific training decreased his stroke length (to 2.02 m), but his frequency of movements increased from 29 to 34 cycle/min. Finally, WS improved velocity, but in a less economical way in comparison to PP. In the whole group, the correlations between the stroke length and the stroke rate (calculated by Spearman's coefficient) were strong, but only in the second test this liaison was significant (Tab. 2).

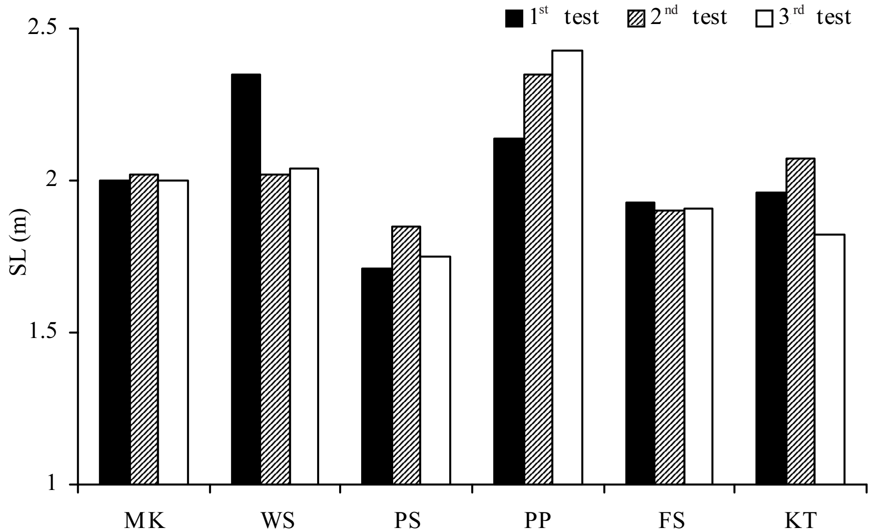

FIGURE 5. Mean stroke length in 100 m freestyle tests – boys

TABLE 2. Correlations between stroke rate and stroke length in boys 100 m freestyle tests according to Spearman's coefficient

Test	1st	2nd	3rd
Parameters	SR/SL	SR/SL	SR/SL
Spearman's coeff.	–0.69423	–0.80753*	–0.73421

* $p < 0.05$

The comparison between the boys' and girls' results in the measured biomechanical parameters is demonstrated in Figures 6 and 7. Boys achieved higher values in all parameters; some of these differences were statistically significant according to the Fisher-Pitman test. It seems that boys' supremacy in velocity and stroke rate is connected with their motor abilities (e.g. strength) rather than with technical proficiency.

DISCUSSION

The above analysis reveals that the same training loads bring different effects to pre-pubertal boys and girls. An improvement in boys' velocity was stronger correlated with the stroke rate. It can be explained by a few reasons. At first, the boys

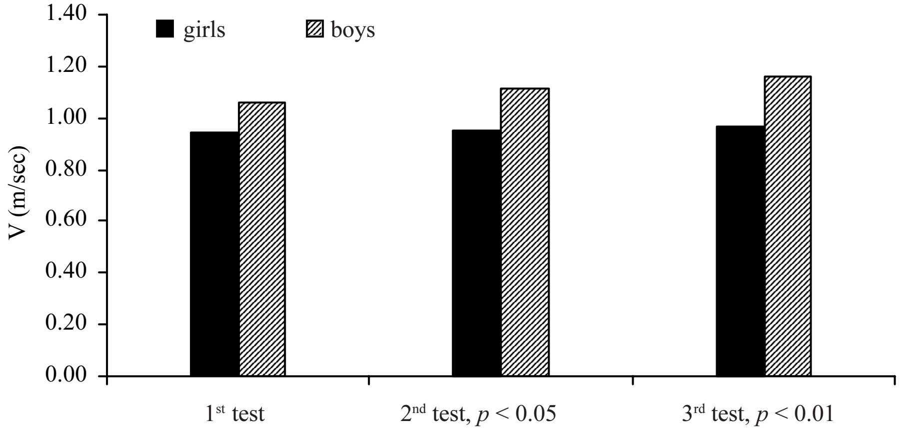

FIGURE 6. Boys and girls velocity in 100 m freestyle tests

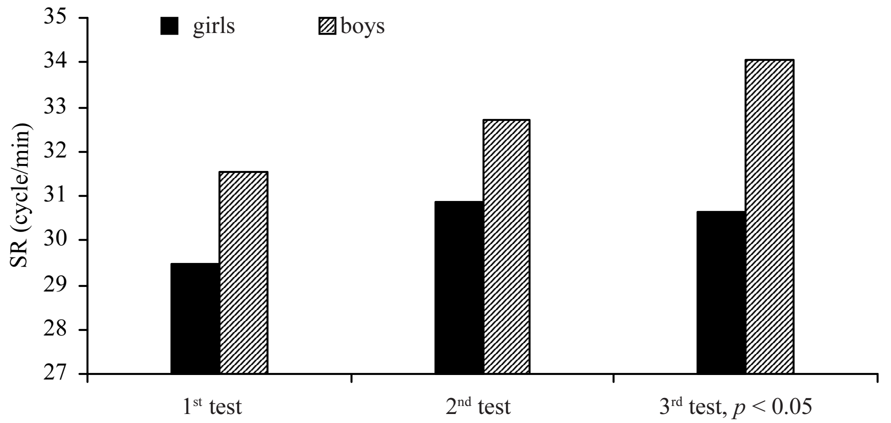

FIGURE 7. Boys and girls stroke rate in 100 m freestyle tests

started the technique program after 4 weeks of aerobic training. This period gave them a specific endurance basis, very helpful in the realization of technique exercises. Although the girls also improved their velocity in the last test, these changes were not as distinct as in the boys' group. In each test, boys had a higher stroke rate than girls, despite the character of training loads. In the 3rd test these differences were statistically significant. It seems that an 8-week training caused the growth of strength in boys, and then they were able to increase the number of movement cycles. The posture of athletes could also affect their strength. Boys were taller (167±4.3 cm vs 152±3.4 cm) and heavier (56.3±2.9 kg vs 44.8±3.6 kg) than girls.

The results presented in other studies confirm some findings described above. Dutto and Cappaert (1994) say that young female swimmers are more technically efficient than boys. However, they cannot achieve comparable times because of the lack of absolute power. The authors also suggest emphasizing technical exercises in boys' workout to support their strength and power attributes. Similar conclusions come from Simmons, Pettibone and Stager's research (2001). According to them, the technique and experience have greater influence on sports results in females than in males. Kennedy et al. (1990) analyzed biomechanical parameters in male and female Olympic swimmers in the 100-m events. He noticed that the swimmers were using various combinations of stroke rate and stroke length to achieve good performance times. Stroke length is the most important factor in predicting a successful result, the author concludes. Having compared anthropometric, neuromotor and fitness variables in young swimmers, Rocha et al. (1997) claims that a training program should be specified for boys and girls in mixed groups.

It seems that 20% of specific technique exercises applied to aerobic training in the presented study was not sufficient to improve stroke length in boys and girls. The total volume of these exercises should be increased in each micro cycle. Moreover, some strength-oriented tasks should be applied in water for girls.

CONCLUSIONS

1. Boys improved their velocity in each successive tests.
2. Boys' results in 100 m freestyle tests were significantly better than girls'.
3. After 8 weeks of aerobic-based training, boys' stroke rate increased essentially.
4. Stroke length did not differentiate the genders.
5. Training loads for pre-pubertal swimmers should be gender-specific.

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Stability during Mirror and Translational Symmetry Movements

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ABSTRACT: The purpose of the study was to test the influence of mirror and translational symmetry movements on the stability of the upper extremities and to find relations between stability and the practised sport. Twenty females taking various sports and untrained ones participated in the study. Those following an active lifestyle demonstrated higher stability during mirror symmetry movements. But women leading sedentary life presented higher stability during translational symmetry movements for both upper limbs.

KEY WORDS: stability, symmetry, upper limbs, swimming

INTRODUCTION

The human body is an object of many scientific studies. In the area of biomechanics its activity is described by the kinetic and kinematical parameters (Winter 1990; Zatsiorsky 1998). In comparison to many of them, the stability of the human movement seems to be the one most frequently neglected. In fact, it plays an important role in the course of repetitions of the same body movements during daily activities e.g., locomotion. In the case of cyclical sports events like swimming, cycling, rowing and running, the stability of the intra-cycle velocity reduces energetic costs of motion (Maroński 1994, 1996, 1998). A high level of stability is characteristic of elite competitors (Fiłon 1995).

During land locomotion human body is propelled by the lower limbs' movements. They perform alternate movements which are called translational symmetrical ones; their configuration is cyclically repeated in the same direction (Koszczyc 1991). In the light of the literature, gait symmetry has been assumed for the sake of simplicity of data collection and analysis (Sadeghi et al. 2000).

However, during water locomotion the upper limbs' movements play the main role (Berger et al. 1999; Toussaint et al. 2002). It is currently held that propulsion in swimming is achieved by forces predominantly generated by the hands (Toussaint et al.

2002). Therefore, the influence of the upper extremities' movements on the swimming efficiency is often studied (Berger et al. 1999; Payton et al. 2002).

Contrary to land locomotion, during motion in water the upper limbs usually execute movements in two ways. Translational symmetry is observed during front crawl and backstroke swimming; mirror symmetry is demonstrated either during breaststroke or butterfly. The upper extremities perform – as manipulators – precise movements (Rutkowska-Kucharska 1999). Therefore for their movements the higher symmetry is expected than for the lower extremities' movements. The results of the studies performed on land indicated deficit in the dynamical and kinematical asymmetry for the upper limbs during breaststroke simulation (Jaszczak 2006a, b). Asymmetry symptoms were observed during front crawl imitation (Potts et al. 2002; Jaszczak 2007). Their magnitude was increased in the water environment (Van Manen, Rijken 1975; Seifert et al. 2005). Meanwhile, asymmetry of the lower limbs during breaststroke swimming was evident (higher for males). Moreover, its magnitude enlarged together with the swimming velocity (Koszczyc 1977; Czabański, Koszczyc 1979).

During daily routines asymmetrical activities are dominating, however, studies of the men's bimanual co-ordination indicate tendency for mirror symmetry movements (spatial and temporal). They are easier initiated and synchronized with higher frequencies. This way the properties of human movement system could be presented i.e., the tendency for homologous muscle activation, the preferences of movements with the same motor parameters and the task congruency (Spijkers et al. 1997; Mechsner et al. 2001; Kunde, Weigelt 2005). Moreover, some influence of the practised sport on the strength stability was observed (Jaszczak 2007). So, the **purpose of the study was to test the influence of mirror and translational symmetry movements on the stability of the upper extremities and to find relations between stability and the practised sport.** For the purpose of the study, simulation of breaststroke and dog paddle was chosen because the preferences of human movement system, especially the upper limbs, can be satisfied mostly during some forms of water locomotion.

MATERIAL AND METHOD

Twenty voluntary female students of the University School of Physical Education in Wrocław participated in the pilot study. All subjects were right handed and had taken part in the three terms of swimming courses at the University. They were representatives of the symmetrical and asymmetrical activities together with untrained subjects. Their characteristics are presented in Table 1. All participants provided written informed consent prior the participation.

After a standardized warm-up, each participant performed a 15 m race, swimming arms as in breaststroke, to cover the distance in the shortest time. Start began from horizontal position, with pullbuoy between legs, without push-off from the wall.

TABLE 1. Characteristics of the participants (means and standard deviations)

	Sym ($N = 7$) ($\bar{x} \pm$ SD)	Asym ($N = 6$) ($\bar{x} \pm$ SD)	None ($N = 7$) ($\bar{x} \pm$ SD)
Age (years)	21.9 ± 0.7	22.2 ± 0.7	21.9 ± 0.5
Body mass (kg)	58.3 ± 5.5	59.2 ± 4.7	54.6 ± 8.2
Body height (cm)	167 ± 4	169 ± 6	164 ± 7
t 15 m (sec)	19.7 ± 2.9*	22.1 ± 1.8	25.5 ± 5.1*

* significant difference $p < 0.05$

Sym – women practising symmetrical sports, Asym – women practising asymmetrical sports, None – untrained females, t 15 m – swimming time on 15 m

The swimming ergometer (WEBA, Austria) was used to collect data (Fig. 1). Strain gauges were mounted between cords and hand paddles to measure the forces generated by each hand separately. Pulling forces, after amplifying, were recorded on a personal computer.

The task of participants was to swim ten cycles with the intensity equal to this performed during a test in water. In the first test each participant simulated breaststroke swimming using only the upper limbs. After the break, the subjects executed dog paddle swimming. According to Fiłon and Pawełko (1985) water polo players achieve movements' stability between the 3rd and 5th cycles. So, the cycles from the 6th to 8th were analyzed in the study. The instability coefficient was computed according to the equation:

$$IC = \frac{\mathrm{SD}}{\bar{x}}$$

where
IC – instability coefficient,
SD – standard deviation,
$\bar{x}$ – mean,
for each upper limb and type of movement separately.

FIGURE 1. The research stand

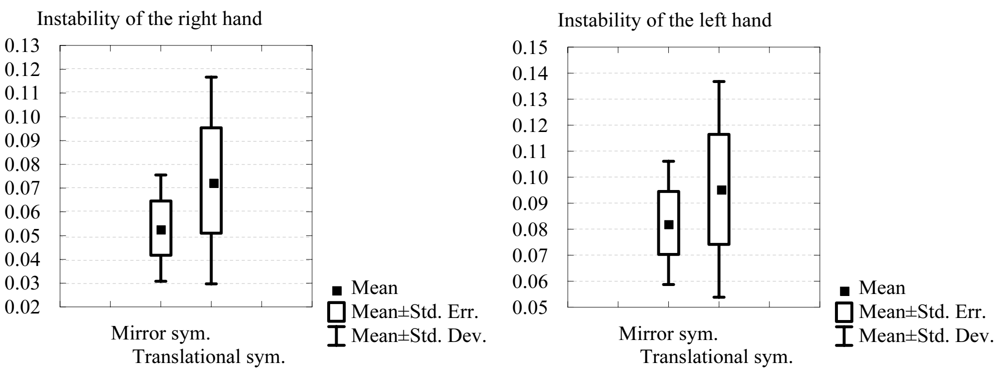
Next Shapiro-Wilk normality test was employed to examine the variables distribution. The statistical analyses involved two procedures, Student's t-test to compare the instability of the upper extremities between two types of movements for every subjects' group and each hand separately and a one-way analysis of variance to examine differences in instability among representatives of different types of physical activities.

RESULTS AND DISCUSSION

Although the obtained results were statistically in significant in all the cases studied (Fig. 2–4), there can still be seen some tendencies. The mirror symmetry movements caused the higher stability for both limbs of subjects practising symmetrical activities. The same feature presented left extremity of representatives exercising asymmetrical disciplines. For the right one type of movement had no influence on the level of stability. Results of untrained females were totally different. The translational symmetry movement enabled them to achieve the higher level of stability for dominant and non-dominant limbs together.

Unfortunately, ANOVA results did not indicate significant relations between stability and the kind of practised sport discipline, either (Tab. 2). It seems that it would be easier to find them for the dominant (right) limb during the two studied types of movement than for the non-dominant one.

The higher stability presented by untrained subjects during translational symmetry movement, than during mirror symmetry movement, was unexpected. This was in spite of the fact that the results of bimanual co-ordination studies suggested the opposite tendency. And it was clearly demonstrated by trained subjects. Probably untrained



$p = 0.436796$ $p = 0.605648$

FIGURE 2. The instability of the upper limbs in the two types of movements for the representatives of symmetrical activities

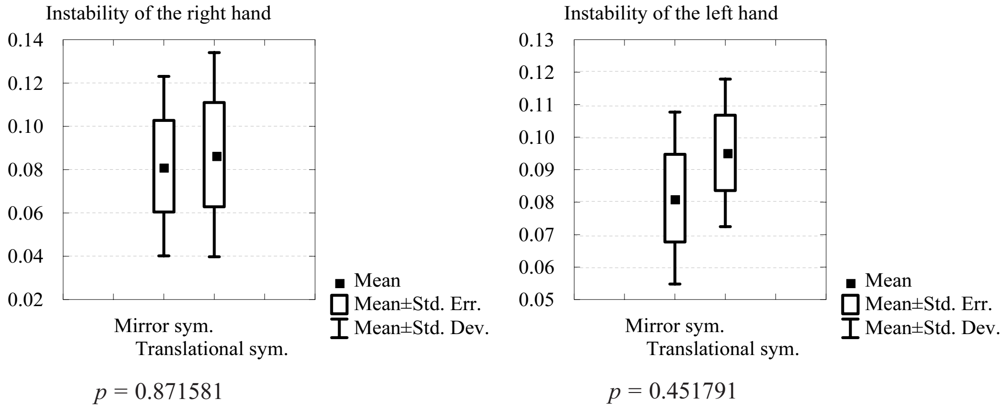


FIGURE 3. The instability of the upper limbs in the two types of movements for the women practising asymmetrical activities

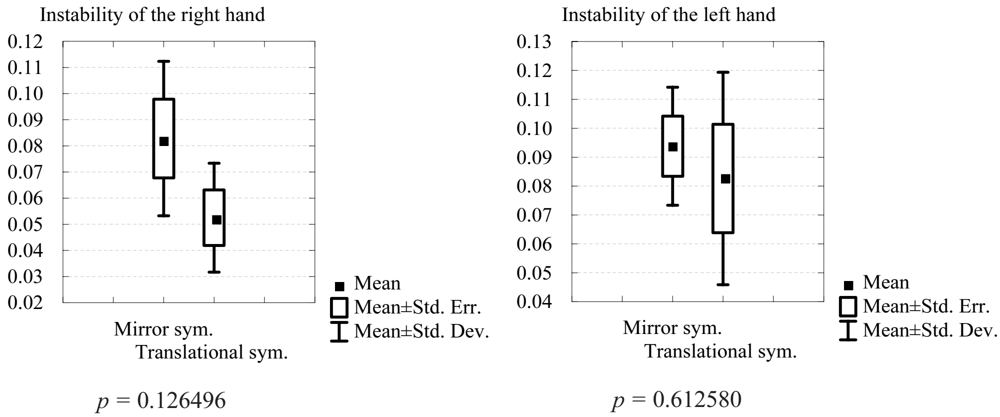


FIGURE 4. The instability of the upper limbs in the two types of movements for the untrained females

TABLE 2. The differences in instability among representatives of symmetrical and asymmetrical activities and untrained participants for each hand and type of movement

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	*p*
RH MS	0.004	2	0.002	0.028	17	0.002	1.155	0.339
LH MS	0.001	2	0.000	0.016	17	0.001	0.342	0.715
RH TS	0.004	2	0.002	0.043	17	0.003	0.781	0.474
LH TS	0.001	2	0.000	0.038	17	0.002	0.164	0.850

RH MS – right hand, mirror symmetry movement,
LH MS – left hand, mirror symmetry movement,
RH TS – right hand, translational symmetry movement,
LH TS – left hand, translational symmetry movement

participants cannot activate homologous muscles simultaneously at maximal intensity. Dickin and Too (2006) announce an inability of the central nervous system to achieve maximal activation motor units due to dispersion of the neural activity to both limbs during bilateral movements. The task was to simulate swimming on the ergometer with the intensity equal to the one achieved during the test in water. But in some cases velocity of movement could be higher than expected causing incomplete activation of fast twitch muscle fibres in bilateral actions when compared to unilateral ones (Dickin, Too 2006). Vandervoort et al. (1984) claim that this reduction is due to a lesser utilization of the fast-twitch fatiguable type of motor unit and this relation increases during long time efforts. But this time fatigue should not play an important role as the cycles from the 6^{th} to 8^{th} were analysed.

Moreover, the lower stability of untrained subjects during mirror symmetry movement may ensue from the increased antagonist activity during submaximal bilateral contractions. More antagonist activity would require more agonist activation to achieve the same submaximal force. Similarly, altered agonist activation may be accompanied by changes in motor unit firing rates (Jacobi, Cafarelli 1998) manifested by disorder in movement performance characteristic of untrained persons (Fidelus 1997).

The studied movements were specific for none of the examined subjects. This can explain why the expected higher stability for the trained persons was not presented. So, these results do not confirm that practising physical activities cause stability or laterality increase (Fiłon 1985; Koszczyc 1991). Although, this relation should be observed as physical activity improves interlimb interactions as a result. For example: untrained subjects exhibited a bilateral deficit (reduction in force that accompanies maximal two-limb efforts relative to single limb performance), the cyclist did not and the weight lifters even produced facilitation (Howard, Enoka 1991). According to Jacobi and Cafarelli (1998) it is said that bilateral deficit occurs more frequently in the upper body and less frequently in contralateral muscle pairs that have undergone bilateral resistance training. Their data from the experiment provide no evidence of alterations in activity of the agonists and antagonists during bilateral and unilateral contractions.

Not only do the trained sport discipline influence on the competitors' stability, but even the sport event does. Strass et al. (1999) observed swimmers and found out that front and back crawlers were not able to generate the same force during bilateral exercises of the upper limbs as during unilateral ones, however, breaststroke and butterfly swimmers were. They observed different patterns of EMG in all muscles for both tasks. Differences were greater for breaststroke and butterfly swimmers. So, neuromuscular activation during bilateral contraction was distinctly different from unilateral one.

Different functional uses might lead to different recruitment profiles for the dominant versus the non-dominant limb. But the dominances aspects observed in some learned motor tasks do not seem to apply to the more automated motor task. Arsenault et al. (1986) found a different profile of activity for homologous muscles (an extra burst of activity) during walking. This difference implies a small addition in the recruitment profile.

Finally, probably the size of the studied population was too small to reveal significant relations between stability and the kind of practised sport discipline. Nevertheless, it seems that the right hand, the dominant one, is more affected by the exercises.

CONCLUSIONS

The results of this study pointed out that:

1. Any physical activity increases stability during mirror symmetry movements.
2. Sedentary lifestyle is characterized by the stability of the translational symmetry movements' development.
3. The influence of different types of symmetrical movements on the stability, especially untrained females, requires an investigation on a larger sample with more measurements e.g., EMG.

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SCIENCE IN SWIMMING II, 2008, 69–78

Co-ordination Abilities and Sports Result of 11–12-year-old Swimmers

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ABSTRACT: The process of training should be precisely planned and monitored since the very beginning, and in particular in relation to the complex of potential properties of the competitor's organism which play a decisive role in achieving the level of motor ability in which co-ordination motor abilities are of high importance (KZM). The inspiration for undertaking this study was searching the data on the impact of specific motor co-ordination abilities on the swimming skill. The objective of this report is an attempt to search a dependence between motor co-ordination abilities and sports result of young swimmers at the stage of purposeful training.

KEY WORDS: specific motor co-ordination abilities, swimming skills, sports result

INTRODUCTION

The basis of each sports discipline is technique and ability of its proper application under the conditions of sports competition. It should be stressed that the level of co-ordination predispositions, which are the 'genetic' basis for mastering sports technique (Starosta 1989), is a decisive factor for the pace of acquisition of the new motion acts (the motion technique) and their improvement. Furthermore, at the first stages of training there is a strong correlation between the level of co-ordination abilities development and the level of sports achievements (Szczepanik, Szopa 1993). This results from the fact that competitors with a higher level of motion co-ordination master and improve more effectively sports techniques and tactics, they also more easily acquire the ability of rational and economical use of energetic potential and continually enrich their motion experience (Raczek et al. 1998). One more and more frequently focuses attention on the level of co-ordination motion abilities ascribes high importance to training (Raczek et al. 2002). Success in swimming depends on many factors including the level of somatic and motor development and appropriate selection of means and methods of influence on the competitor's organism – properly selected according to the competitor's age and his/her level of progress. The process of training should be precisely planned and monitored since the very beginning, and in particular in relation to the complex of potential properties of the competitor's organism which play a decisive role in achieving the level of motor ability, in which co-ordination motor abilities are of high importance (KZM) (Ljach 2003).

AIM OF THE REPORT

The inspiration for undertaking this study was an analysis of the data on the impact of specific motor co-ordination abilities on the swimming skill.

The objective of this report was an attempt to search for the dependence between motor co-ordination abilities and sports results of young swimmers at the stage of purposeful training.

SUBJECTS OF ANALYSIS

1. What is the level of diversity between the examined competitors in the area of co-ordination abilities?
2. Are there correlations between the considered parameters of co-ordination abilities and swimming skills of 11–12-year-old swimmers, and if so, what is their level?

ANALYSIS' HYPOTHESIS

The considered co-ordination abilities prove correlation relations with the swimming skill, however, the strongest dependences are observed between kinaesthetic parameters of time differentiation and the pace in front crawl and the sports results of 11–12-year-old swimmers.

MATERIAL AND METHOD

The research was conducted by observation to the measurement of swimming skill and the level of motor co-ordination abilities. The screening included a group of 30 competitors at the age of 11–12 years training swimming at KS Korona sports club in Kraków (17 girls and 13 boys).

In order to evaluate the level of co-ordination skills we conducted a special skill test, i.e. a swimming one, using trials used by Kunicki (2004). The tests were modified by the present authors for the purpose of their research. The trials diagnosing the level of co-ordination skills were mainly conducted by means of front crawl technique.

The following tests of special skill was taken into account:

1. Differentiation of time in front crawl (DTBC)
   The examined swimmer swam front crawl stroke the distance of 25 m twice in full style co-ordination, but sector 1 of 25 m with the intensity of 100% (DTBC-100), and sector 2 of 25 m with the intensity of 75% (DTBC-75). The time was measured with the accuracy of 0.01 s.
2. Kinaesthetic differentiation of motion pace sensation (KDMPS)
   The examined swimmer swam front crawl stroke the distance of 25 m twice in full style co-ordination, but sector 1 of 25 m with the intensity of 100% of his/her possibilities (KDMPS-100), and sector 2 of 25 m with the intensity of 75% (KDMPS-75). The number of arm work cycles at different swimming speed was measured.
3. Indicator of swimming co-ordination (ISC)
   The swimmer swam sector 1 of 25 m with the use of front crawl movements (P 25 AM), sector 2 of 25 m working only with the use of the legs (P 25 LL), and sector 3 of 25 m in crawl stroke in full style co-ordination (P 25 SC).
   With the scored results we calculated 'the indicator of swimming co-ordination according to the formula':
   Co-ordination index (CI) = P 25 AM + P 25 LL – P25 SC/2
4. Ability of space orientation (ASO)
   The competitor under study was in the distance of 7.5 m from the relapse wall, when given the signal, he/she swam crawl stroke with maximum speed to the relapse wall, made a somersault relapse with an aquaplanning and returned to the start, i.e. to the point of 7.5 m from the wall. The time of execution of the trial was measured.
5. Ability of quick reaction (AQR)
   The examined competitor stood on the start goal post and made a jump. The time from the start signal till the moment of detachment from the goal post was measured. In order to properly measure the trial, it was recorded on the video tape and played several times.
6. Ability of balance keeping (ABK)
   The competitor stood on the start goal post, when given the signal he/she jumped into the water with the legs downwards and with the arms lengthwise the body – the stopwatch was turned on in the moment of the start signal, then the swimmer had to lie on his/her back on water and in the moment of reaching balance the stopwatch was turned off. Then, when given the next signal (the stopwatch was turned on), the competitor moved to his/her pouch position (lengthwise the transverse axis of the body) and in the moment of re-reaching the balance on the pouch in the position of arrow stroke the stopwatch was turned off.

The above trials were measured with the accuracy of 0.01 sec and were conducted twice taking into account the better trial result.

The following kinematics parameters were examined:

Distance per stroke length – the length of the arm stroke – (AM–DPS)

The number of movement cycles with the exclusive use of the arms (frequency) Stroke Rate (AM–SR)

The measurements of the level of special ability was made in the period of one training macro-cycle, twice in February and March 2007, during four training units. The sequence of carrying out the tests was identical. The screening was preceded by standard warm-up on the ground and in water, and the time of its duration amounted to about 20 min.

In order to evaluate the level of swimming skill we used the results obtained from the examined competitors during sports competitions – Team Championships of Young Sportsmen and Correspondence Championships of Poland of 10–11-year-old competitors at the distance of 100 m individual medley (100 IM). These results were acquired from the competition reports and specification of ratings and swimming records.

Having analyzed the data, we presented the obtained results in basic statistical values. The correlations within the scope of the isolated parameters were searched by Person's line correlation (ANOVA, simple effects).

RESULTS

Having analyzed the data, at first we attempted at evaluating the level of diversity between the examined competitors in the area of co-ordination abilities. The data indicating the individual level of motor co-ordination abilities are presented in Tables 1 and 2.

The results evaluating the individual level of development of co-ordination abilities in young 11–12-year-old swimmers are characterized by a high level of differentiation and divergence (Tab. 1, 2).

The highest differences, both in girls and boys, were observed on the level of kinaesthetic abilities of time differentiation, V = 67.75% in girls and V = 68.23% in boys. The lowest differences were obtained in the tests examining the speed of reaction V = 19.27% in girls and V = 19.47% in boys.

The subsequent consideration of this report was to define to what extent the level of co-ordination abilities determines the sports results of 11–12-year-old swimmers. For this purpose we calculated the speed of swimming DTBC-75, DTBC-100, 100 IM of the whole group taking into account the gender and age of the subjects.

The analysis (Tab. 3, 4) reveals that sports results is closely correlated with kinaesthetic differentiation of time in front crawl. The speed of swimming of the 25 m sector with the intensity of 75% of the competitor's own possibilities was almost identical with the speed of swimming at the distance of 100 individual medley both

TABLE 1. The differences in range in age groups (11, 12 years) of the co-ordination parameters among girls (ANOVA, simple effects)

Dependent variable	Difference of the average between younger and older girls	Standard error girls	P girls	V%
DTBC	**–12.47***	**0.06**	**<0.01**	**67.75**
DTBC-100	–2.91	0.08	<0.01	45.21
DTBC-75	–7.41*	0.06	<0.01	46.21
KDMPS	–4.83*	0.06	<0.01	55.29
KDMPS-100	**–2.70***	**0.07**	**<0.01**	**64.83**
KDMPS-75	–3.58*	0.06	<0.01	59.16
ISC	–3.73*	0.04	0.05	34.76
P 25 S.C.	–2.49*	0.04	<0.01	22.82
P 25 AM	–7.94*	0.03	<0.01	33.56
AM–SR	–8.49*	0.04	<0.01	32.97
AM–DPS	–0.54	0.05	<0.01	34.7
P 25 LL	–2.23*	0.04	<0.01	34.83
ASO	–2.32*	0.05	0.06	25.87
AQR	**–30.03***	**0.05**	**0.02**	**19.27**
ABK	–7.58*	0.05	0.02	22.55
100 IM	–40.05	0.07	<0.01	30.45

* Double correlation is significant at the level of 0.05.

in 11- and 12-year-old children. Considering the above, it is obvious that the dependences between sports results and the level of special swimming skill, expressed in kinaesthetic differentiation of time in front crawl – 75% are significant. The level of the obtained speed at the distance of 100 m individual medley was identical with almost 90% of speed obtained in the sector DTBC-75.

Furthermore, on the basis of the obtained results (Tab. 3, 4) one could observe that the speed of swimming with the exclusive use of the arms (T 25 AM) both among the girls and boys in the considered age categories is close to the speed at the distance of 100 m individual medley.

In order to explain the issue if there are any correlations between the considered parameters of co-ordination abilities and swimming skills of the examined competitors, expressed in co-ordination parameters correlated with age and gender of the swimmers, we examined the correlations between these variables (Tab. 5).

Analyzing the above results (Tab. 5), we discovered in most cases essential correlations between special co-ordination parameter and sports result ($p < 0.01$). The lowest number of essential dependences ($p < 0.05$) with the sports results showed the following parameters: frequency of arms stroke rate (RR–SR), balance ability (BA),

TABLE 2. The differences in range in age groups (11, 12 years) of the co-ordination parameters among boys (ANOVA, simple effects)

Dependent variable	Difference of the average between younger and older boys	Standard error boys	P boys	V%
DTBC	**–10.34***	**0.09**	**<0.01**	**68.23**
DTBC-100	–60.06*	0.11	<0.01	48.21
DTBC-75	–9.76*	0.09	<0.01	46.78
KDMPS	–60.07*	0.09	<0.01	58.23
KDMPS-100	**–10.07**	**0.10**	**<0.01**	**65.21**
KDMPS-75	–2.87	0.09	<0.01	60.11
ISC	–3.37	0.05	<0.01	35.84
P 25 S.C.	–1.53*	0.06	<0.01	22.63
P 25 AM	–5.63	0.05	<0.01	32.77
AM–SR	–8.22*	0.06	<0.01	31.1
AM–DPS	–2.59*	0.07	<0.01	33.54
P 25 LL	–5.25*	0.05	<0.01	35.45
ASO	–3.28*	0.07	<0.01	25.68
AQR	**–3.86***	**0.07**	**<0.01**	**19.47**
ABK	–12.39*	0.05	0.02	22.97
100 IM	–14.92*	0.05	0.02	30.57

* Double correlation is significant at the level of 0.05.

TABLE 3. The level of special swimming co-ordination parameters among the girls 11–12-year-old considering their gender and age

Girls	Average		Standard deviation		*N*	
Age	**11**	**12**	**11**	**12**	**11**	**12**
DTBC	10.03	1.21	0.08	0.09	7	10
DTBC-100	1.15	1.37	0.10	0.07	7	10
DTBC-75	**0.98**	**1.13**	**0.07**	**0.10**	**7**	**10**
KDMPS	14.80	12.74	1.26	10.00	7	10
KDMPS-100	13.22	10.66	1.37	0.94	7	10
KDMPS-75	15.30	13.39	10.05	1.23	7	10
ISC	3.30	1.86	1.54	2.42	7	10
P 25 SC	10.03	1.21	0.08	0.09	7	10
P 25 AM	**0.94**	**10.06**	**0.07**	**0.12**	**7**	**10**
AM–SR	41.33	33.53	50.05	7.58	7	10
AM–DPS	1.43	20.07	0.18	0.47	7	10
P 25 LL	0.78	10.02	0.13	0.20	7	10
100 IM	**0.90**	**1.12**	**0.08**	**0.11**	**7**	**10**

TABLE 4. The level of special swimming co-ordination parameters among the boys 11–12-year-old considering their gender and age subjects

Boys	Average		Standard deviation		*N*	
Age	**11**	**12**	**11**	**12**	**11**	**12**
DTBC	10.05	1.42	0.09	0.05	8	5
DTBC-100	1.23	1.60	0.16	0.09	8	5
DTBC-75	**0.97**	**1.36**	**0.08**	**0.04**	8	5
KDMPS	14.82	10.65	1.31	1.19	8	5
KDMPS-100	12.37	8.44	1.64	0.58	8	5
KDMPS-75	15.51	11.43	1.25	1.39	8	5
ISC	1.76	.79	1.66	2.36	8	5
P 25 SC	10.05	1.42	0.09	0.05	8	5
P 25 AM	**0.94**	**1.29**	**0.08**	**0.08**	8	5
AM–SR	40.28	34.15	60.01	7.18	8	5
AM–DPS	1.49	2.39	0.24	0.48	8	5
P 25 LL	0.79	1.24	0.07	0.08	8	5
100 IM	**0.95**	**1.40**	**0.11**	**0.09**	8	5

TABLE 5. Correlations between the sports result, age and gender of the competitors and the special swimming skill parameters

Parameters	100 ZM	F	M	11-y-old	12-y-old
DTBC	0.70**	2.26*	3.61*	–0.38*	–0.47**
DTBC-100	0.71**	4.17*	5.52*	–0.34*	–0.33*
DTBC-75	0.66**	11.88*	4.04*	–0.47**	–0.39*
KDMPS	0.75**	4.13*	5.81*	–0.41**	–0.45**
KDMPS-100	0.82**	2.56*	3.96*	–0.68**	–0.68**
KDMPS-75	0.76**	3.93*	5.49*	–0.73**	–0.70**
ISC	0.69**	4.56*	4.02*	–0.69**	–0.70**
P25SC	0.77**	4.81*	5.69*	–0.64**	–0.59**
P25AR	0.84**	3.34*	5.12*	–0.08	–0.07
AR–SR	0.76**	4.83*	6.21*	–0.23	–0.24
AR–DPS	0.75**	1.45	–0.48	–0.34*	–0.29
P 25 LL	0.70**	3.03*	3.44	–0.18	–0.17
ASO	0.82**	2.54*	1.69*	–0.04	0.00
AQR	0.85**	4.22*	3.90*	–0.11	–0.09
ABK	0.85**	2.65*	2.05*	–0.05	0.03
100 IM	0.85**	16.89*	3.71*	0.72**	0.82**

* Double correlation is significant at the level of 0.05; ** double correlation is significant at the level of 0.01.

ability of quick reaction (AQR), ability of space orientation (ASO). The highest number of essential double correlations at the level of 0.05 were mainly obtained for the parameters of 100 m individual medley and ability of kinaesthetic differentiation of time and pace of movement.

DISCUSSION

Motor co-ordination abilities and sports skills are integral elements of the structure of motor fitness, which conditions the effectiveness of sports activities (Raczek 1987). The main idea of this study was an attempt to define the degree of differentiation of the level of development of the selected motor co-ordination abilities and their influence on the sports result in young swimmers aged 11–12 in the stage of directed training.

The research results obtained so far (Ljach 2000) reveal the existence of a very close link between sports effectiveness and the level of co-ordination motor abilities especially in the process of training in the first stages of competitors' training. The phases of heightened susceptibility of an organism to the shaping of the co-ordination motor abilities, the so-called sensitive periods, most frequently occur at the ages of 7 to 11–12 (Raczek et al. 1998) that is why it seems sensible to shape the co-ordination motor abilities both in the period of versatile training and especially in directed training.

The present study referring to the diagnosis of co-ordination motor abilities of young swimmers indicated that the 11–12-year-old competitors show high individual differences in their level of developing these abilities. The biggest differences were noted in the level of the ability of kinaesthetic differentiation of time and the abilities of kinaesthetic sense of movement pace, and, on the other hand, the smallest values were manifest in the tests examining the speed of reactions. The obtained results are in accordance with the test data obtained by other authors (Ljach, Starosta 2001), which indicate a highly differentiated level of the development of specific co-ordination motor abilities in children. This can be connected with a considerable influence of the genotype on the manifestations of different co-ordination motor abilities (Ljach 2003), as well as with a differentiated training experience of young swimmers. Subsequently in the tests an attempt at the evaluation of the level of parameters of special swimmers' co-ordination (of the whole group) was made, taking into consideration the sex and age of the tested groups and their influence on the sports results.

On the basis of the tests carried out it was established that the dependences between the sports results and the level of co-ordination abilities of the tested group were most significant in the area of feeling and motor habits, which determine the quality of the processes of steering and regulating the movements. Thus, we verified the hypothesis that assumed the existence of connections between the level of co-

-ordination motor abilities and the sports results, especially in the area of the parameters of the ability to differentiate the time and pace of movement.

Although the sports results in young competitors can also be influenced by other factors, such as technique and tactics of swimming, the level of development of fitness abilities and abilities concerning speed and strength, physical development of the competitors or their training experience (Płatonow 1999; Dybińska 2004), still the level of co-ordination of motor abilities also marks its presence in swimming skills. Thus a significant predicator of the development of competitors' development is special co-ordination, evaluated on the basis of the tests of swimmers' fitness suggested in the study.

While interpreting the obtained results, one needs to be in a way cautious, as in this analysis the kinematic parameters describing the swimming technique were not checked, nor was the training experience of the competitor taken into consideration, which may influence the interpretation of the results.

CONCLUSIONS

On the basis of the analyses, the following statements were formulated:

1. High differentiation among 11–12-year-old swimmers was observed in the area of the analysed co-ordination abilities, which is proved by the results of variability factor in the range from 19.47% to 68.23%.
2. The level of co-ordination abilities proved to be, both in boys and girls, a significant factor determining the sports results. Especially, such parameters as kinaesthetic differentiation of time and pace of movement in front crawl, were of significant influence.
3. It seems that carrying out such a type of observations is purposeful, as there has been lack of detailed data concerning the influence of specific co-ordination motor abilities on the effectiveness of the training process in swimming, or tests elaborated in such a way as to enable one to evaluate the level of those abilities. Measurements and continuous monitoring of co-ordination abilities allow one to obtain significant information concerning the quality of the training means in use as well as the level of competitors' training.

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Method of Assessing Progress in the Process of Teaching the Swimming Technique

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ABSTRACT:
In the process of striving for the empirically worked out model of motor activity, it is necessary to assess the degree of proficiency in this area, not only after finishing the planned teaching cycle but also during it. Defining indices of movement accuracy on the current basis allows one to specify the types and reasons for inaccuracies – errors, deficiencies and deviations, providing the teacher-coach with the possibility of correcting the didactic approach he or she adopts. One can find numerous methods of assessing the swimming technique employed in practical teaching. However, they turn out to be inappropriate, if one wishes to achieve an objective picture of the actual technique demonstrated by the learners. This work aims at showing the possibility of objective assessment of the students' progress in swimming learning and improvement with the use of simple mathematical methods.

Materials and methods: Twenty-six fourth-form pupils of primary school, aged 10, constituted the group of research subjects. These children participated in the breast stroke teaching programme.

After finishing the teaching cycle, assessment of its results was organized in two stages. During the first stage the technique demonstrated by all the subjects was filmed and during the second one it was compared to the binding standard model described in the literature. The swimming accuracy index, taking into account, among other things, the number of omitted movements as compared to the standard structure of the technique was applied for this purpose

$$Wo = \frac{lw}{lc} = \frac{lc - lo}{lc} = \frac{14 - lo}{14}$$

as well as the number of transposed and omitted movement elements with the application of the following formula

$$Wop = \frac{Lpw}{lc} = \frac{lc - lo - lp}{lc} = \frac{14 - lo - lp}{14}$$

Results: As a result of the applied procedures, it was possible to point out precisely the errors, defects and deficiencies to be found in the taught technique, allowing for quick methodological correction of the technique's shortcomings.

Conclusions: The means of improving the swimmers speed should be searched for in the technique they demonstrate. To do so, objective methods of technique evaluation

from the perspective of eliminating even the slightest flaws are needed. The evaluation method of assessing the swimming technique suggested by the present authors may also serve this purpose.
KEY WORDS: swimming technique, swimming technique assessment, teaching effectiveness

INTRODUCTION

Swimming teaching-learning is a hierarchical process taking place in several stages in which the learners, through tasks carefully selected by the teacher and methods he or she applies, reach the objectives of various nature defined by the teacher. While acquiring the successive swimming competencies, firstly they become familiar with the water environment, and then learn the basic swimming technique, followed by the standard one, whereas few of them reach the champion level (Czabański et al. 2003).

Teaching swimming at school aims at equipping the pupils with the movement standards – the ready solutions to the sports tasks (Czabański 2000). The said standards, prepared on the basis of the research results and earlier experiences in practising sport, provide the model of performing a movement task independently from the pupil's age, body height, body mass, strength or endurance (Czabański 1991). Reaching the technique standard guarantees the optimal and thus efficient and economical way of performing movements. In the process of striving for the empirically worked out model of motor activity, it is necessary to assess the degree of proficiency in this area, not only after finishing the planned teaching cycle but also during it. Defining indices of movement accuracy on the current basis allows for specifying the types and reasons for inaccuracies. Their scope may vary. Should the performed activity diverge significantly from the intended movements, being accompanied by elements inconsistent with the anticipated objective, then we are dealing with the technique error. If the movement behaviour is consistent with the intended one but lacks some basic movements or movement acts, we face the technique deficiencies. The third category of inaccuracies comprises deviations from the technique resulting from individual, intersubject differences in bodily build and functional capabilities of the swimmers. Discovering and defining the scale of divergences between the model and the registered movements, provides the teacher with the possibility of correcting the didactic approach he or she adopts.

One can find numerous methods of assessing the swimming technique employed in practical coaching. However, they turn out entirely inappropriate and do not provide grounds for drawing conclusions about compliance with the assumed standard at the stage focused on the standard technique. So far, the teachers have used subjective methods in their work, consisting in the technique assessment based on the visual observation. Due to the dynamic development of the modern technology and its general availability, objectivization of this assessment becomes highly possible. Its test can be its quantitative description.

This work aims at determining if the applied method is an effective tool of assessing the swimming technique.

MATERIALS AND METHODS

Twenty-six fourth-form pupils of the Primary School no. 149 in Łódź participated in the study. The somatic, intellectual and motor differences between boys and girls aged 10 do not play a significant role during learning the motor activities. Thus, it is possible to teach coeducational classes (Wolański 1977). After finishing the breast stroke teaching cycle consisting of 8 lessons, the movements performed by all research subjects were recorded. A digital camera placed vertically over the water surface at the height of 2 m was used for this purpose. The camera was fixed to a specially constructed stand, moving along metal guides, parallel to the pool side and children swimming one by one. Movements performed by a swimmer presenting a model technique of breast stroke were recorded identically. The research material obtained after recording was transferred to the computer and analysed with the use of the computer programme Ulead Video Studio 9.0 SE DVD (Zatoń 1981, 1982).

Analysis of the model movements allowed for identifying 14 sensorimotor sequences, constituting a specific algorithm of decisions and actions, comprising successive changes of angles in the following joints: palmar flexion, branchial abduction, head raising, elbow joints flexion, knee joints flexion, hip joints flexion, elbow joints extension, branchial abduction, downward head movement, dorsiflexion, hip joints extension, knee joints extension, plantar flexion, legs adduction in hip joints (Zatoń 1986). The film frame in which the slightest change of the angle in the specific joint occurred was considered the starting point of the movement and the frame in which it was observed that this angle was changed for the last time was considered the final point. The film frame starting the first sequence was numbered 0 and the remaining frames were given successive numbers. The largest number was ascribed to the frame finishing the last sequence. Method of recording movement, identical to the one applied for the model, was applied for children taking part in the experiment. The obtained records of movements were referred to the model. On this basis, it was possible to determine the number of present sequences, omitted sequences and transposed sequences, i.e. taking place in the wrong time. The information about the number of omitted sequences allowed for calculating the swimming accuracy index (*Wo*) for each pupil:

$$Wo = \frac{lw}{lc} = \frac{lc - lo}{lc} = \frac{14 - lo}{14}$$

where: *lw* is the number of present sequences, *lc* – the total number of sequences, *lo* – the number of omitted sequences, as well as *Lo* – the index of the teaching-learning process effectiveness

$$Lo = \log_2(14 - lo)/\log_2 14$$

Determining the transposed sequences required standardizing records of movements for particular subjects because their movement cycles comprised a number of film frames different from the cycle of the model – comprising 63 film frames. The number of the frame closing the last present sequence was selected from each record. Also, the last film frame of the same sequence was taken from the model record. All values of the digital record were multiplied by the C factor.

C = Pki/Pki, where Pki is the digital marking of the frame finishing the i-*th* sequence of the model,

Pki – is the digital marking of the frame finishing the i-*th* sequence of the subject.

This procedure allowed for direct comparison of each movement record with the model. The numbers of film frames corresponding to the beginnings of the sequences were marked on the time axis. Similarly, points meaning the sequence beginning after standardization were placed on the time axis. This enabled us to determine the total number of the transposed sequences. As a consequence, a possibility of more comprehensive assessment of the swimming accuracy appeared, by means of calculating for each subject the index taking into account the number of omitted and transposed sequences (*Wop*):

$$Wop = \frac{lpw}{lc} = \frac{lc - lo - lp}{lc} = \frac{14 - lo - lp}{14}$$

as well as the index of the teaching-learning process effectiveness (*Lop*)

$$Lop = \log_2(14 - lo - lp)/\log_2 14$$

RESULTS AND DISCUSSION

The obtained (Tab. 1) results allow to explain the difficulties encountered while acquiring some of the sensorimotor sequences by particular pupils. Sequence 1 (palmar flexion) was omitted most frequently, followed by 10 and 13 (dorsiflexion and plantar flexion), as well as 14 (adduction of the hip joint). Single subjects did not perform the following sequences: 3 (raising head), 6 (hip joint flexion), 9 (downward head movement) and 11 (hip joint extension).

Identification of the most frequently transposed sequences has revealed the portions of activity connected with the most serious problems with movement co-ordination. The most frequently transposed sequences were as follows: 12 (knee joint extension), as well as 9 (downward head movement), 10 (dorsiflexion in the ankle

TABLE 1. Numerical description of movement for all subjects

Subject	*lw*	*lo*	*lp*	*Wo*	*Lo*	*Wop*	*Lop*
1	10	4	3	0.71	0.87	0.5	0.74
2	14	0	2	1	1	0.86	0.94
3	14	0	5	1	1	0.64	0.83
4	12	2	5	0.86	0.94	0.5	0.74
5	14	0	5	1	1	0.64	0.83
6	13	1	1	0.93	0.97	0.86	0.94
7	14	0	3	1	1	0.79	0.91
8	14	0	3	1	1	0.79	0.91
9	13	1	5	0.93	0.97	0.57	0.79
10	11	3	2	0.79	0.91	0.64	0.83
11	14	0	3	1	1	0.79	0.91
12	9	5	1	0.64	0.83	0.57	0.79
13	14	0	4	1	1	0.71	0.87
14	14	0	4	1	1	0.71	0.87
15	14	0	5	1	1	0.64	0.83
16	12	2	3	0.86	0.94	0.64	0.83
17	11	3	6	0.79	0.91	0.36	0.61
18	13	1	5	0.93	0.97	0.57	0.79
19	14	0	6	1	1	0.57	0.79
20	14	0	4	1	1	0.71	0.87
21	14	0	4	1	1	0.71	0.87
22	9	5	6	0.64	0.83	0.21	0.42
23	13	1	4	0.93	0.97	0.64	0.83
24	14	0	3	1	1	0.97	0.91
25	14	0	3	1	1	0.79	0.87
26	13	1	2	0.93	0.97	0.79	0.91
Total	335	29	97				

joint), 7 (elbow joint extension), 4 (elbow joint flexion), 8 (branchial abduction) and 6 (hip joint flexion). Several subjects transposed sequences 3 (head raising) and 5 (knee joint flexion). Single subjects transposed sequence 1 (palmar flexion), 2 (branchial adduction) and 11 (hip joint extension).

In total, 29 sequences were omitted, 335 sequences were performed where 97 sequences were transposed. The presented results show that proper movement co-ordination turned out to be much more difficult for the subjects than learning particular movements. Values of indices *Wo*, *Lo*, *Wop* and *Lop* fluctuated between 0 and 1, where 1 meant an excellent value. Information about the most frequently omitted or transposed sequences is at the same time a useful guidance for the teacher who is able to correct his or her teaching methods, placing emphasis on the activities whose acquisition or co-ordination turns out most problematic.

Applying numerical description of movement aims at objectivization of the swimming technique assessment which may be carried out at any moment of the teaching process. It has the clear advantage over the teacher's subjective assessment also thanks to the possibility of tracking the learning progress, not only describing the teaching results. The fact that it enables one to prepare the quantitative description of the group, allows one to make any type of comparison between groups as regards the obtained results at the given stage of teaching.

CONCLUSIONS

The presented method turned out to be an effective way of providing objective assessment for the swimming technique. Its application is particularly well-grounded at the opening stage of teaching where apart from teacher's subjective perception of the movement correctness, no other methods of technique assessment are available.

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PART THREE

PERIODIZATION OF TRAINING PROGRAM

An Analysis of Chosen Training Load Parameters and the Athletic Performance of Twelve-year-old Swimmers

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ABSTRACT: The aim of this work was to analyze the influence of selected parameters of training loads on swimming sports results achieved by young swimmers and to determine the usefulness of these parameters to predict swimming results during later training stages. The study group consisted of 12-year old competitors – 8 girls and 6 boys. Structure of physical effort was evaluated using the method of recording training loads based on the data gathered during exercises performed in water. Progress of sports results observed in young swimmers leads to the conclusion that technical exercise and swimming in a variety of styles without concentrating on the best style, positively influences sports development of young swimmers.

KEY WORDS: training loads, swimming, analysis of sport results

INTRODUCTION

For the last few years Polish swimmers have been achieving significant results in European and world competitions. Growing popularity of swimming has resulted in a great number of children and adolescents taking interest in this form of activity. Recruiting for swimming lessons and training is usually done in grades 3 and 4 which is equivalent to 9–10 years of age (Czabański et al. 2003). Due to the fact that swimming practice begins at an early stage of educational process, the basic problem underlying training is the right choice of training loads regarding the physical and mental development of the young swimmer (Bartkowiak 1999). Incorrectly conducted training may ruin a developing talent.

The fundamental problem in swimming is determining the magnitude of the training load to achieve the maximum level of physical skill (Kosmol 2000).

The effectiveness of training load in swimming is first of all determined by the proportion of the training volume and intensity and its variation at particular training stages (Płatonow 1997).

While working with young swimmers, the coach should schedule the training so as to ensure his trainees a gradual development of athletic mastery without excessive stress to the body. During ontogenesis the body is continuously changing, which is reflected in its growth and maturity (Perkowski, Śledziewski 1998).

Consequently, training of the young swimmer demands a constant monitoring of his readiness to perform and using the observations to adjust training loads as well as to determine their effects. The fundamental element of planning and control of swimming training is based upon competition results (Lach, Rolski 1996).

AIM OF THE PAPER

The aim of the paper was to analyze the influence of chosen training load parameters on results in swimming achieved by young swimmers and to determine their usefulness for anticipation of prospective results in the course of the training process.

MATERIAL AND METHODS

The research group consisted of students Secondary Sports Schools in Gdańsk Oliwa and the athletes of the swimming team of AZS-AWFiS Gdańsk born in 1995 (8 girls and 6 boys).

The research was carried out for the whole of the training year 2006/2007. The analysis comprises the volume of training work in water and on dry land.

In order to assess the structure of physical effort there was used a method based on gathering data on workouts performed in water.

All these workouts were divided into 6 groups:

1. Workouts comprising swimming warm-ups.
2. Workouts carried out solely through the use of the arms (all styles).
3. Workouts performed solely through the use of the legs (all styles).
4. Workouts performed with full co-ordination (swimmer's own style).
5. Workouts performed with full co-ordination (complementary styles).
6. Swimming technique practice and technique elements (all styles).

Spreadsheet software Excel 2003 was used to archive the training data.

The unit of measurement used to specify training loads was a kilometer. On the other hand, the athletic level of the researched group was specified by means of time records and positions achieved in competitions.

In order to assess the influence of six training loads on the level of athletic results there was made an analysis of the results achieved by the athletes during competitions. The results were taken from the competition documents.

In order to compare the results achieved at different distances and at different swimming-pool lengths with the application of training loads, athletic results were converted into points according to the FINA medley swimming tables valid in the years 2005–2008.

RESULTS

The research proved that in the training year 2006/2007 the athletes did 881 training hours during 43 microcycles, i.e. 598 hours in water, 283 hours on dry land (Tab. 1).

Because of the events timetable, the athletes performed a different number of microcycles between the competitions (Fig. 1).

The most training practice was accomplished after the 'Światło i dźwięk' ('Light and Sound') competition, which took place in Lębork on 16 December, 2006 – 12 weeks. It was a preparation period for the Macro Regional Junior Championship – one of the main events of the 2006/2007 season.

The least amount of work was done at the end of the training year 2006/2007 – 1 and 2 micro- cycles before the end-of-the season competitions.

In the period under study, during which the athletes swam 883.8 km, most of the time was devoted to full co-ordination complementary exercises – 287.5 km (32.53% of general work volume) and to warm-ups – 186.5 km (21.10%) and to technique practice – 179 km (20.25%) (Tab. 2, Fig. 2).

Depending on the rank of the competition, the athletes covered a varying number of kilometers per week (Tab. 1, Fig. 3).

TABLE 1. Numerical characteristics of training work between the particular competitions

Competitions/date/place	Number of microcycles	Number of training hours			Number of kilometres	
		Land	Water	Total	Total	Average/microcycle
'Versatility of Style' 10.11.2006 Tczew	10	70	170	240	211.8	21.1
'Light and Sound' 16.12.2006 Lębork	5	37	83	120	123.1	24.6
MacroRegional Junior Championship 29–30.03.2007 Gdańsk–Chełm	15	94	202	296	322.8	21.5
Junior League POZP 29.04.2007 Kartuzy	4	32	47	79	76.9	19.2
'Baltic Olympic Hopefuls' 19–20.05.2007 Gdańsk Oliwa	3	13	40	53	60.8	20.2
'Versatile Speed Medley' 09.06.2007 Gdańsk Morena	3	24	33	57	52.7	17.5
The Summer Open POZP Championship 16–17.06.2007 Gdynia Oksywie	1	7	11	18	20.7	20.7
National Intervoyevodship Junior Championship 12-year-olds 29.06–1.07.2007 Dębica	2	6	12	18	15	7.5
Total	43	283	598	881	883.8	20.5

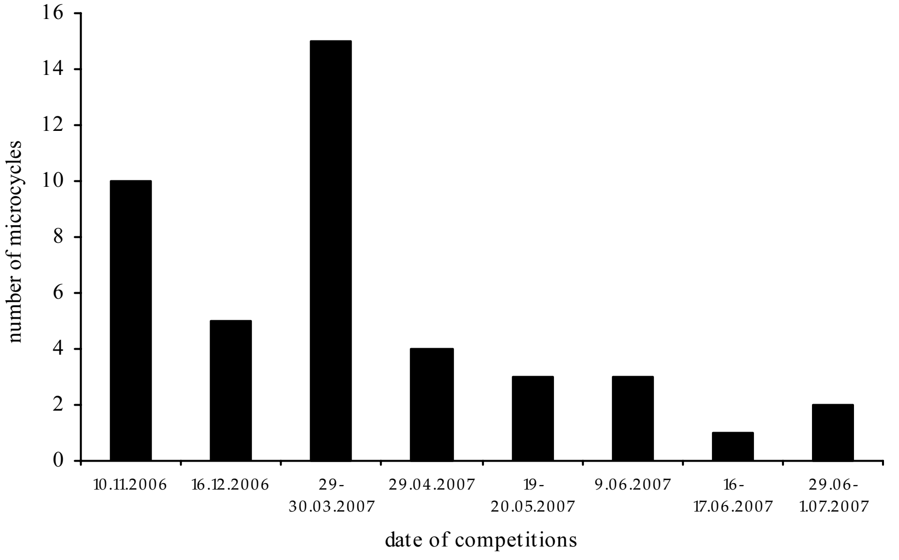

FIGURE 1. Number of microcycles made between the particular competitions

In the first part of the season, in preparation for the trial competition 'Versatility of Style', the athletes swam on average 21.1 km.

For another, less significant event of the 'Light and Sound' competition, the number of kilometers per week increased to 24.6 km. At that time the aim of the increased training work volume was to boost the level of oxygen uptake.

In preparation for the first main competition of the season, for the Macro Regional Junior Championship, we notice a drop in the intensity of practice to 21.5 km a week. After that competition there was a decrease in training load volume to 19.2 km in a microcycle.

Then the volume began to undulate until another competition:

– till the trial competition the 'Baltic Olympic Hopefuls', which took place on 19–20 June, 2007 an average number of kilometers covered in a micro cycle amounted to 20.2 km,
– till another trial competition the 'Versatile Speed Medley', a weekly training load volume clearly dropped to 17.5 km,
– but for the second main competition of the season the 'Summer Open POZP Championship', the volume of the kilometers swum grew to 20.7 km.

In the last two microcycles preparing for the 'National Intervoyevodship Junior Championship', which took place between 29 June and 1 July 2007, the volume of training went down to 7,5 km a week (one athlete qualified for this championship after the Macro Regional Junior Championship).

It can be noticed that a variety of training means was used in the training work between the particular competitions (Fig. 4). At the outset of the season, predominant efforts constituted full co-ordination complementary styles workouts, with little time

TABLE 2. The characteristics of selected parameters of training work made between the particular competitions

Competitions	Number of micro cycles		Warm-up	Arms	Legs	One's own style	Complementary styles	Technique and technical elements	Total
'Versatility of Style' 10.11.2006 Tczew	10	km	50.6	17.6	34.2	12.8	52.2	44.4	211.8
		%	23.9	8.3	16.1	6.1	24.6	21.0	100.0
'Light and Sound' 16.12.2006 Lębork	5	km	25.1	3.4	15.7	9.7	39.5	29.7	123.1
		%	20.4	2.7	12.8	7.9	32.1	24.1	100.0
MacroRegional Junior Championship 29–30.03.2007 Gdańsk Chełm	15	km	67.0	12.4	33.3	24.7	116.6	68.8	322.8
		%	20.8	3.8	10.3	7.7	36.1	21.3	100.0
Junior League POZP 29.04.2007 Kartuzy	4	km	14.5	1.2	8.4	8.4	34.2	10.2	76.9
		%	18.9	1.6	10.9	10.9	44.5	13.2	100.0
'Baltic Olympic Hopefuls' 19–20.05.2007 Gdańsk Oliwa	3	km	11.7	5	7	7.5	18.7	10.9	60.8
		%	19.2	8.2	11.5	12.3	30.8	17.9	100.0
'Versatile Speed Medley' 09.06.2007 Gdańsk Morena	3	km	10.5	3.5	4.3	9.2	16.3	8.9	52.7
		%	19.9	6.6	8.2	17.5	30.9	16.9	100.0
The Summer Open POZP Championship 16–17.06.2007 Gdynia Oksywie	1	km	4.3	0.8	2.4	3.3	8.1	1.8	20.7
		%	20.8	3.9	11.6	15.9	39.1	8.7	100.0
National Intervoyevodship Junior Championship 12-year-olds 29.06–1.07.2007 Dębica	2	km	2.8	0.9	2.3	2.8	1.9	4.3	15.0
		%	18.7	6.0	15.3	18.7	12.7	28.6	100.0
Total	43	km	186.5	44.8	108.0	78.4	287.5	179.0	883.8
		%	21.1	5.07	12.18	8.87	32.53	20.25	100.0

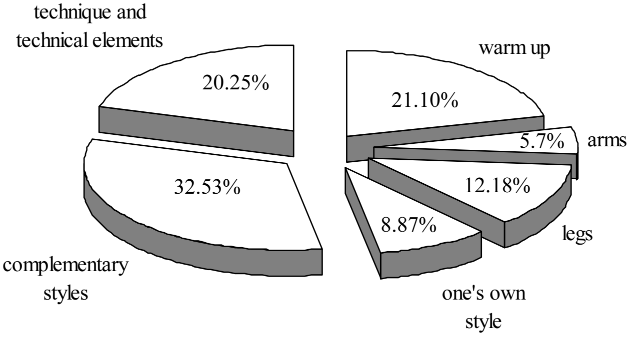

FIGURE 2. Percentage of particular kinds of exercises in the training year 2006/2007

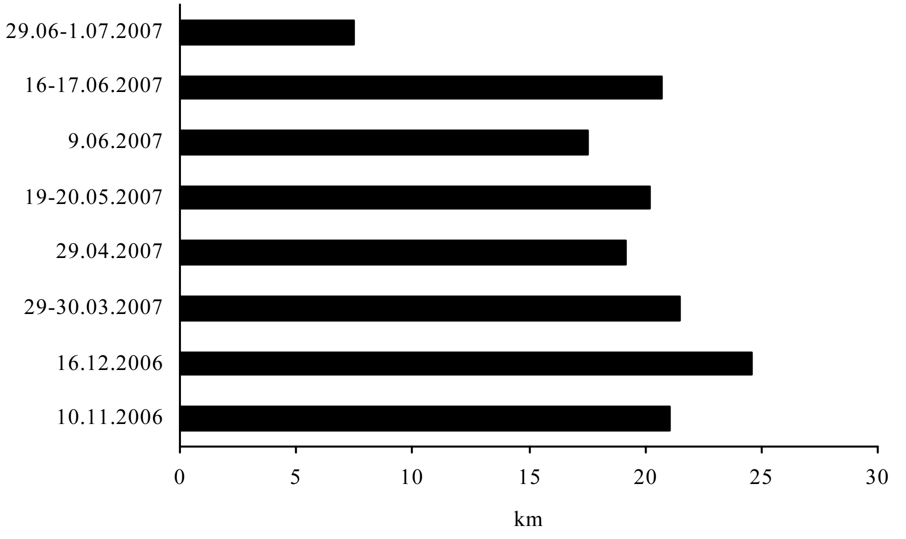

FIGURE 3. Average number of kilometers swum during the microcycle between the particular competitions

spent on arm practice and the swimmers' swimming style. At the end of the training year 2006/2007 it is possible to notice a marked increase in workouts performed in their own style (almost by 100% in regard to the beginning of the season).

The most stable training means, applied in an invariable amount (from 18.7% to 23.9%) throughout the whole of the analyzed training period, was workouts connected with warm-ups (Tab. 2).

The athletes took part in 8 competitions and the best results were achieved mostly during the main event of the season:

The Macro Regional Junior Championship – 8 persons

The Summer Open POZP Championship – 4 persons

The Macro Regional Junior Championship for 12-year-olds – 1 person

Although the majority of the competitors achieved their life records during their first main event of the season, which was a qualifier for the Macro Regional Junior Championship for 12-year-olds, only one person managed to qualify.

The group in question represented a varied athletic level. Mostly it consisted of girls whose best results regardless of style and distance ranged from 499 points – the athlete K.L. to 307 points – the athlete D.W. according to the FINA medley tables. In the boys' group the results were much worse ranging from 296 points – the athlete M.M. to 236 – the athlete K.G. (Tab. 3).

The best results of the whole group in the training year 2006/2007 were achieved by the athlete K.L., who qualified for the National Intervoyevodship Junior Championship for 12-year-olds and the results scored were the best for the whole training group (Tab. 3).

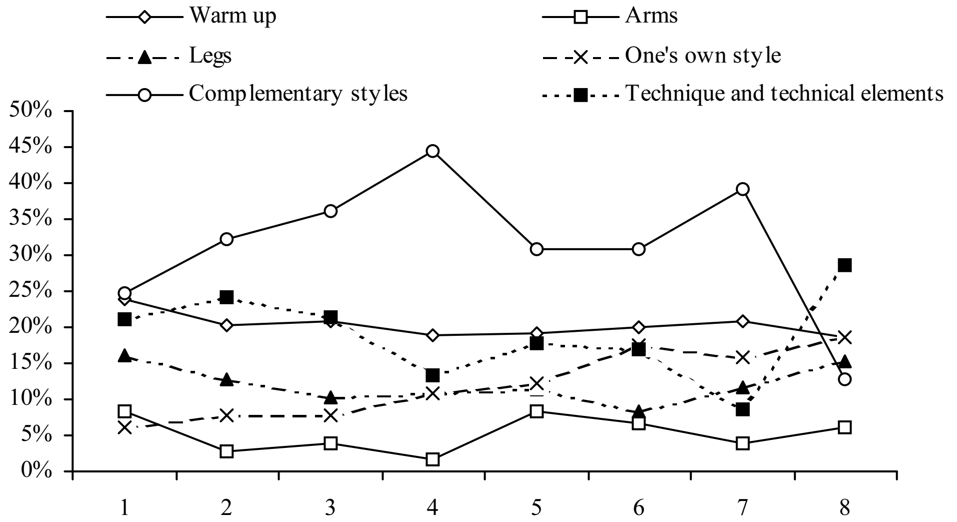

FIGURE 4. Participation of the particular training means, applied between the particular competitions given in (%)

TABLE 3. The best results achieved in the training year 2006/2007 by competitors who were born in 1995

Name and surname	Name of Competitions/Date/Place	Length of swimming pool	Distance	Time	Result according to tables of all-round event
K.L.	‘Versatility of Style’ 10.11.2006 Tczew	25	200 IM	3:17.58	277
	‘Light and Sound’ 16.12.2006 Lębork	25	100 FRE 100 IM	1:14.64 1:26.88	354 333
	Junior Team Sports Voyevodship Competitions 12-year-olds 29–30.03.2007 Gdańsk Chełm	25	400 FRE 200 IM 100 FRE 200 FRE	5:20.93 2:58.45 1:09.71 2:34.50	425 376 435 413
	League POZP – part 2 29.04.2007 Kartuzy	25	100 IM	1:23.36	377
	‘Baltic Olympic Hopefuls’ 19.05.07 Gdańsk Oliwa	25	50 FRE	0:31.86	438
	National Intervoyevodship Junior Championship”12-year-olds 29.06–1.07.2007 Dębica	50	100 FRE 200 FRE 800 FRE	1:08.13 2:28.28 11:03.64	**499** 495 432
D.W.	‘Versatility of Style’ 10.11.2006 Tczew	25	200 IM	3:24.58	250
	‘Light and Sound’ 16.12.2006 Lębork	25	100 IM 50 BRE	1:30.67 0:47.28	293 262

TABLE 3. (*continued*)

Name and surname	Name of Competitions/Date/Place	Length of swimming pool	Distance	Time	Result according to tables of all-round event
D.W.	Junior Team Sports Voyevodship Competitions 12-year-olds 29–30.03.2007 Gdańsk Chełm	25	100 BRE 100 IM	1:36.96 1:34.95	**307** 255
	League POZP – part 2 29.04.2007 Kartuzy	25	100 BRE 100 IM	1:39.22 1:34.06	287 262
	‘Baltic Olympic Hopefuls’ 19.05.2007 Gdańsk Oliwa	25	50 BRE	0:45.90	287
	Open POZP Championship 16–17.06.2007 Gdynia Oksywie	50	100 BRE	1:41.67	286
M.M.	‘Light and Sound’ 16.12.2006 Lębork	25	50 FRE 100 BAC 50 FLY	0:35.88 1:31.28 0:39.35	209 176 198
	‘Baltic Olympic Hopefuls’ 19.05.2007 Gdańsk Oliwa	25	50 FLY 100 IM	0:35.32 1:22.12	274 274
	Open POZP Championship 16–17.06.2007 Gdynia Oksywie	50	50 FLY 100 FRE 400 FRE 200 IM	0:35.32 1:14.35 5:51.50 3:11.11	**296** 274 260 240
K.G.	‘Versatility of Style’ 10.11.2006 Tczew	25	200 IM	3:15.74	204
	‘Light and Sound’ 16.12.2006 Lębork	25	100 FRE 50 FRE	1:18.42 0:36.16	212 204
	Junior Team Sports Voyevodship Competitions 12-year-olds 29–30.03.2007 Gdańsk Chełm	25	200 FRE 400 FRE	2:53.50 5:54.55	211 236
	‘Baltic Olympic Hopefuls’ 19.05.2007 Gdańsk Oliwa	25	50 FRE	0:35.82	210
	League POZP – part 2 29.04.2007 Kartuzy	25	100 FRE	1:17.71	218
	Open POZP Championship 16–17.06.2007 Gdynia Oksywie	50	50 FRE 100 FRE 1500 FRE 200 IM 400 IM	0:36.18 1:22.55 24:49.28 3:29.92 7:00.76	221 200 213 181 215

Regular font – girls; Italics – boys;
FRE – Freestyle; BAC – Backstroke; BRE – Breaststroke; FLY – Butterfly; IM – Individual Medley

CONCLUSIONS

1. The progress observed in young swimmers allows one to conclude that technique workouts and practising all swimming styles, without focusing on a single one – the best, positively contribute to the athletic development of young swimmers.
2. A marked increase or decrease in the training load volume in the particular 6 groups of the performed workouts by the 12-year-old athletes between the particular competitions positively influenced their athletic development. Most of them achieved their life records.
   However, one has to bear in mind that a homogenous structure of the training process allowing only for a volume increase or decrease is not much effective in a several-year training process.
3. Worse athletic results achieved by male subjects may stem from the deficiency of arms-only workouts performed during the whole of the training year.
4. The research proved that systematic monitoring of the training process enables one to obtain data which may well serve as a prediction for composing training schedules for the years to come. In the analyzed case, the athletes, further in their training years, might increase the volume of workouts performed with arms only or in their own style at the expense of workouts of group 1 (warm-ups).
5. The division of training workouts into 6 groups enables one to monitor the training of young swimmers only with regard to the volume and provides no information about the intensity of the tasks performed. Therefore the register of training loads for young swimmers still remains open for discussion, which requires further observation both by coaches and sports theoreticians.
6. The present study serves as an introduction to further research into proper and effective training loads proportions. In order to perform a detailed analysis of the applied training loads and their influence on the results achieved in competitions, one would have to use a sport-tester or lactic acid measurements, which would indicate the physiological changes occurring in the body at individual levels of development of the athletic form.

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Some Metabolic Responses to Reduced Breathing Frequency during Exercise

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ABSTRACT: The purpose of this study was to compare metabolic responses (ventilatory, gas exchange, oxygen saturation and heart rate) during exercises with two different breathing conditions. Twelve healthy male subjects performed an incremental bicycle exercise test on an electromagnetically braked cycle ergometer twice: first with spontaneous breathing (SB), and second with reduced breathing frequency (B10), which was defined as 10 breaths per minute. As work rates increased, significantly higher VE and VCO_2 were measured during the exercise with SB rather than during the exercise with B10. Consequently, PET CO_2 and PET O_2 were higher and lower, respectively, during the exercise with B10 than during the exercise with SB at 120 W and at 150 W. Comparing the data at the same relative intensity (the last work stage that individual subject was completed at different breathing conditions) there were significant differences at almost all measuring parameters. In summary, reduced breathing during exercise at lower absolute intensity did not produce similar conditions as they were during the exercise with spontaneous breathing at higher absolute intensity.

KEY WORDS: reduced breathing frequency, incremental bicycle exercise

INTRODUCTION

During front crawl swimming swimmers could manipulate with different breathing patterns. They usually take breaths every second stroke cycle. However, they could reduce the breathing frequency with taking breath every fourth, fifth, sixth or eighth stroke cycle. Swimming training with reduced breathing frequency is often referred to as ‘hypoxic training’. It was thought that, by limiting inspired air, the reduction of oxygen available for muscular work would result and therefore cause muscle hypoxia, similar to that experienced at altitude (Kedrowski 1979).

Previous studies demonstrated that a reduced breathing frequency during the exercise elicits a decrease in pulmonary ventilation (VE) with the concomitant increase in tidal volume (VT) (Dicker et al. 1980; Holmer, Gullstrand 1980; Yamamoto et al. 1987; Town, Vanness 1990; Sharp et al. 1991; West et al. 2005) and systematic hypercapnia. The latter was determined by analysing expired air during the exercise (Dicker et al.

1980; Holmer, Gullstrand 1980; Yamamoto et al. 1987; Town, Vanness 1990; West et al. 2005) and by measuring capillary blood sampled during (Sharp et al. 1991) and after the exercise (Kapus et al. 2003). West et al. (2005) obtained lower VO_2 due to reduced breathing frequency during swimming. Considering that they speculated that high intensity workloads can be simulated at moderate intensities by reduced breathing frequency. Therefore, the purpose of this study was to compare metabolic responses (ventilatory, gas exchange, oxygen saturation and heart rate) during exercises with two different breathing conditions. Due to an incremental exercise (protocol with multiple exercise intensities) two different analyses were made. At absolute analyses the data measured at the same work stage were compared. In addition, the best results obtained at different breathing conditions were compared at relative analyses. To overcome some technical limitations for measuring the data during swimming, the bicycle exercise test was used.

MATERIAL AND METHODS

Subject. Twelve healthy male subjects (age 24±2 years, height 179.8±4.7 cm, weight 79.3±7 kg and $\dot{V}O_{2max}$ 42.23±4.41 ml/kg/min) volunteered to participate in this study.

Procedures. The subjects performed an incremental bicycle exercise test on an electromagnetically braked cycle ergometer (Ergometrics 900, Ergoline, Germany) twice: the first with spontaneous breathing (SB), and the second with reduced breathing frequency (B10), which was defined as 10 breaths per minute. RBF was regulated by breathing metronome. The breathing metronome consisted of a gas service solenoid valve (Jaksa, Slovenia) and a semaphore with red and green lights. Both were controlled by a micro automation Logo (Siemens, Germany). The subjects were instructed to expire and to inspire during a 2 sec period of the open solenoid valve (a green light at the semaphore was switched on) and to hold breath using almost all lung capacity during 4 sec of the closed solenoid valve (a red light at the semaphore was switched on). Prior to the exercise testing each subject was familiarized with breathing through the breathing metronome. The protocol of the incremental exercise test consisted of measuring a base line followed by a progressive exercise where the work rate increased by 30 W every 2 min until volitional exhaustion. Pedalling frequency, digitally displayed to the subjects, was kept at ~60 rpm.

Instruments. During the incremental bicycle exercise test, the subjects breathed through a mouthpiece attached to a turbine device. The subject's respired gas was sampled continuously by a V_{MAX29} (Sensor Medicis, USA) metabolic cart for a breath-by-breath determination of metabolic and ventilatory variables. The turbine device and the O_2 and CO_2 analysers were calibrated prior to the test with standard 3-l syringe and precision reference gases, respectively. SO_2 was estimating using TruStat Oximeter (Datex – Ohmeda, ZDA) pulse oximeter. The ear probe was attached to the earlobe after cleaning the area with alcohol. HR was measured continuously by PE3000 (Polar Electro, Finland).

Data analysis. Exercise values of VE, VT, VO_2, VCO_2, R, SO_2 and HR were calculated from 60 sec averages during the second minute of each work stage. The values were presented as means (M) ± standard deviations (SD). The paired t-test was used to compare the data between the incremental bicycle exercises in two different breathing conditions.

RESULTS

Table 1 shows the intensity of last work stage (W_{peak}) at the incremental bicycle exercise with two different breathing conditions that the subjects completed.

As shown in Table 1, 150 W was the intensity of the last work stage at the incremental bicycle exercise with B10 that all of the subjects completed. Thus, the data obtained by some participants over 150 W work stage were used to absolute analyses. The results of breathing parameters, SO_2 and HR are given in the following figures.

TABLE 1. W_{peak} obtained at the incremental bicycle exercise with SB and with B10

Subjects	SB	B10
1	270	180
2	300	150
3	330	210
4	270	240
5	300	180
6	330	210
7	300	180
8	300	210
9	330	180
10	270	210
11	300	150
12	240	150
M (SD)	295±28	188±29*

* $p < 0.01$

Figure 1 demonstrates that, as work rates increased, significantly higher VE and VCO_2 were measured during the exercise with SB than during the exercise with B10 ($p < 0.05$; $p < 0.01$). Consequently, PET O_2 and PET CO_2 were higher and lower, respectively, during the exercise with B10 than during the exercise with SB at 120 W and at 150 W ($p < 0.01$). In addition, HR was higher during the exercise with SB than

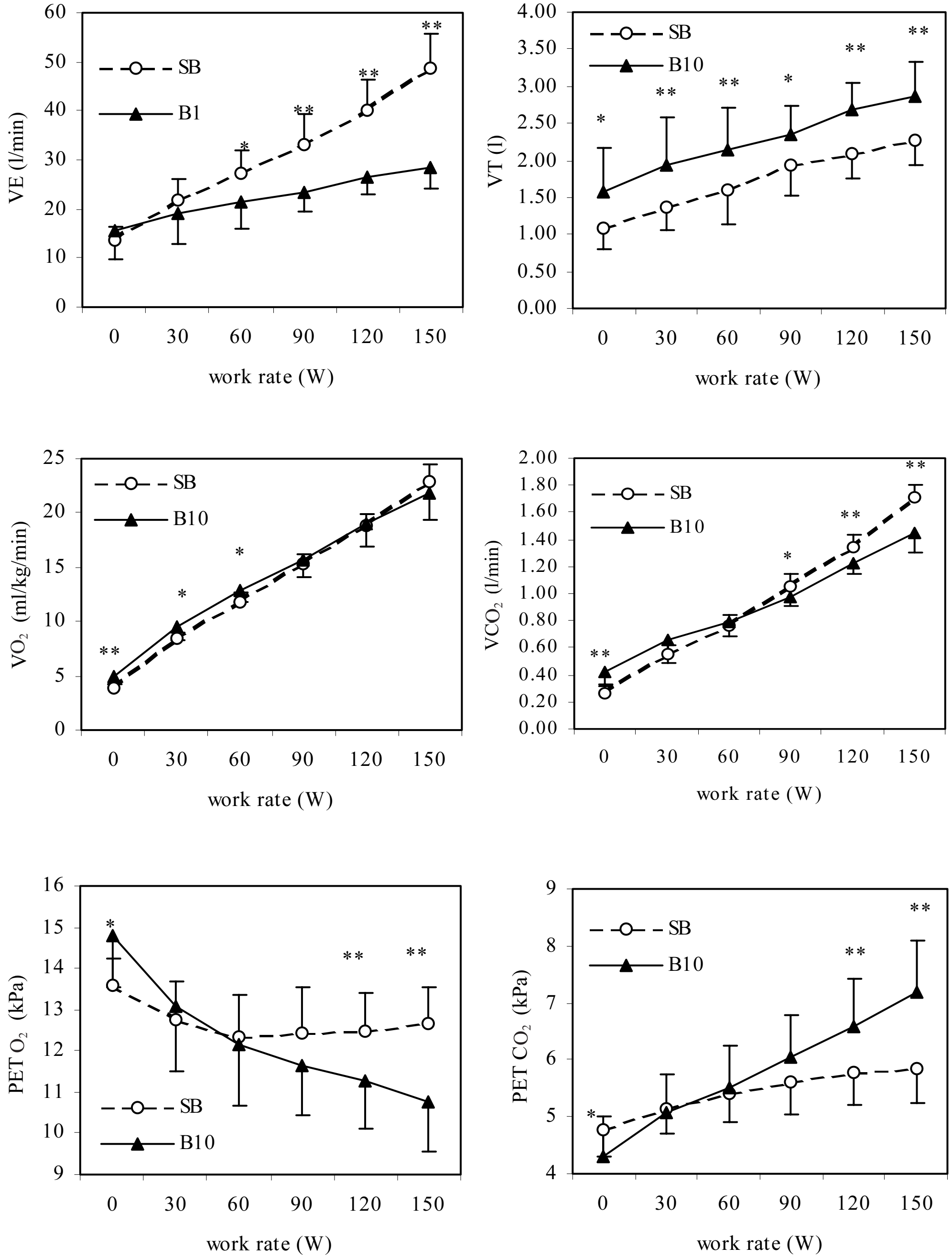

FIGURE 1. The relationship of VE, VT, VO_2, VCO_2, PET O_2, PET CO_2, SO_2 and HR to work rate during the incremental bicycle exercise with SB (open circles) and with B10 (closed triangles) (* $p < 0.05$; ** $p < 0.01$)

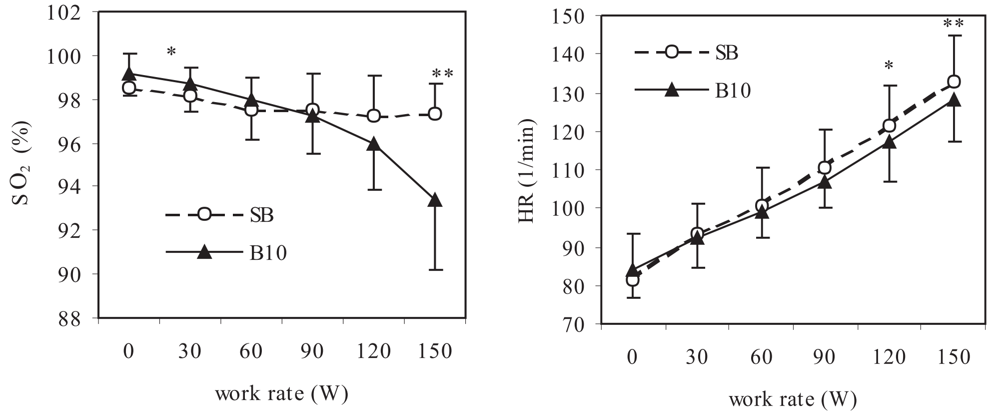

FIGURE 1. (*continued*)

during the exercise with B10; significant differences were achieved at 120 W ($p < 0.05$) and at 150 W ($p < 0.01$). However, VO_2 showed no significant difference between the exercises in two different breathing conditions. The results of breathing parameters, SO_2 and HR measured at W_{peak}, therefore at the same relative intensity are given in the Table 2.

DISCUSSION

In the present study the reduced breathing frequency during the incremental bicycle exercise decreased a subject's performance by 36%. Despite insignificant higher VT throughout the incremental bicycle exercise with B10, the reduced breathing frequency induced significant lower VE from 60 W to the end of the test in comparison with the spontaneous breathing conditions. Reductions of approximately 43% and 73% in VE were measured at 150 W and at W_{peak}, respectively. The reduction by 43% in VE were in accordance with the results of previous studies in which 10 breaths per minute were used for the reduced breathing conditions (Yamamoto et al. 1987). Furthermore, similar reduction in VE was reported when swimmers reduced their breathing frequency during swimming from usual taking breath every second stroke cycle to taking breath every fifth (Dicker et al. 1980) or sixth (Town, Vanness 1990) stroke cycle. Marked hypoventilation during the incremental bicycle exercise with B10 induced higher PET CO_2 and lower PET O_2 and SO_2 in comparison with SB conditions. These results were similar to the results of previous studies in which dry land activities such as cycling on cycle ergometer (Yamamoto et al. 1987; Sharp et al. 1991), treadmill running (Matheson, McKenzie 1988) or an exercise on arm crank ergometer (Stager et al. 1985) were used as an experimental exercise. On the contrary, hypoxia (determined by analysing expired air during the swimming (Dicker et al.

TABLE 2. Breathing parameters, SO_2 and HR measured at W_{peak}

Parameter	SB	B10
VE (l/min)	113.59±18.07	31.05±5.23*
VT (l)	3.07±0.42	3.11±0.52
VO_2 (ml/kg/min)	42.23±4.41	26.34±4.98*
VCO_2 (l/min)	3.73±0.33	1.80±0.36*
PET O_2 (kPa)	12.2±1.0	9.9±0.8*
PET CO_2 (kPa)	6.0±0.6	8.1±0.7*
SO_2 (%)	95±2	90±4*
HR (min^{-1})	184±6	143±16*

* $p < 0.01$

1980; Holmer, Gullstrand 1980; Town, Vanness 1990) and by measuring capillary blood sampled after the swimming (Kapus et al. 2003) has not been proved as a product of reduced breathing frequency during swimming yet. The reason for this phenomenon could be technical limitations for direct measuring SO_2 during swimming. Recently, Miyasaka et al. (2002) succeeded to measure SO_2 during the sprint swimming. Severe arterial desaturation was detected due to the hypoventilation during the swimming.

Although SO_2 was lower at 150 W with B10 in comparison with SB, there were no significant differences in VO_2 between two different breathing conditions comparing the exercises at the same absolute intensity. These results indicated that an aerobic metabolism was not impeded by the reduced breathing frequency during the incremental bicycle exercise. According to these results, it could be argued that training with reduced breathing frequency induces aerobic adaptations similar to the high altitude training (Sharp et al. 1991). In addition, high $\dot{V}O_{2max}$ is an important parameter for a successful swimmer (Maglischo 2003). Considering that high intensity training should be performed at intensity at which $\dot{V}O_{2max}$ is elicited (Hill, Rowell, 1997). In the present study, VO_2, obtained at W_{peak} was significantly lower during the exercise with B10 (due to lower absolute intensity) in comparison with to the exercise with SB. According to that, it could be suggested that training with reduced breathing frequency is not useful for improving $\dot{V}O_{2max}$.

In addition, the results of influences of reduced breathing frequency during the exercise on HR were insufficient. The reduced breathing frequency induced an increased (Yamamoto et al. 1987), decreased (Holmer, Gullstrand 1980; West et al. 2005) or unchanged HR (Dicker et al. 1980; Holmer, Gullstrand 1980; Town, Vanness 1990; West et al. 2005) in comparison with the spontaneous breathing during the exercise. Considering that it was suggested that HR targets (typically used for determining training intensity) should be adjusted when this kind of breathing is used during testing for determining training intensity (West et al. 2005).

CONCLUSIONS

In summary, reduced breathing frequency during an exercise at lower absolute intensity did not produce similar conditions as they were during the exercise with spontaneous breathing at higher absolute intensity. It seems that swimming training with reduced breathing frequency could adapt a swimmer to hypercapnia and hypoxia. In addition, these adaptations could be attained in increasing a swimmer's ability to swim with fewer breaths. This could be an important advantage during the final part of competition races.

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Critical and Maximal Lactate Steady State Speeds, and Stroke Parameters in Swimming Front Crawl Performance

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ABSTRACT: Because swimming coaches and scientists need to define accurately exercise intensity domains to optimize and evaluate aerobic and severe swimming training programs, the purposes of this review are to:

1. Review the recent studies conducted on the assessment of the Critical Swimming Speed (CSS) in order to well define the intensity domains and their boundaries.
2. Verify whether the speed corresponding to the slope of the distance-time relationship ($S_{d\text{–}t}$) in swimming is sustainable and represents the boundary between the heavy and severe intensity domains in swimming.
3. Assess whether intermittent swims at $S_{d\text{–}t}$ are tolerable and induce a physiological and psychological stress.
4. Analyze changes in the traditionally-measured stroke rate and stroke length during aerobic exhaustive swims, (introduction of an 'optimal swimming technique speed').

KEY WORDS: swimming, critical velocity, aerobic intensity domain, stroking parameters

INTRODUCTION

Recent studies on the energy system's contribution to maximal exercise have shown a higher aerobic contribution to the total energy demand than previously thought. This scenario has implications for all Olympic swimming distances. The assessment of swimmers' aerobic potential is fundamental in this sport to monitor training effects and prescribe training intensities. Swimmers' aerobic potential can be evaluated by measuring a single or several performances (concept of critical swimming speed: CSS related to *d–t* relationship), the performance of several sub-maximal constant-load tests (maximal lactate steady state), or an incremental test (ventilatory or lactate thresholds).

In order to optimise and evaluate aerobic and severe training programs the purpose of this paper is to review the recent studies conducted in swimming on the assessment of aerobic potential and using CSS. It is important that exercise intensity at critical speed have to be accurately defined and its physiological underpinning well understood. Indeed, each methodological approach should provide a useful index of aerobic potential, but they cannot be used interchangeably because they all represent different physiological entities. Indeed, the methods are associated with boundaries of several intensity domains whose characteristics differ according to physiological responses during exercise. The intensity domains have to be well understood and their boundaries accurately defined to optimize training programs and their assessment.

CSS has been defined as a sustainable and tolerable intensity above which fatigue and ensuing exhaustion would occur (Scherrer, Monod 1960; Walsh 2000). It should therefore be maintainable for a very long time with no major physiological or psychological stresses (Poole et al. 1989). It has been associated to the boundary intensity between the heavy and severe domain (Poole et al. 1989; Whipp 1996). By definition, when exercising within the heavy domain, i.e. below CSS, capillary blood lactate concentration ($[La]_B$) as well as oxygen uptake (VO_2) would remain steady although the VO_2 would see its steady state being delayed (Whipp 1996). When exercising within the severe domain, i.e. above CSS, drifts in $[La]_B$ and in VO_2 to $\dot{V}O_{2max}$ should be observed (Poole et al. 1989; Hill, Ferguson 1999; Coast et al. 2003). Therefore, the anaerobic contribution should not progressively increase when exercising at CSS.

Thus, it is also important to know whether the speed corresponding to the slope of the distance-time relationship ($S_{d\text{–}t}$) in swimming is sustainable and represents the boundary between the heavy and severe intensity domains in swimming and to assess whether intermittent swims at $S_{d\text{–}t}$ are tolerable and induce a physiological and psychological stress.

EMPIRICAL ASSESSMENT OF THE TWO COMPONENTS OF AEROBIC POTENTIAL

Training programs aimed at improving the aerobic potential of swimmers are designed to increase the maximal oxygen uptake ($\dot{V}O_{2max}$) and ability to utilise a high percent of the $\dot{V}O_{2max}$ for a long time (i.e., endurance; see: Bosquet et al. 2002 for a review). To set training intensities, coaches traditionally use performances recorded during competitions to ease the screening of their swimmers (Smith et al. 2002). A 400-m performance is highly correlated to $\dot{V}O_{2max}$ in an heterogeneous-level group (Costill et al. 1985) and it has long been seen as a gold standard for estimating Maximal Aerobic Speed (MAS) and prescribe training intensities and an index of swimming level (Wakayoshi et al. 1993a). The 1500-m performance, as the longest distance competitive event, could be seen as the second standard competitive test for profiling swimmers' aerobic potential. Alternative methods for aerobic endurance estimation, based on a single performance: 2000 up to 3000-m; 30-min and 60-min tests (Madsen 1982; Olbrecht et al. 1985), have been proposed in the literature (Costill et al. 1985). Indeed, the 400-m performance is not sufficient on its own to screen aerobic potential of a competitive swimmer. For example, two swimmers of identical 400-m personal bests could have different 1500-m times as a function of their different ability to utilise a high percent of their $\dot{V}O_{2max}$ over the race distance (i.e. different aerobic endurance capacities). Similarly, the variance between subjects 300-m and 400-m performances was better explained by an index of aerobic endurance than $\dot{V}O_{2max}$ (Cellini et al. 1986; Ribeiro et al. 1990). Therefore, to complete the assessment of a swimmer's aerobic profile, alongside a 400-m performance, a performance of longer duration should be recorded.

CRITICAL SWIMMING SPEED

In swimming, the modelling of the *d–t* relationship using a two-parameter model (Equation 1: $e = e_{anae} + \dot{e}_{ae} \cdot t$) remains under debate. This is because it has to be assumed that the swimming energetic cost (Cs) is constant across the severe intensity domain (di Prampero 1999). Equation 1 can then be divided by Cs, leading to a linear *d–t* relationship (Equation 2: $d = ADC + CSS \cdot t$). Rather, Cs increases with swimming speed. Therefore, the *d–t* relationship might be distorted, and the speed corresponding to the slope of the *d–t* relationship ($S_{d\text{–}t}$) may not represent a CSS as previously thought (di Prampero 1999). However, swimming literature reports very good fit of the relationship ($r < 0.99$) between times (t) required to cover given distances as fast as possible (d), leading to a debatable conclusion that the 2-component model could be applied in swimming (Wakayoshi et al. 1992; Dekerle et al. 2002; Rodriguez et al. 2003).

The physiological responses at and around CSS during continuous exercise have never been investigated in swimming. It is still not understood whether $S_{d\text{–}t}$ is related to CSS. If $S_{d\text{–}t}$ was representing the speed that can be maintained relying solely on a maximal release of aerobic energy, swimming times at $S_{d\text{–}t}$ should be of rather long duration (i.e. > 60 min) and the exercise tolerable. Since e_{anae} would not contribute to the supply of energy, capillary blood lactate concentration ($[La]_B$) should remain steady. According to the definitions of Hill and Ferguson (1999), if $S_{d\text{–}t}$ was equivalent to CSS, $\dot{V}O_{2max}$ should be reached when exercising above $S_{d\text{–}t}$, but should not when exercising at and below this intensity. Only one study has examined the physiological responses during sets of four 400-m swims performed at and above $S_{d\text{–}t}$ (Wakayoshi et al. 1993b). The authors reported drifts of $[La]_B$ when swimming above but not at $S_{d\text{–}t}$, supporting $S_{d\text{–}t}$ as a measure of CSS. However, the 30–45 sec break that enabled blood samples to be taken between the 400-m blocks could have enhanced lactate oxidation, limiting the drift in $[La]_B$ (Beneke et al. 2003). Later findings suggest that S_{d-t} is not an intensity swimmers could sustain for very long, and with blood $[La]_B$ steady state (Wakayoshi et al. 1993b; Pringle, Jones 2002; Dekerle et al. 2005). This would be in agreement with other reports in cycle ergometry (Dekerle et al. 2003) and treadmill (Smith, Jones 2001).

THE MAXIMAL LACTATE STEADY STATE AND THE HEAVY INTENSITY DOMAIN

Since speed is a ratio of distance over time, CSS is also represented by the time asymptote of the speed–time hyperbolic relationship. The CSS construct can be mathematically defined as the maximal speed that can be maintained, in theory, indefinitely. According to the concept, the anaerobic work capacity should only be utilised for the energy supply during exercise performed above CSS. Therefore, when exercising at CSS, blood lactate concentration ([La]) should remain stable. This is the result obtained by (Wakayoshi et al. 1993b) whose swimmers were required to perform four 400 m at CSS. However, the results of other studies do not support this finding. CSS has been shown in swimming to be higher than Maximal Lactate Steady State (MLSS) directly measured from the performance of several 30-min tests (Dekerle et al. 2005). Similar results have been obtained in cycling (Pringle, Jones 2002) and running (Smith, Jones 2001) suggesting that CSS overestimates MLSS, or alternatively these methods do not correspond to the same physiological entities.

According to VO_2 kineticists, MLSS (and not CSS) represents the boundary between the heavy and severe domain (Barstow 1994). Above MLSS, drifts of blood [La], heart rate and VO_2 ('slow component') is observed, and exercise maintained up to an hour (exhaustion times usually recorded at MLSS). Capillary blood [La] could attain 8–10 mmol/l (Brickley et al. 2002). However, because of the different definitions of the severe intensity domain depending on the model (the VO_2 kinetics, i.e. drift of [La] during exercise and VO_2 slow component; the CSS concept, i.e. attainment of $\dot{V}O_{2max}$ at the end of exercise), we suggest for now, to set a new domain between CSS (times to exhaustion of around 30 min) and MLSS (times to exhaustion of 60 min) called the 'very heavy' domain. In this domain the drift of [La] is observed alongside a VO_2 slow component that does not reach $\dot{V}O_{2max}$ at the end of exercise. Clarity about this domain is needed in future experiments.

MLSS can be defined as the highest speed maintained with the highest stable [La] values resulting from a constant ratio between appearance and disappearance of lactate in and out the blood compartment (Beneke 1995). Therefore, one method usually used by scientists to determine MLSS is based on [La] measurements at minute 10 and 30 of several constant intensity tests (Beneke, von Duvillard 1996). The speed corresponding to MLSS is identified as the highest speed that can be swum with a drift lower than 1 mmol/l between these two instants. Despite the substantial theoretical interest in using this method (accuracy), the requirement of performing several sessions of testing, and the collection of relatively few blood samples, lead physiologists to investigate the other possibilities to estimate MLSS more easily for coaches. An exercise performed at MLSS can be maintained for about an hour, i.e. the 60-min test of Madsen (1982). In swimming, MLSS is about 85% of the speed of a 400 m in trained swimmers (Dekerle et al. 2005) and corresponds to the speed a swimmer would spontaneously choose during the first 15 min of a 2-hour test (Baron et al. 2005).

MLSS has a real physiological meaning compared to CSS but is rather difficult to apply in the field. Its determination is based on a set criteria whose change could affect the MLSS value (Baron et al. 2003). Moreover, undertaking [La] measurement is not always practical, especially in populations such as children where the CSS determination could be more attractive (Greco et al. 2002; Toubekis et al. 2006). Furthermore, MLSS requires the performance of several 30-min swims, which can only be conducted in swimmers with a sufficient level of fitness.

$S_{d\text{–}t}$ – CSS

While some authors do not support the application of the critical speed concept in swimming (di Prampero 1999), others have demonstrated its validity (Toussaint et al. 1998). No study has investigated the responses when exercising at and around the speed corresponding to the slope of the *d–t* relationship ($S_{d\text{–}t}$). The physiological responses when swimming above and below $S_{d\text{–}t}$ are also poorly understood. These questions need to be answered to provide a physiological description of $S_{d\text{–}t}$ in swimming, and assess whether or not this parameter corresponds to the boundary between the heavy and severe intensity domain.

Thus, the purpose of one of our recent study was to analyse the physiological responses when exercising continuously at and around $S_{d\text{–}t}$. It was hypothesised that $S_{d\text{–}t}$ would overestimate the boundary between the heavy and severe intensity domain, i.e. CSS.

Within a 3-week period, 9 trained front crawl competitive male swimmers performed a 100-, 200-, 400-, and 800-m all-out effort in a 25 m indoor swimming pool in order to model the *d–t* relationship and determine $S_{d\text{–}t}$ and peak VO_2. They also swam in a randomised order a constant-speed efforts to exhaustion swum at and 5% above and below $S_{d\text{–}t}$ on different days. Capillary blood samples for measurement of $[La]_B$ were obtained from capillary blood samples taken from the finger-tip and Oxygen uptake (VO_2) was measured breath-by-breath with a portable automated system (K4b^2, Cosmed, Rome, Italy) during the first 30 sec of the recovery period. Whole body RPE was recorded using the Borg 1–10-category scale (Borg 1982).

$S_{d\text{–}t}$ could be maintained for 24.3±7.7 min with an increase in RPE and $[La]_B$ ($p < 0.05$), peak VO_2 being reached at exhaustion. Time to exhaustion (TTE) increased by two-fold when the speed was lowered by 5%; $[La]_B$, VO_2, and RPE remained stable.

TTE dramatically decreased at S_{d-t} + 5% (8.6±3.1 min), with end $[La]_B$ and VO_2 values of 10.2±1.9 mmol/l and 96±7% of peak VO_2, respectively.

It can be concluded that swimming continuously at S_{d-t} would not be possible for a very long time, and would induce increases in $[La]_B$ and VO_2 responses, with end VO_2 values reaching their maximum.

INTERMITTENT SWIMS AT S_{d-t}

In the previous study it was also hypothesised that $[La]_B$ would remain steady during a set of ten 400-m blocks swum at S_{d-t}. The same swimmers were also asked to swim ten 400-m blocks at their S_{d-t}. A 40 sec break period enabled a blood sample to be taken after each 400 m. RPE were also reported at the end of each 400 m.

The results have shown that even if the RPE progressively increases, $[La]_B$ values remain stable during the 10 × 400-m blocks swum at S_{d-t}. This supports the hypothesis that 40 sec of passive recovery between 400 m swum at S_{d-t} enables the $[La]_B$ to remain stable. These results can be of great interest for coaches willing to work at maximal steady state in an attempt to improve muscular buffering capacities with training (Laursen, Jenkins 2002). This might be achievable during long duration (and therefore volumes) sets of 400 m swum at S_{d-t} as long as the passive recovery is of sufficient duration. These results are in accordance with those of Wakayoshi et al. 1992, 1993a) reporting a $[La]_B$ steady state when swimming a 4 × 400 m at S_{d-t} while a drift was observed when swimming 2% faster led to the conclusion that S_{d-t} was corresponding to CSS. It can be concluded that intermittent swims at S_{d-t} are tolerable but induce heavy physiological and psychological stresses.

STROKING PARAMETERS

Numerous studies have shown that efficiency during constant-load exercise is dependent on frequency in cyclic sports such as swimming (Swaine, Reilly 1983; Weiss et al. 1988; Pelayo et al. 1996, 1998). Therefore, coaches have to take into account the different combinations of SL and SR associated with a given speed. The SL and SR values and combinations are determined by various factors such as anthropomorphic variables, muscular strength, physical conditioning, and swimming economy. It has been acknowledged that biomechanical skill in swimming is of far greater importance for metabolic economy than in running and cycling, and that elite swimmers adopt very different combinations of stroke parameters compared to their less proficient counterparts. The relationship between S and SR has been described as a stroke rate-velocity curve (Craig, Pendergast 1979) while Keskinen and Komi (1993) found a strong positive correlation (r = 0.86) between S and SR.

Since S depends on SR and SL, swimmers can chose different strategies to develop their maximal S as a function of the race distance. Swimmers can attempt to maintain this chosen S in spite of the growth of fatigue throughout the race. This is obviously true whatever the intensity domain swimmers are exercising in. Racing strategies have been the focus of several studies (Craig, Pendergast 1979; Craig et al. 1985; Keskinen, Komi 1988) showing that among the large number of possible SL and SR strategies, only a few are actually chosen by most swimmers. It is clear that most well-trained swimmers neglect their SL and vary their SR in order to increase or maintain their S. Indeed, swimmers adopt higher and higher SR to increase S as race distance decreases (Craig, Pendergast 1979; Craig et al. 1985) or attempt to maintain S during races of 200 m and longer (Craig et al. 1985; Keskinen, Komi 1993). This pattern of stroking is to the detriment of SL which tends to slowly decrease as fatigue develops. Thus, coaches have been advised to focus their attention in training on increasing SL and maintaining SR as fatigue occurs during a training set (Keskinen, Komi 1988; Wakayoshi et al. 1996). It is evident that training a long distance per stroke is an important attribute of skilled swimmers. Swimmers have to maintain an optimal and elevated SL in spite of the emergence of fatigue, which tends to decrease the ability to develop the force necessary to overcome the resistance to forward movement (Craig et al. 1985; Keskinen, Komi 1988; Wakayoshi et al. 1996).

The changes in the stroking parameters is partly dependent upon the aerobic potential, and more particularly upon aerobic endurance. The extent to which the anaerobic metabolism is involved in the total energy release also influences the changes in the swimming stroking. This notion is in line with the slight decrease in SL observed when swimming above the anaerobic threshold (Keskinen, Komi 1988, 1993; Wakayoshi et al. 1996). Dekerle et al. (2005) have shown that above MLSS, swimmers tend to neglect their SL to the benefit of their SR in order to increase or maintain their S. Thus, MLSS represents not only a boundary intensity between the moderate and heavy domain, but also a biomechanical boundary beyond which the SL becomes compromised over time. The MLSS could represent the gold standard intensity to develop aerobic endurance and perform technical work of very high standard quality. Coaches could easily use critical speed (CS) combined with critical SR in order to control both the physiological and technical work done during training sets (Dekerle et al. 2002). The concept of a critical stroke rate (CSR) defined as the SR theoretically maintained continuously and indefinitely without exhaustion, and expressed, as the slope of the regression line between the number of stroke cycles and time, seems pertinent to use for training (Dekerle et al. 2002). Coaches should consider CSS and CSR for design of aerobic training sets and controlling swimming technique.

CONCLUSION

Swimming coaches and scientists need to assess aerobic potential and define accurately exercise intensity domains to optimise and evaluate training programs. The speed corresponding to the slope of the *d–t* relationship (S_{d-t}) in swimming cannot be maintained for a long time and is hardly tolerable. It lies within the severe intensity domain. However, while S_{d-t} is not accurately representing CSS, it does demarcate two different intensity domains. The modelling of the *d–t* relationship in swimming can be of interest to depict intensity domains and set training intensities. The training effects when swimming at and below S_{d-t} could be the focus of future investigations.

Moreover, coaches should determine where the SR and SL breakpoint occurs, i.e. MLSS, to train their swimmers to keep a constant SR and SL ratio when swimming within the heavy domain. This type of work should maintain the swimmer's SL while increasing their SR to swim faster, irrespective of the intensity domain swimmers are exercising in.

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Periodization of Training and the Choice Training Loads for Events of the High Class Swimmers

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ABSTRACT: The aim of this work was the analysis of the size and structure of the training loads in the successive cycles in the training season 2005/2006 carried out by competitors of the highest class in swimming. The research included 9 swimmers (2 women and 7 men) of high international sport level. The size and structure of the loads were analysed according to the specially prepared sheet, which was divided into two parts: information and energy sphere. The volume of work, in particular the period of micro cycle to ME in Budapest (2006) was marked. Significant differences in the volume of swimming (km) with the usage of particular training means were shown and the percentage distribution of the volume of swimming in individual energy spheres was set.

KEY WORDS: training load, swimming, periodization, training

INTRODUCTION

Planning the annual cycle of training of high class swimmers requires taking specific aspects into consideration. The preparations are subordinated to the principles of shaping the main components of the championship.

The main aims set before the beginning of the training are realized in successive cycles. The cycles of different length refer to the dynamics of various loads. In energy area (energy sphere).

Sozański and Śledziewski (1995) proposed the classification of the loads in the system outline – at present very popular – which assumes that in every organism (treated as a system) two areas exist (subsystems): information system and energy system. In the information area we can distinguish three kinds of training means. The application of these means qualifies the loads as versatile, directed and special. In energy area five levels of effort intensity were distinguished. (T_1–T_5) using physiological criteria (HR level before and immediately after effort), biochemical (lactate level in blood) and determining the time and length of the effort of the assigned intensity (Sozański 1992; Sozański, Śledziewski 1995).

Because of the specificity of the aquatic environment the selection of training loads is a very complex problem and is considered by many theoreticians and practitioners as fundamental for the theory of training. Therefore the efforts made in order to optimize them, undoubtedly expand the knowledge in this field and the practice proves its usefulness.

Planning the annual cycle of training of the first-class competitors in swimming requires taking into consideration specific aspects of preparation in this discipline, which are subordinated to the principles of shaping the main components of the championships.

According to Płatonow and Sozański (1991) methodology of the structure of the macro cycles at this stage has a specific, very often individual character, and is conditioned by many factors.

Among them we can distinguish: specific character of the discipline, preparing the competitor for the participation in the competition, individual, adaptive skills of the competitors and the level and structure of the training (Płatonow, Sozański 1991).

According to Bompa (1988) constructing the annual training plan allows one to divide individual training tasks appropriately and to arrange them in the entire training season in this way so that the development of the ability, motor and psychological features proceeds in the logical and methodological order. Thus one of the basic problems in the methodology of training is such an arrangement of the methods, forms and exercises to active the highest level of sport condition, at the time of the main competitions (Naglak 1999; Sozański 1999).

Taking all that into account, the aim of this work became the analysis of the size and structure of the training loads in successive (consecutive) cycles in the training season 2005/2006 carried out by competitors of the Polish Olympic Team in swimming. The main event in the analysed macro cycle was the European Championships in Budapest.

MATERIAL AND METHODS

The research included 9 people (2 women and 7 men) presenting a high sport level in swimming. The examined athletes have been in the Polish Olympic Team for many years. They are record holders of the country, finalists and medalists of the European championships, the world championships, and part from them also of the Olympic Games.

They are of the international master class (MM). The age of the subjects was between 21 and 24, whereas the training experience from 10 to 16 years. The size and the structure of training loads were analysed basing on the sheet prepared for this purpose which was divided into two parts. In the first sphere the participation of particular group of means of training was analytically recorded (e.g. swimming on RR, NN, with breath held, swimming with paws, swimming with flippers, and co-ordination swimming). In the second one – energy sphere – the level of intensity of the exercises performed was determined (shown in the first part) on the basis of the concentration of lactic acid in blood.

Therefore the particular tasks of each training unit were matched with the appropriate range (level) of intensity (which means: 2; 2–3, 3–5; 5–… mmol/l), considering, among others, speed of swimming, kinds of the tasks and the current level of training of the competitors.

In order to compare the results, analysis of the ANOVA–MANOVA variance was used in the 3 × 5 arrangement for the volume of swimming between particular energy spheres in the successive cycles and 3 × 10 for the volume of swimming with using particular groups of means of the training in successive cycles.

The gravity of differences was evaluated post hoc – LSD test (the least significant difference test). In the statistical analyses carried out the level of $p < 0.05$ value was accepted as essential. All the calculations were carried out with Statistica (v. 5.5, StatSoft, USA).

RESULTS

In the 2005/2006 season the three cycled structures were studied. All the competitors made the greatest volume of work in the second preparatory period (6 February – 17 May) which is given in Table 1. The main aim of this training period was gaining the optimal starting readiness during MP, which was the event qualifying to ME in Budapest – long swimming pool.

TABLE 1. The volume of work in the macro cycle individual periods

Subjects	Training periods								
	I Prep.	I Start	I Interim	II Prep.	II Start	II Interim	BPS	III Start	III Interim
	Volume of work (km)								
O.J.	305.0	0.0	15.8	794.3	14.0	37.6	572.5	30.7	0.0
P.B	640.2	316.8	12.8	900.7	12.0	37.9	569.7	23.2	0.0
P.K.	551.2	274.9	18.0	878.9	16.0	6.0	609.5	30.7	0.0
Ł.D.	602.9	295.9	18.0	831.9	16.0	13.0	592.0	30.7	0.0
S.K.	768.2	76.7	15.8	851.7	16.0	39.6	593.4	26.7	0.0
Ł.G.	830.7	28.0	63.8	696.7	0.0*	13.6	505.2	0.0*	0.0
Ł.Gi.	886.7	91.2	29.5	901.8	16.0	26.4	506.3	30.7	0.0
M.R.	730.6	14.2	12.0	827.7	16.0	26.4	622.5	30.7	0.0
M.W.	621.4	90.1	75.7	746.7	8.0	13.6	473.4	14.0	0.0

* Suspended by The Polish Swimming Association

In the first preparatory period for The Polish Winter Championship (ZMP) (5 September – 24 November) the competitors swam the average distance 733 km. Those who qualified to ME (in the short swimming pool) participated in the next phase of preparation through training and starting.

After ME swimmers were training and at the same time they started simultaneously in World Cup. They had the interim period between 27 January and 5 February, which began preparations for MP (long swimming pool). Before the main event of the season the direct sport preparation was planned (BPS) in the 29 May – 30 July.

In Tables 2–5 mean values were presented to the value of swimming (km) with the participation of individual training means and in individual energy spheres (scopes of intensity) in the next cycles. Moreover, a percentage of the general volume of work was determined in individual spheres (scopes).

In Tables 2–5 the mean values of the swimming volume were presented (km) for particular training means and individual energy spheres with the usage of the particular means (ranges of intensity) in the successive cycles. Moreover, the rate of the general volume of work was determined in the individual spheres (ranges).

In the analysed period (season) the volume of swimming (km) differed significantly with the use of particular means in each cycle (Tab. 2).

The differences on the level of gravity ($p < 0.05$) appeared also in the general volume of swimming in individual ranges of intensity (Tab. 4, 5).

DISCUSSION AND CONCLUSIONS

The analyses and the research conducted in this scope (Siewierski 2007; Siewierski et al. 2007) resulted in the conclusion that macro cycle of training of the high class swimmers usually has three cycle structure with three or sometimes two interim periods.

The time of each of the successive periods (or of average cycles) within the analysed macro cycle is diversified and conditioned among others with specificity of preparing competitors for the participation in the next competitions of the highest rank (Polish Winter Championships – 25 m, the European Championships – 25 m, the Summer Polish Championship – 50 m, European Championship – 50 m).

The research findings and their analyses lead to the following conclusions:

- In spite of the fact that absolute value of the volume of swimming (km) changed in the consecutive cycles, the percentage distribution of the general size of the loads in the scope of individual groups of means did not differ statistically ($p < 0.05$) which is shown in Table 3.
- The examined swimmers made the predominant volume of the work in oxygen scopes. The smaller volume manifested mixed and anaerobic efforts (Tab. 4).

TABLE 2. Differences in the swimming volume (km) (the average ± SD) with the use of training means during the successive cycles

Cycles	Swimming volume with the use of training means (km)									
	Developing swimming at one's own style (1)	Coordination swimming (2)	Swimming at shoulders (3)	Swimming at legs (4)	Swimming with breath held (5)	Technique development (6)	Swimming with paws (7)	Swimming with flippers (8)	Swimming with cups (9)	Tether swimming (min) (10)
I	68.0±25.1	500.8 [a] ±124.4	176.9 [ab] ±46.7	143.0 [ab] ±35.1	51.2 [bcd] ±14.6	39.6 [bcd] ±15.2	265.2[abcdef] ± 73.0	118.5 [abcefg] ±36.7	55.0 [bedgh] ±20.0	14.9 [abcdeghi] ±7.1
II	84.7 ± 9.1	519.4 [a] ±41.2	189.3 [ab] ±23.8	153.4 [abc] ±16.8	37.5 [abcd] ±3.9	46.7 [abcd] ±3.7	302.5 [abcdef] ±45.8	143.5 [abcefg] ±14.3	52.4 [abcdgh] ±7.0	42.2 [abcdgh] ±14.1
III	75.9 ± 7.3	379.9 [a] ±35.6	115.6 [ab] ±12.4	100.4 [abc] ±12.4	21.0 [abcd] ±1.2	34.7 [abcde] ±5.5	203.3 [abcdef] ±19.5	80.0 [bcdefg] ±5.9	22.0 [abcdfgh] ± 1.4	23.8 [abcdfgh] ±4.3
% of the work total volume	10.0 ±0.7	61.5 [a] ±0.9	21.11 [ab] ±0.5	17.4 [abc] ±0.6	4.8 [abcd] ±0.4	5.3 [abcd] ±0.6	33.9 [abcdef] ±1.3	15.0 [abcdefg] ±0.7	5.6 [abcdegh] ±0.8	X

The average values differ significantly between: (1) and (2), (3), (4), (5), (6), (7), (8), (9), (10); [a] $p < 0.05$; (2) and (3), (4), (5), (6), (7), (8), (9), (10); [b] $p < 0.05$; (3) and (4), (5), (6), (7), (8), (9), (10); [c] $p < 0.05$; (4) and (5), (6), (7), (8), (9), (10); [d] $p < 0.05$; (5) and (6), (7), (8), (9), (10); [e] $p < 0.05$; (6) and (7), (8), (9), (10); [f] $p < 0.05$; (7) and (8), (9), (10); [g] $p < 0.05$; (8) and (9), (10); [h] $p < 0.05$; (9) and (10); [i] $p < 0.05$

TABLE 3. Differences in the swimming volume (km) (the average ± SD) between the successive cycles with the usage of the individual training mean groups during 2005/2006 season

Training mean groups	Volume of work (km)		
	I cycle	II cycle	III cycle
Developing swimming at one's own style	68.0±25.0	84.7[a] ±9.1	75.9±7.3
Plan percentage	90.0±33.2	90.2±11.4	95.3±7.0
Coordination swimming	500.8±124.4	519.4±41.2	379.9[ab]±35.6
Plan percentage	81.3±20.3	86.7 ±4.7	95.9[a]±2.1
Swimming at shoulders	176.9±46.7	189.3±23.8	115.6[ab]±12.4
Plan percentage	79.4±21.0	84.9±7.8	98.8[ab]±8.1
Swimming at legs	143.0±35.0	153.4±16.8	100.4[ab]±12.4
Plan percentage	80.4±19.9	85.7±5.6	96.8[a]±6.3
Swimming with breath held	51.2±14.6	37.5[a]±3.9	21.0[ab]±1.2
Plan percentage	76.2±21.8	84.7±8.7	97.9[a]±3.1
Technique development	39.6±15.2	46.7±3.7	34.7[b]±5.5
Plan percentage	81.5±31.8	89.6±7.6	93.4±15.5
Swimming with paws	265.2±73.1	302.5±45.8	203.3[ab]±19.5
Plan percentage	80.8±22.3	84.8±10.6	98.9[ab]±3.8
Swimming with flippers	118.5±36.7	143.5[a]±14.3	80.0[ab]±5.9
Plan percentage	83.2±25.9	86.0±6.7	100.0[a]±4.5
Swimming with cups	55.1 ± 20.0	52.4 ± 7.0	21.9 [ab] ± 1.4
Plan percentage	79.8 ± 29.0	84.4 ± 10.2	99.6 [a] ± 7.0
Tether swimming (min)	14.9 ± 7.1	42.2 [a] ± 14.1	23.8 [b] ± 4.3
Plan percentage	87.4 ± 39.1	104.0 ± 38.4	98.1 ± 12.8
Work total volume	820.7 ± 204.0	862.0 ± 79.3	595.8 [ab] ± 59.5
Plan percentage	80.2 ± 20.2	85.3 ± 6.2	94.9 [a] ± 7.6

The average values differ significantly relative to: cycle I vs cycle II, cycle III – [a] $p < 0.05$; cycle II vs cycle III – [b] $p < 0.05$.

– Percentage distribution of the general volume of swimming in individual energy spheres (scopes of intensity) differed on the level of the statistical gravity ($p < 0.05$).

The volume of the work significantly differed statistically between cycle I and II in anaerobic scopes lactate and non lactate and between I and III as well as II and III in all the energy spheres excluding anaerobic lactate and non lactate scopes. There were no significant differences between cycles II and III.

Coaches and competitors must be aware that they face new requirements. The most important refer to raising the standard and quality of training, which means achieving the highest effectiveness. The appropriate planning and programming of

TABLE 4. Differences in the individual energy spheres during the successive cycles during 2005/2006 season

Cycles	Work volume according to the intensity levels (km)				
	Up to 2 (mmol/l)	2–3 (mmol/l)	3–5 (mmol/l)	5–… (mmol/l)	Sprint
I	70.0±17.5	478.1^{a}±108.7	239.0^{ab}±78.6	14.1^{abc}±5.7	19.5^{abc}±5.9
II	70.6±11.2	507.0^{a}±29.7	242.0^{ab}±40.2	24.7^{abc}±8.0	14.7^{abc}±5.1
III	43.8±2.4	405.5^{a}±42.0	112.9^{ab}±16.9	29.7^{bc}±3.2	4.0^{abcd}±0.4
% of the work total volume	8.1±0.7	61.2^{a}±2.0	25.9^{ab}±2.0	3.1^{abc}±0.4	1.7^{abcd}±0.5

The average values differ significantly between: up to 2 and 2–3, 3–5, 5.., sprint – $^{a}p < 0.05$; 1–3 and 3–5, 5..., sprint – $^{b}p < 0.05$; 3–5 and 5..., sprint – $^{c}p < 0.05$; 5 and sprint – $^{d}p < 0.05$

TABLE 5. Differences in the swimming volume (km) (the average ± SD) between the successive cycles within the individual energy spheres

Levels of intensity according to lactate concentration in blood (mmol/l)	Work volume (km)		
	Cycle I	Cycle II	Cycle III
0–2	70.0±17.5	70.6±11.2	43.8^{ab}±2.4
2–3	478.1±108.7	507.0±29.7	405.5^{ab}±42.0
3–5	239.0±78.7	242.0±40.2	112.9^{ab}±17.0
5–…	14.1 ±5.7	27.7^{a}±8.0	29.7^{a}±3.2
Sprint	19.5±5.9	14.7^{a}±5.1	4.0^{ab}±0.4
Σ	820.7±204.3	862.0±79.2	595.8^{ab}±59.5

The average values differ significantly between: I cycle and II cycle, III cycle – $^{a}p < 0.05$; II cycle and III cycle – $^{b}p < 0.05$

training particularly within the scope of the selection of training loads as well as the cycles conditioned by the dates of starts are the basis for high repetitiveness of sport success on the domestic and international arena.

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Influence of Swimming Pool Length on the Determination of Critical Velocity in Young Male and Female Freestyle Swimmers

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ABSTRACT: The purpose of the present study was to examine whether the calculation of critical speed and the y-intercept of the regression between swimming distance and time are influenced by swimming pool length (25 m vs 50 m). Furthermore, we examined if there was the effect of gender when critical speed and the y-intercept were calculated in two different swimming pools. Twenty-three well-trained swimmers (10 males and 13 females, mean age 14±2 years) were instructed to swim as fast as they could over five different distances (15, 25, 50, 100 and 200 m) on five different occasions. Critical speed (CS) was estimated from the slope of the linear regression line between swimming distance and time and was calculated over three distance ranges 15–50 m, 15–100 m and 15–200 m, CS values decreased significantly ($p < 0.01$) as the distance over which they were calculated increased. This was evident for both males and females. Tukey's post hoc test revealed no difference for $V_{crit}50$ between the short and the long pool for males, while the difference in critical speed between the two pool sizes increased as the distance range increased. In contrast, the difference in CS between the two pool sizes decreased as the distance range used for the calculations in females increased. The results of this study demonstrated that critical speed calculation is significantly affected by the size of the swimming pool, with faster speeds at the shorter pool and this should be taken into account when training in pools of different sizes. Also, male swimmers were shown to have a higher CS in the short pool as the swimming distance increased, while females showed the opposite trend. This may indicate that males use a greater number of turns in a short swimming pool as an advantage for faster swimming.

KEY WORDS: critical speed, swimming pool length, freestyle swimmers

INTRODUCTION

One of the most commonly used parameters for planning of training programs of high level swimmers is swimming velocity corresponding to the anaerobic threshold (Maglischo 2003). A large part of training aiming to improve aerobic fitness is performed at speeds around the anaerobic threshold and therefore the identification of the individual critical speed is necessary for the coach. Furthermore, the effectiveness of training can be assessed by measuring critical speed at certain time points during a training cycle. Different testing practices have been used to determine the appropriate speed for aerobic swimming training (Olbrecht et al. 1985). However, the concept of critical speed, i.e. the fastest swimming speed that the swimmer can maintain without fatigue, has been proved to be the simplest method for monitoring aerobic fitness (Wakayoshi et al. 1992; di Prampero et al. 2007). Critical speed is calculated as the slope of the regression line between swimming distance and time taken to cover it. The y-intercept of the regression line has been termed 'anaerobic swimming capacity' and represents the maximal distance that could be swam anaerobically (Dekerle et al. 2002). Critical speed and the y-intercept of the regression line are usually calculated from distances from 50 to 400 m that the athlete covers at maximal effort (Wakayoshi et al. 1993) but in some cases longer distances are utilized (e.g. up to 1500 m, Toussaint et al. 1998; Matković et al. 1999). One of the main advantages of this method of assessing aerobic and anaerobic fitness of swimmers is that it is non invasive and easy to perform (Wakayoshi et al. 1992, 1993; Dekerle et al. 2002; Rodriguez et al. 2003).

Swimming training and competition may be performed in both long (50 m) and short (25 m) swimming pools. The length of the swimming pool may be an important factor affecting the calculated value of critical speed and it is possible that the values of critical speed calculated from swimming in a pool of certain size may not be transferable and should not be used for training in a pool of different size. The purpose of the present study was to check whether the calculation of critical speed and the y-intercept of the regression between swimming distance and time are influenced by swimming pool length (25 m vs 50 m). Furthermore, since swimming in a short pool involves a greater number of turns compared with a long pool, we investigated if there was an effect of gender when critical speed and the y-intercept were calculated in the two different swimming pools.

MATERIAL AND METHODS

In the research twenty three (23) trained male and female swimmers participated voluntarily (males: $N = 10$, age: 14.9±2 years; height: 172.7±6.0 cm; body mass: 56.7±16.4 kg; females $N = 13$, age: 13.8±1.1; height: 162.8±9.6 cm and body mass: 48.4±6.9 kg).

Testing procedure. The swimmers trained systematically (5 days per week, at least 2 hours per day). They were informed about the aim of the research and the testing procedure and following their approval we proceeded in carrying out the test. For all swimmers (male and female) the height and weight were taken in the afternoon before a training session.

Before the performance measurements, the participants followed an 800 m warming up session. For the main trials, they were guided to swim at maximum effort five distances on five different occasions (15 m, 25 m, 50 m, 100 m and 200 m). The order of the measurements was random with 1–3 days in between.

All measurements took place in open air swimming pools of 25 and 50 m at water temperature of 26°C. For the purpose of the research all the participants swam 15 m, 25 m, 50 m, 100 m and 200 m free style at maximum intensity and the time of swimming each distance was recorded. The individual distances were measured with start up within the water and under the same conditions. The performance achieved in each distance was measured electronically (Seiko Water Resistant 10 BAR, S140).

Method of determining the critical speed. The mathematical model calculates the value of the critical speed of the distances under consideration, i.e. 15 m, 25 m, 50 m, 100 m and 200 m (Thanopoulos et al. 1994; Toussaint et al. 1998; Matković et al. 1999; Martin, Whyte 2000; Housh et al. 2001).

The way of calculating the critical speed (V_{crit}) comprised the following parameters: the time needed to swim the distances of 15 m, 25 m, 50 m, 100 m and 200 m is placed in a linear correlation of time – distance by applying the simple equation of $y = a + bx$. The standard a is the value of y for $x = 0$ and it is the y-intercept, whereas the standard b defines the slope of the line (Toussaint et al. 1998; MacLaren, Coulson 1999; Martin, Whyte 2000; Dekerle et al. 2002).

The standard a defines the initial intensity of the phenomenon examined (the variable) whereas the standard b defines the changes in the intensity of the phenomenon under study (the variable) in relation to time. This approach defines the characteristics of maintaining the capacity, i.e. the resistance of the phenomenon (variable) (Wakayoshi et al. 1992; Matković et al. 1999).

From a natural point of view, the standard of speed, that is the standard b is proportionate of the critical speed and it is the equivalent of the theoretical speed which the participant can swim without signs of tiredness (Godik 1988). It has been found that speed corresponds to the anaerobic swimming ceiling of the swimmer.

Critical speed was calculated for three different swimming distance ranges: (a) 15, 25 and 50 m ($V_{crit}50$), (b) 15, 25, 50 and 100 m ($V_{crit}100$) and (c) 15, 25, 50 100 and 200 m ($V_{crit}200$). The y-intercept (y-INT) was assumed to represent anaerobic swimming capacity and was calculated for the same distance ranges.

The intercept was taken to correspond to anaerobic swimming capacity (ASC) and represents the maximal distance that could be swum anaerobically (Toussaint et al. 1998; MacLaren, Coulson 1999).

Statistical analysis. The results are reported as mean ± SD. Differences between the parameters of the time needed to swim each distance, critical speed and the y-intercept in the two swimming pools were assessed by two-way analysis of variance with repeated measures on both factors and differences between means were located using Tukey's *post hoc* test. The level of significance was set as $p < 0.05$.

RESULTS

The times to swim all distances for males and females are shown in Table 1. For males, the times to cover the distances from 15 m up to 50 m were similar in long and short pools. However, the time to cover 100 m and 200 m distance was significantly shorter ($p < 0.01$) in the short (25 m) compared with the long (50 m) pool (Tab. 1). In females, differences in time between the two pools were only significant for the 200 m distance ($p < 0.01$).

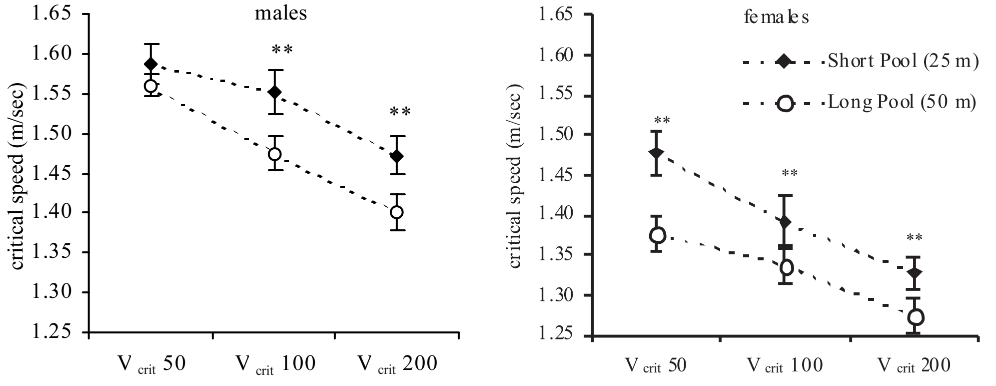
TABLE 1. Time taken to swim all distances in the short (25 m) and the long (50 m) pool for male ($N = 10$) and female ($N = 13$) freestyle swimmers. Values are expressed in seconds (sec) and are mean ± SEM. Men were faster compared to women in all distances ($p < 0.01$)

Gender	Swimming time (sec)									
	Short pool (25 m)					Long pool (50 m)				
	15 m	25 m	50 m	100 m	200 m	15 m	25 m	50 m	100 m	200 m
Males	7.42 ± 0.06	13.33 ± 0.21	29.40 ± 0.38	62.11 ± 1.00	133.07 ± 2.14	7.35 ± 0.06	13.41 ± 0.14	29.70 ± 0.25	64.81* ± 0.89	139.13* ± 2.14
Females	8.40 ± 0.15	15.39 ± 0.47	32.09 ± 0.51	69.82 ± 1.52	147.60 ± 2.11	8.09 ± 0.12	15.29 ± 0.23	33.57 ± 0.50	71.77 ± 1.28	153.63* ± 2.63

* $p < 0.01$ from corresponding distance in the short pool

The r^2 values (goodness of fit) of the linear regressions equations between swimming distance and time taken to cover it were always >0.998 ($p < 0.001$). The critical speed values calculated over the three distance ranges ($V_{crit}50$, $V_{crit}100$ and $V_{crit}200$) were always higher in the males compared with the females ($p < 0.01$). Critical speed values decreased significantly ($p < 0.01$) as the distance over which they were calculated increased (Fig. 1). This was evident for both males and females. There was an interaction between the pool size and the range of speed used for the calculation of critical speed for both males and females ($p < 0.01$). Tukey's *post hoc* test revealed no difference between $V_{crit}50$ for the short and the long pool for males, while the difference in critical speed between the two pool sizes increased as the distance range increased. In contrast the difference in critical speed between the two pool sizes decreased with the distance range used for the calculations in females (Fig. 1).

The y-intercept of the regression lines between swimming distance and time was assumed to represent anaerobic swimming capacity. No difference was found in the y-intercept between male and female swimmers for any of the three ranges of distances used for the calculations (Int50, Int100 and Int200). The y-intercept was always lower in the short pool compared with the long pool for both males and females (main effect $p < 0.01$). Furthermore, the y-intercept values increased as the distance



** $p < 0.01$ from corresponding long pool value

FIGURE 1. Critical speed (m/sec) for the three ranges of distances measured ($V_{crit}50$, $V_{crit}100$ and $V_{crit}200$) for male (left panel) and female swimmers (right panel)

used for the calculation of the regression lines increased in both males and females (main effect $p < 0.01$; see Tab. 2).

DISCUSSION

The results of this study demonstrate that the critical speed which was calculated from the slope of the linear regression line of the swimming distance and time, is differentiated according to the swimming pool length. This has very important practical applications since this parameter is commonly used to guide training and assess progress in swimming. It is noteworthy that swimming times over the distances of 15 to 50 m were similar in the long and short pools for the males, while in females

TABLE 2. Anaerobic swimming capacity expressed by the y-intercept of the regression between distance and time for the short (25 m) and the long (50 m) pool in male ($N = 10$) and female ($N = 13$) freestyle swimmers. Values are expressed in seconds (sec) and are mean ± SEM. There was no difference between male and female swimmers for any of the three ranges of distances used for the calculations (Int50, Int100 and Int200). There was the main effect of the swimming pool length ($p < 0.01$) and for the different distance ranges ($p < 0.01$) in both male and female swimmers

Range of distance	Males		Females	
	Short pool (25 m)	Long pool (50 m)	Short pool (25 m)	Long pool (50 m)
Int50	3.5±0.2	3.8±0.2	2.5±0.4	3.9±0.1
Int100	4.03±0.3	5.1±0.3	4.0±0.6	4.6±0.2
Int200	5.92±0.3	6.9±0.2	5.6±0.4	6.3±0.2

similar times were recorded up to 100 m. This shows that males possibly have a greater advantage when swimming in short compared to longer pools. These differences may depend on the greater number of turns when swimming the same distance in a shorter pool. To our knowledge, there is no evidence that males have a better turning technique compared to females. However, males are stronger than females (Blimkie, Sale 1998) and this increased strength during the push following the turn may result in greater swimming speed at the start of each swimming length. These differences in leg push-off strength may therefore provide a plausible explanation for the opposite trends of critical speed in males and females when comparing the two swimming pools and the different distance ranges (Fig. 1).

The y-intercept of the speed vs distance regression (anaerobic swimming capacity; ASC) showed the opposite trends compared to critical speed, i.e. an increase in the long compared to the short swimming pool. Although there is some theoretical basis for its use as a criterion of anaerobic fitness, most studies suggest that it is not valid and should be interpreted with caution (Toussaint et al. 1998; di Prampero et al. 2007). The results of the present study show smaller values of ASC for these young athletes compared with other studies (Toussaint et al. 1998) and this may be due to the lower anaerobic capacity related to the level of maturation of these athletes (Zanconato et al. 1993).

In summary, this study has indicated that the calculated critical speed is affected not only by the distances used to calculate it but also by the swimming pool length. This has important practical applications and would suggest that critical speed calculated from a short pool should not be used for training in a longer pool. The differences between males and females regarding the effect of pool length on swimming time and critical speed suggest that males are able to perform better than females in a short pool as swimming distance, and hence the number of turns, is increased. This may be due to the greater muscle strength and power of the leg muscles of the males that increase swimming speed after each turn. The results of this research should be verified for older swimmers.

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Relationship between the Swimming Speed and the Work Performed on the Swim Ergometer

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ABSTRACT: The swim ergometer (Swim Ergometer; Weba Sport und Medicine Artikel GmbH – Vienna, Austria) is an acknowledged device used for assessment of training effects in swimming. This work attempted at finding out if the swimming speed of the leading swimming style is related to the amount of work performed in similar movement cycles and the same time on the ergometer. It was assumed that the amount of work on the ergometer will directly prognosticate the swimming speed at various distances.

The research subjects comprised swimmers belonging to the swimming section of the Students Sport Association of the University School of Physical Education, Wrocław. All the subjects presented high sports level. In total, 13 male subjects participated in the study, of the average age – 20, height – 185.5 cm and body mass – 75.2 kg. The research was divided into two stages. In the first stage each subject swam the distance of 100, 200 and 400 m with the critical speed using his main stroke. In the second stage the subjects were expected to perform work on the swim ergometer consisting in performing movements identical to the movements in water, but only with their upper limbs (with the same leading style used for the distance of 100, 200 and 400 m) and in the same time. In consequence, an interesting relationship between the amount of work performed on the ergometer and the swimming time for particular distances was revealed. The obtained results are promising but equivocal. It seems that further research on effective methods of the training effects control should be enriched by the measurement of the physiological cost of work in water and on the ergometer.

KEY WORDS: swimming, training of swimming, Swim Ergometer

INTRODUCTION

Two phenomena characterize the development of a living organism, i.e. its growth and differentiation during development: retaining a specific structure and the structure's simultaneous change. Any analysis of an organism's state at a specific point in time provides us solely with the cross-section of the continuous process. The whole process can be divided into numerous partial processes, separated spatially from each other and taking place simultaneously or following each other in succession. Thus, for assessing the course of processes accompanying, or even constituting life, one would need a 'transverse section' in time of the complete process and the 'longitudinal section' presenting the order of succession of particular processes.

This introduction, perhaps excessively philosophical, aimed at bringing our attention to the extraordinary difficulty that the control of processes accompanying the sports training must cope with. For doing training is always only a fragment of life, thus training taking place somehow 'in the background' of life complicates it even further... Therefore, profound biological and methodological knowledge is required for performing control over the training effects. Usually, while planning the said control, one does not take into account the fact that even the very course of events, e.g. the endurance adaptation provoked by training may be of the multidirectional and multiphasic nature. Thus, in practice, diagnosis of the state rather than the course of the event is made (Zatoń 1990; MacDougal et al. 1991). This limits the value of the control and frequently leads to false assessment (Zatoń 1998). The reasons for this attitude are frequently quite trivial: most often it is the lack of funds, aversion of sportsmen or more rarely – incompetence. The so-called laboratory test batteries – applied in the specialized laboratories, may produce the endurance changes having nothing in common with the practised sports discipline and as a result create further confusion. The majority of textbooks and various studies on the endurance tests assume detailed standards, aiming at comparable measurements of particular organism traits, generally considered significant. However, as seen in the research, even appropriately frequent measurement of the traits planned in advance does not contribute much to the training control. Thus in practice, the researchers permanently search for the efficient control of the training effects, useful in planning and correcting the training. This search is usually limited to a selected group of traits and rather rarely refers to the usefulness of these traits in assessing the training effects. The trait of magical dimension in sport, indicated by almost all specialists, is supposed to be the aerobic capacity (MacDougal et al. 1991; Brooks et al. 1996; Jaskólski, Jaskólska 2005). It has already been repeatedly documented, even years before (Malerecki 1976; Astrand et al. 2003) that this highly genetically determined trait cannot be used to control the short-term training effects because it stabilizes over a few years of training and does not describe the dynamics of the adaptation changes. The concept of metabolic thresholds introduced to the literature (Costill et al. 1992), was intended for compensating the insufficiencies of control of aerobic capacity and other measurements of physiological and biochemical traits but despite of being more and more expensive and complicated, they do not add anything new or add very little to the said control. However, work of some coaches should be paid special attention to. Detailed materials about their work have provided (for many years) some excellent reflections and purely technical forms of researching the training effects that turned out efficient and suitable (even till today) for serious verification of the training effectiveness. Swimming is one of the sports disciplines where this type of research produces notable effects. Most probably, the little usefulness of laboratory tests in this sport results from the specific environment in which the training takes place. Lack of relationship between the results of the ergometric and swimming research has been documented on numerous occasions (Costill et al. 1992). Therefore, the methods of application directly connected with the activities performed exactly while swimming have been devised for many years (Vandewalle et al. 1989; Costill et al. 1992; Hill 1993).

In this work it was assumed that the ergometer designed for diagnosing the swimming efficiency may be a good tool for assessing an organism's preparation for swimming. This hypothesis would turn out trivial if we started verification of, for example, physiological traits obtained while working on this device and in water or on classical laboratory ergometers. However, the verification was more explicit: the objective was establishing the relationship between the swimming speed and the amount of work performed on such an ergometer.

Demonstrating the existence of this relationship would allow one to specify the method of complex assessment of the training effects – enabling forecasting the sports results and thus making possible the permanent (inter-training) control of effectiveness of the sports training process. For this type of ergometer is the frequently used mean of supplementary training. Thus, applying it does not bring about additional mental strain that might hinder objective assessment of the training effects.

RESEARCH SUBJECTS AND METHOD

The subjects comprised eleven male swimmers, members of the swimming section of the AZS AWF Wrocław (*Students' Sports Association of the University School of Physical Education, Wrocław*) (Tab. 1).

The critical speed test was applied in the study (Wakayoshi et al. 1992a, b; Hill 1993; Vautier et al. 1995; Pelayo et al. 1999; Dekerle et al. 2002, 2006) for three distances: 100, 200 and 400 m. The swimmers swam with their favourite swimming style. After determining the critical speed for the given distances – the measurement of the swimming time served this purpose, the efforts of the highest intensity (at the time identical to swimming the particular distances) were applied to the swim ergometer Weba Sport (Austria). The ergometer measured efforts were performed also with

TABLE 1. Age, body size and class of sportsmen participating in the research

Trait	Age (years)	Body mass (kg)	Body height (cm)	Class of sportsmen
$\bar{x}$	20.00	75.20	184.50	From MK (national champion class – second best class, in the 7-grade scale)
SD	1.24	4.71	6.78	To II (class II sportsmen – the fourth class, in the 7-grade scale)

the use of the movement co-ordination typical of the chosen swimming style. The swimming and ergometric tests were carried out with at least 7-day-long break. It means that the subsequent speed measurements were performed once a week, not more frequently, similarly to the ergometric tests. **Spearman's** rank correlation describing any **monotonic** relationship was applied to analyses comparing the speed and work performed in three trials on the ergometer. If one variable is monotonically dependent on the second one, e.g., $x_i = y_i^3$ the rank correlation coefficient between them is +1, whereas ordinary correlation produces lower results. The rank correlation has one more advantage – as opposed to Pearson's correlation coefficient – no assumptions related to the normal distribution are made here. As a consequence, it is better suited to the distributions distant from the normal distribution. Rank correlation is insensitive to the diverging elements – able to extremely disturb the result of Pearson's correlation, and these elements appeared while swimming with various swimming styles. Only one criterion was used for assessment of the statistical relevance: the level of the rank correlation coefficient (r) which exceeded $p \leq 0.05$ for $n-1$ of the degree of freedom was considered significant.

Notation:

Test I – swimming speed at the distance of 100 m

Test II – swimming speed at the distance of 200 m

Test III – swimming speed at the distance of 400 m

Erg I – work performed on the Weba Sport ergometer during the time period equal to the time of swimming 100 m

Erg II – work performed on the Weba Sport ergometer during the time period equal to the time of swimming 200 m

Erg III – work performed on the Weba Sport ergometer during the time period equal to the time of swimming 400 m.

RESEARCH RESULTS

The calculation results presented in Table 2 show that the swimming speed for 100 m is prognosticated with great accuracy using the amount of work performed in three ergometric tests. Whereas the swimming speed for 200 m is prognosticated with the ergometric test I and II and the swimming speed for 400 m is prognosticated only with the amount of work performed in the ergometric test III, i.e. during the time period equal to the time needed for swimming this distance.

In this situation, it was interesting to find out if division of work performed during particular ergometric tests into equal time segments (e.g. lasting 30 sec), in which the subjects performed the efforts in their individual rhythm, would show a relationship with the results of the swimming speed measurements. This thesis turned out possible after analysing Spearman's rank correlation coefficients shown in Table 2.

TABLE 2. Spearman's rank correlation coefficients – *r* between the work performed on the ergometer and the swimming speed during the three tests

Trait	Test I 100 m	Test II 200 m	Test III 400 m
Erg I	**0.849**	**0.795**	0.596
Erg II	**0.831**	**0.837**	0.629
Erg III	**0.826**	0.594	**0.930**

Significant rank correlation coefficients were marked in bold.

Table 3 shows the calculation results of rank correlation between the amount of work performed in the first thirty seconds of each ergometric test and the swimming speed at the so-called critical distances. It turned out that the force and extent of the relationship is greater than in the case of confrontation of the total amount of work performed on the ergometer, measured during the time defined by swimming at the specified distances. Thus, one may assume that in order to prognosticate the swimming speed, it is necessary to carry out ergometric tests lasting 30 sec and at that time measure the amount of the performed work.

TABLE 3. Spearman's rank correlation coefficients – *r* between the work performed on the ergometer during the first 30 sec of each ergometric test and the swimming speed at the three distances

Trait	Test I 100 m	Test II 200 m	Test III 400 m
Erg I (first 30 s)	**0.889**	**0.810**	**0.721**
Erg II (first 30 s)	**0.866**	**0.845**	**0.712**
Erg III (first 30 s)	**0.898**	**0.798**	**0.891**

Significant rank correlation coefficients were marked in bold.

DISCUSSION

The results of research and statistical calculations presented in this work, when the swimming speed was compared with the amount of work performed in particular ergometric tests, turned out extremely interesting. For if they are connected by a linear relationship, it means that foreseeing the swimming speed is possible thanks to a very simple index. On the other hand, it may be the way of carrying out the endurance tests, impossible to be overestimated in the process of controlling and regulating the training. It is possible that the first tests carried out with quite accidental group, representing moderate sporting level, will have to be repeated several times to obtain reliable results. Also the difference between physiological reactions to the efforts performed on the ergometer and in water may turn out interesting. It is suggested by Costill et al. (1992) and confirmed by own research (Zatoń et al. 2006). However, it is beyond doubt that as early as in the research by Zatoń (1990), Vandewalle et al. (1989) and others, it has been suggested that independently of the practised swimming distance, the training environment and the typical horizontal position create such conditions of work for an organism in which the oxygen – thus common for all swimming – ATP resynthesis paths may dominate – in a sense independently of the distance. This might explain the universal meaning of the forecasts presented above. Still, it remains to be decided, how to select the rhythm and frequency of the work performed on the ergometer, which in the research presented here was in a way a function of the planned working time, the longer the distance – the lower the intensity, i.e. the frequency of movements powering the ergometer, thus lower the instantaneous power. Perhaps to a greater extent it is the result of individual algorithmization of swimming activities which is suggested by some researchers dealing with assessing the technique (Pelayo et al. 1996, 1998). This issue remains open and requires further research. It is beyond doubt, however, that confirming results presented in this work with a larger group of swimmers, of higher level of sports proficiency, might start a new stage in controlling the training effects. For it may be assumed that performing the endurance tests outside water will enable applying any physiological devices and will create better conditions for more complicated and thanks to that thorough observations.

CONCLUSIONS

1. The relationship between the work performed on the swim ergometer and the swimming speed measured for the distances 100, 200 and 400 m shows the possibility of prognosticating the latter one on the basis of the ergometric tests.
2. The strong relationship between the work performed during the first thirty seconds of each ergometric effort and the swimming speed for all tested distances (100, 200 and 400 m) may suggest a unique universality of the endurance tests carried out in this way and indicate the possibility of using them to a wider degree, for example to the physiological control of training effects, which would facilitate their implementation.

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PART FOUR

EXTERNAL FACTORS ASSISTING IN TRAINING PROGRAM

Factors Deciding about Choosing Early School Sport Specialisation in Swimming

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ABSTRACT: Sport is one of the most popular forms of physical activity pertaining to three domains: play, study and work. It engages motor activity as well as intellect and emotions, therefore children find it so attractive. The basic research problem stated in the study is to identify the factors which decidedly indetermined the choice of swimming as the future sport specialisation in terms of 4–6 grade primary school children as well as whether those factors had any impact on the results in swimming. The research was carried out by means of the opinion poll method and application of a questionnaire as the research tool. In order to measure sports achievements, the results of swimming 100 m medley in 25 m pool were analysed and calculated into points according to multidiscipline contest swim tables for each of the examined children.

Among the factors which influenced the choice of early school sport specialisation the children enumerated: pleasure of practising swimming and contact with their sports school class. For their parents, however, the most important factor was fitness training. The only statistically significant factor chosen by children, correlating with sports result, is the pleasure of practising swimming.

KEY WORDS: swimming, school sport, motivation

INTRODUCTION

It is impossible to overestimate the values implied by even basic physical activity. It is an inseparable part of regular human existence. One of the example can be sport in its institutionalised form – practised in sports clubs or, considering children and youth – taken at schools. It has long been known that physical activity contributes to positive development of various mental qualities, social behaviours, motor skills, and improves physical efficiency and health. It contains elements of dynamics and changeability, fully engaging motor skills, intellect and emotions of a child.

Sport is an activity included in three domains: play, study and work. Children and youth sports activity is the first stage of long-time contestant training. Thus, this stage, often called the stage of comprehensive contestant preparation, has its defined place in the system of sports championship development; whose long-term aim is ‘the development of the highest sport dispositions parallel to increasing abilities of biological body potential, reaching its highest point in adulthood’ (Sozański 1999).

The coach leading the training in this period of contestant’s development should head towards applying rules concerning health, education, up-bringing and, first of all, physical and mental development. However, the practice shows that even the most engaged trainer can encounter difficulties in shaping the future sportsman if the parents support is not provided. Therefore constant parents, coach and contestant co-operation creates optimal conditions for leading the training process.

The most frequent reasons for taking up sports training confirmed by research, many scientists and experienced trainers are:

– need for entertainment and pleasure as well as stimulation expressed by movement, competition and having fun in peers company,
– the need to experience one’s self-esteem in terms of physical activity, ability, competence, achievements and success (Czajkowski 1989),
– the desire to succeed, to achieve certain social position, affiliation and self-development (Mroczkowska 2000).

Motivational and emotional processes constitute inseparable part of sports activity, accompanying the contestant during the training and in the start period. We observe the influence of those processes on the contestant, both, in professional as well as school sport. These processes organise, steer and stimulate activities of the nervous system in the way that the steered activity achieves goals defined by motives, where the latter are experiences stimulating the human to act or either supporting, being conductive to or disturbing it (Sankowski 2001).

The literature indicates existence of two kinds of motivation: external and internal, where the internal one is more significant for majority of sportsmen. Internal motivation makes the training an intentional act directed at self-improvement and achieving high sport results. Intrinsic motives in sports activity are expressed through excitement, joy, willingness to act, present and improve ones achievements; they also affect contestants’ emotions. Development of the intrinsic motivation leads to the situation where the contestant finds pleasure and satisfaction in training and he or she will eagerly come back to each training. Other factors prompting to take up sports activity can be: expecting to improve one’s fitness or sports results, being aware of the training importance and feeling of responsibility resulting from it, chance to succeed and be rewarded (Sankowski 2004). The prize, trophy as well as non-material benefits like fame, social position, podium place, all these are manifestation of the external motives (Jarvis 2003).

In the light of the above statements the problem of premises convergence having impact on the choice of the early school sport specialisation in swimming becomes significant.

The aim of the present study is to identify the factors which considerably influenced the decision of choosing swimming as the future sport specialisation.

In order to verify the aim of the study the following research question has been introduced:

Which factors decided about the ultimate choice of early school sport specialisation and did they have any impact on the sport results?

Research methodology. Seventy-eight students attending one of Wrocław primary schools, 4–6 grade of sports profile class as well as their parents took part in research. Selection of the research group came from the fact that swimming, as an early development discipline, requires taking a decision as to when to begin swimming trainings right after completing the stage of early school education.

The scope of training hours: 4 grade – 8 hours per week on average, 5 grade – 12 hours per week, 6 grade – 16 hours per week, all swimming lessons carried out by certified swim teachers having either a licence of the swim trainer or swim instructor.

In order to justify the aim of the study the research was carried out with the usage of the opinion poll method, applying questionnaire as a tool. The questionnaire for children contained 3 half-open questions with a set of ready answers. The respondents were to rank each answer, choosing one position on the 1–5 numerical scale. The questionnaire for parents consisted of similarly built 3 half-open questions. The time for filling the questionnaire was unlimited.

In order to measure swimming achievements, the results of swimming 100 m medley in a 25 m swimming pool were collected and calculated into points according to multi-contest swim tables for each of the examined children. The authors of the study are convinced that the chosen distance is the most suitable to reveal the general contestant's versatility in this age category.

Analysis of the results. The collected research data were analysed and the average of the most frequent answers was calculated. Also, the correlation of children's and parents' choices with the swimming results was the subject of calculation.

The effects of the analysis show that among the most frequently pointed factors are sheer pleasure of practising sport and contact with colleagues from the same school sports class (Fig. 1). The second place took parents' command to practise sport, and the opportunity to remain in touch with friends during sports contests.

For the parents, though, the algorithm of reasons looked a little differently (Fig. 2). They did share the view that the most significant reason of attending sports class was fitness improvement, children's physical and mental development was identified on the second place along with the possibility of taking up physical activity. Further positions were taken by such factors as sheer pleasure of practising swimming, organised time and contact with classmates. Achieving masterly sports results by their children was ranked as the least important.

The correlation of reasons for taking up learning in a class of sports profile with the sports results points out explicitly that the only statistically significant motive is the pleasure of practising swimming (Fig. 3). This truism confirms previous research related to the area of intrinsic motivation in sport. Only those who take pleasure in training and taking part in sports competitions are able to achieve high results.

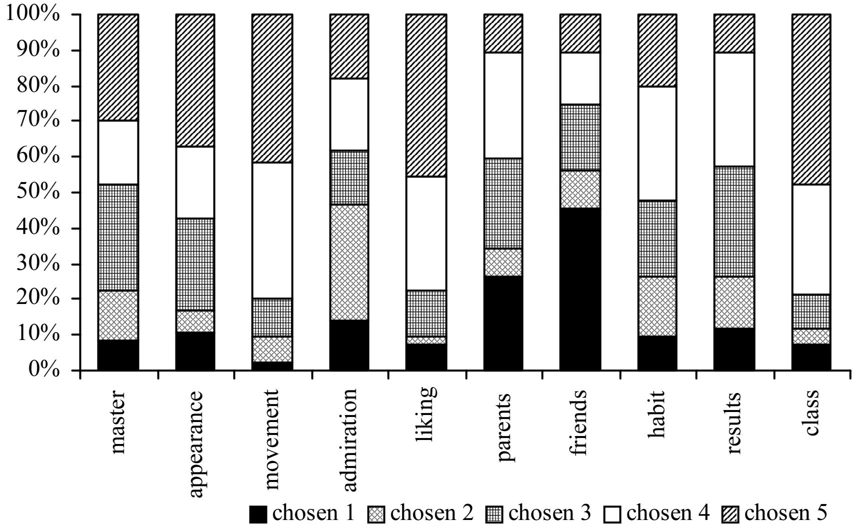

FIGURE 1. Scale of subjects' choices for each of the enumerated factors deciding about choosing sport specialization

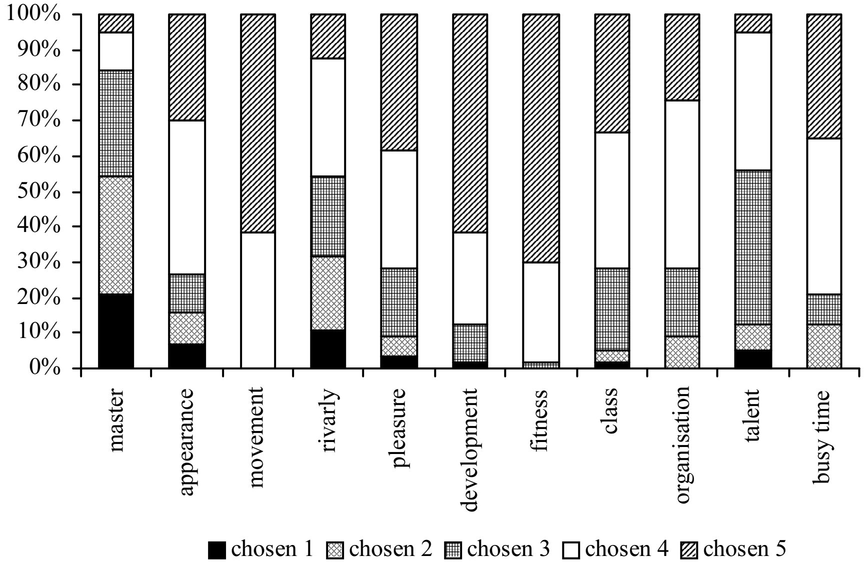

FIGURE 2. Parents' opinions on the reasons of attending sports class

The results presented allow us to conclude that no correlation between parents' choices and their children sports results was observed. Moreover, it is worth stressing that parents pointed talent to be the most significant factor of taking up learning in a class of sports profile.

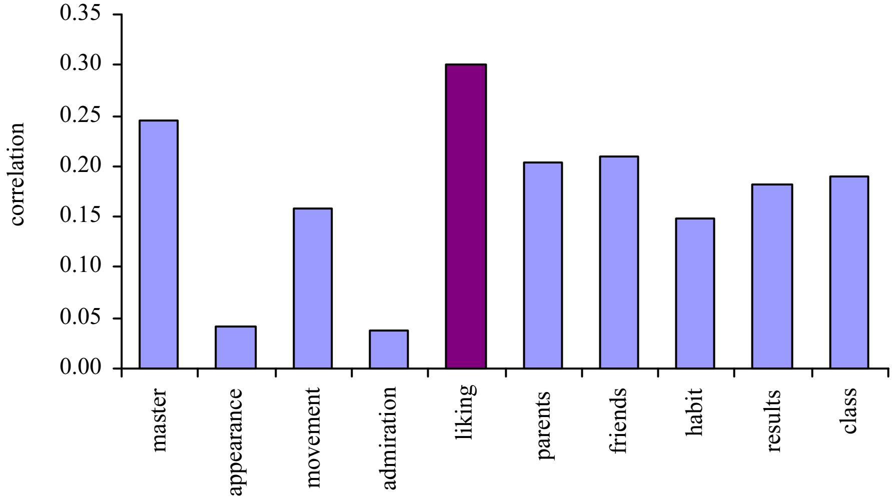

FIGURE 3. Correlation of declared factors and sports results of the examined children

SUMMARY AND CONCLUSIONS

In the research carried out by Ashford (1993) among children at the age of 11–15 the main motive of practising sport were intrinsic factors but also the desire of being part of a team and the need of achievements. Daley and O'Gara (1998) who studied motivation of British high school students presented similar results. Raszewska (2005), on the other hand, reported results of her research done among 13–15 years old students, whose strongest motivation was care of physical appearance and health followed by championship, staying in good shape and pleasure.

If the sport of children and youth was a challenge for them (providing enjoyment, ensuring realisation of chosen goals, mobilising to improve their own achievements, and to take up creative activity), the level of internal motivation would grow, shaping the attitude towards sport of the individual.

The present authors believe that it is the internal motivation where the positive social and educational influence on the contestant should be looked for and in prospect – improvement of sport results and continuation of sports career in later years.

It must be mentioned too, that among the parents the choice of sport class was not connected with the thought about high sport results and championship. For many parents sport is the educational and up-bringing instrument, shaping a child's personality, showing how to deal with difficulties and weaknesses, as well as developing conscientiousness.

On the basis of the research results the following conclusions can be drawn:

1. Pleasure of practising sport and contact with their sports class were the factors pointed by children, which influenced the choice of taking up the early school

sport specialisation. For the parents, however, the most important factor was shaping and improving fitness of a child.

2. The only statistically significant factor chosen by children correlating with their sport results is the pleasure of practising sport.
3. Among the factors declared by parents there were no statistically significant correlations with their children results.

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Effect of the Fast-Skin Swimsuit on Iranian Elite Swimmers' Performance

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ABSTRACT: Twenty-four male and female elite swimmers of an average age of 17.25±1.92 years, weight of 57.75 ±4.49 kg and height of 166.75±4.63 cm swam 50 and 200 m trials with and without Fast-Skin at approximately 80–100% of maximal effort (to control intensity, blood lactate and heart-rate was measured) in four swimming styles. In 400 m freestyle swimming, traditional swimsuit compared with shoulder-to-ankle (SA) and shoulder-to-knee (SK) of Fast-Skin.

According to the obtained results, it was evident that swimming record of all events followings the use of Fast-Skin decreased. But no significant decrease was observed in 50 m females' breaststroke and males' front crawl and butterfly. In addition, even for males, there was a different significant effect between SA and SK. The Fast-Skin had a different significant effect on speed and semi-endurance swimming. Bearing in mind the results, for females using SA especially in speed front crawl and semi-endurance butterfly and SK for endurance freestyle swimming and for males using SA in speed backstroke, semi-endurance front crawl and endurance freestyle swimming are recommended.

KEY WORDS: Fast-Skin, drag, four swimming styles

INTRODUCTION

There have been great efforts in the recent years to improve swimming performance and setting new records. These include measures directed towards identifying factors which influence skill, conducting specific physical fitness training, improving swimming techniques, employing sports psychologists for swimming teams, in addition to using new facilities and equipment (Sanders et al. 2001). In this regard, methods and measures such as shaving head and body's hair and using special swimming caps for the purpose of reducing swimming records can be mentioned (Toussaint et al. 2000). In 2000 Sydney Olympic games, the use of Fast-Skin as a method for improving records was officially begun and this attracted many coaches and swimmers' attention (Rushall 2000). Manufacturers of such swimsuits claim that these clothes can reduce drag on the resisting force of water facing the swimmers and therefore result in swimming performance with the end consequence of setting new records. In year 2001, Speedo company presented a swimsuit named 'Fast-Skin' and claimed that this product can lead to setting better swimming records by decreasing the drag force by 7.5% which translates to 1 or 1.5 sec decrease in swimming record of 100 m distance (Sanders et al. 2001). However, Toussaint reported that using the Fast-Skin swimsuit can only decrease the drag force by 2% (Toussaint et al. 2002). The result of researches conducted by others indicates that the decreasing effect of wearing these types of swimsuit is more pronounced when passive comparing to the time of being active (Benjanuvatra et al. 2001). The more a swimmer spends time in gliding, the more effective the swimsuit using can be. Thus, it is expected that in breast stroke, the swimsuit should be recommended since 10% of the entire time, the swimmers spend on gliding (Cappeart 1997). But, such assumptions were not confirmed by Benjanuvatra (Benjanuvatra et al. 2002). Bergen showed that contrary to this speculation, wearing breast stroke swimsuit had a negative effect on the swimmer's performance and increased swimming record time (Bergens, Rushall 2001). A review of the literature in regard of these swimsuits reveals that insufficient evidence exists to support firmly the advantage or disadvantage of employing them in competition. There are numerous studies that reveal no significant decrease in swimming record due to wearing such a swimsuit. Therefore, new research is needed to examine whether using these swimsuits has any significant effect on improving swimming records and in case there is such an effect, which of the four swimming styles benefits more. More specifically, the purpose of this research was to evaluate the effect of these swimsuits on improving the performance time of Iranian elite swimmers.

MATERIAL AND METHODS

The study involved 24 male and female elite swimmers of average and standard deviation age of 17.25±1.92 years, weight of 57.75±4.49 kg and height of 166.75±4.63 cm. The subjects were asked to participate in four swimming styles events at 50 m (speed) and 200 m (semi-endurance) distance at 80 to 100% maximum oxygen consumption which was monitored through the swimmers heart rate and blood lactate level. The subjects were requested to complete the events on two different occasions, one with wearing an ordinary swimming swimsuit and another with wearing the Fast-Skin swimsuit produced by Speedo Company.

Prior to the conducting of recording time for each participant, the swimmer engaged in warm-up swimming exercise covering a distance between 1000 to 1500 m at light intensity. In order to control the testing condition, all recording was carried out at a definite time, between 11 and 13 at a swimming pool 25 m long, at the temperature between 26 and 28°C. The recording time for each swimmer began by the sound of a whistle. Three examiners simultaneously recorded the performance time by independent hand timers and the average of these three records was used as the recorded time for each swimmer. To decrease data noise, the subjects were asked to use identical starting at all recording events (with and without Fast-Skin), the swimmers in the backstroke and breaststroke were recommended to use saltu return. In each event, six trials – three for the ordinary and three for the Fast-Skin swimsuits were used. In another part of this research, in 400 m free style, the ordinary swimsuit with shoulder-to-knee (SK) and shoulder-to-ankle (SA) of Fast-Skin models were compared. Kolmogrove-Smirinov test was used to check the normality of the swimming scores. In addition, descriptive statistics was employed to calculate the index of central tendencies and dispersions. Inferential statistical tests including the dependent t-test to compare the within group variation prior and after swimming records in addition to analysis of variance (ANOVA) to compare inter-group variations was used. All significant levels were set to $\alpha = 0.05$. Where significant differences were observed, Benferroni post hoc test was used to locate the differences at $\alpha = 0.008$ and 0.016.

RESULTS

Swimming records of all four speed events prior and after the use of Fast-Skin are presented in Table 1. It is evident that swimming records of all events followings the use of Fast-Skin decreased compared to the record of the swimmer before using them. These decreases for males and females were 5.66 and 0.50% in crawl, 4.67 and 2.06% backstroke, 0.90 and 1.72% in backstroke and 4.09 and 0.52% in butterfly swimming. The most pronounced effect for wearing Fast-Skin was observed in female swimmers in crawl event (5.66%) and the least effect was present for breaststroke events (0.90%). Such a condition in male swimmers was observed in backstroke (2.06%) and crawl events (0.50%).

Table 2 demonstrates the swimming records of swimmers prior and after using the Fast-Skin. In four events, the records of the swimmers decreased following the use of Fast-Skin compared to the swimming record without the use of them. These decreases in male and female swimmers were 2.61 and 5.54% in crawl, 2.77 and 1.47% in backstroke, 0.59 and 2.85% in breaststroke, 3.14 and 4.43% in butterfly respectively. The results of the analysis of dependent t-test revealed that using Fast-Skin significantly lowered the swimming record of male and female swimmers in 200 m distance in all four events ($p < 0.05$). The highest effect of using Fast-Skin was observed in 200 m events in female swimmers in butterfly (3.14%) and the least effect was noticed in breaststroke (0.59%). This condition was present in male swimmers in crawl (5.54%) and backstroke (1.47%) event.

TABLE 1. Central tendency and variability statics of fast four swimming styles records and the Fast-Skin effect comparison by paired samples t-test in 0.05 level of significance

Swimming styles	Subject	Fast-Skin suit	Mean (deviation standard)	Range	T value	P value
Front crawl	female	without	33.76 (0.44)	0.87	9.72	0.01*
		with	31.85 (0.13)	0.31		
	male	without	29.63 (0.16)	0.25	2.98	0.1
		with	29.48 (0.23)	0.45		
Back-stroke	female	without	36.57 (0.37)	0.75	41.75	0.001*
		with	34.75 (0.33)	0.45		
	male	without	37.29 (0.23)	0.66	10.43	0.01*
		with	36.52 (0.26)	0.52		
Breast-stroke	female	without	39.97 (0.32)	0.62	4.27	0.051
		with	39.61 (0.34)	0.90		
	male	without	37.07 (0.57)	0.68	71.81	0.000*
		with	36.43 (0.44)	0.88		
Butterfly	female	without	36.22 (0.43)	0.87	15.49	0.004*
		with	34.74 (0.39)	0.68		
	male	without	30.49 (0.34)	0.74	2.65	0.118
		with	30.33 (0.40)	0.77		

* shows significant differences in 0.05 level

The results of the variance analysis revealed that using Fast-Skin significantly decreased the swimming records of both male and female swimmers in speed and semi-endurance swimming events ($p < 0.05$), this difference in performance record is presented in Table 3.

The results of Benferroni t-test at the significant level 0.008 presented in Table 4 indicated that the difference in 50 m distance for swimming events for female swimmers could be attributed to the effect of wearing Fast-Skin in butterfly versus backstroke and breaststroke, and front crawl versus breaststroke. Males manifested similar differences and additionally for backstroke and front crawl. Also, the difference in 200 m swimming distance in female swimmers can be attributed to the divergence related to the effect of wearing these swimsuit on their breaststroke record with front crawl and backstroke and butterfly with backstroke and breaststroke swimming record. In male swimmers, the difference in swimming record due to wearing the swimsuit was between the backstroke event versus crawl and butterfly records.

TABLE 2. Central tendency and variability statics of semi-endurance four swimming styles records and the Fast-Skin effect comparison by paired samples t-test in 0.05 level of significance

Swimming styles	Subject	Fast-Skin suit	Mean (deviation standard)	Range	T value	P value
Front crawl	female	without	152.85 (0.76)	1.51	11.19	0.008*
		with	148.86 (0.47)	4.06		
	male	without	162.04 (2.03)	0.94	31.55	0.001*
		with	153.05 (2.00)	3.96		
Back-stroke	female	without	170.99 (0.32)	0.65	54.66	0.000*
		with	166.26 (0.04)	8.03		
	male	without	184.89 (2.76)	0.73	5.59	0.031*
		with	180.33 (2.49)	4.75		
Breast-stroke	female	without	184.50 (0.47)	0.94	6.14	0.025*
		with	183.42 (0.73)	4.19		
	male	without	191.73 (2.13)	1.34	8.71	0.013*
		with	186.25 (1.73)	3.28		
Butterfly	female	without	171.80 (0.50)	0.95	99.02	0.000*
		with	166.40 (0.50)	4.43		
	male	without	192.80 (2.22)	0.99	22.79	0.02*
		with	184.24 (2.35)	4.62		

* shows significant differences in 0.05 level

In Table 5, the record of swimmers in endurance event (400 m crawl) in three types of swimsuit is presented. As can be seen, the record of swimmers following the use of SK and SA compared to other condition where no Fast-Skin was used decreased. This decrease during the use of SK in female and male swimmers was 2.38% and 2.94%, respectively. In addition, during the time of wearing SK versus SA, the decrease in female swimmers was 0.98% but 3.2% increase in male swimmers record. The highest effect in female swimmers was observed during the use of SK Fast-Skin (2.38%) and in male swimmers this effect was found during wearing SA Fast-Skin (5.94%). Also, wearing various Fast-Skins resulted in different effects on swimming performance at endurance event (400 m crawl).

These effects were found by using ANOVA and Benferroni *post hoc* test. At the significant level of 0.016, indicating that the difference between the performances of male versus female swimmer was due to wearing ordinary swimsuit compared to SK and SA Fast-Skin. In addition, there was a difference between the performance of male swimmer using special SK and SA swimsuit.

TABLE 3. The mean differences comparison of fast and sub-endurance four swimming styles records by ANOVA test in 0.05 level of significance

Swimming type	Subject	Source	Sum of squares	Variance	F value	P value
Fast (50 m)	female	between groups	32.54	1.52	52.95	0.000
		within groups	1.01	0.04		
		total	33.55			
	male	between groups	1.04	0.35	52.95	0.000
		within groups	0.05	0.01		
		total	1.09			
Semi-endurance (200 m)	female	between groups	32.54	10.85	85.62	0.000
		within groups	1.01	0.13		
		total	33.55			
	male	between groups	43.62	14.54	15.06	0.001
		within groups	7.72	0.97		
		total	51.35			

DISCUSSION

The main purpose of the present research was to determine the effects of wearing Fast-Skin on male and female Iranian elite swimmers. The result of the data analysis revealed that using Fast-Skin significantly decreased swimming records of the swimmers in all four swimming styles events in various distances (50, 200 and 400 m). However, this decrease was not significant in 50 m breaststroke for female swimmers and 50 m crawl and butterfly events for the male swimmers. This finding in this part of the analysis was similar to the findings of Bergens and Rushall (2001) reported earlier in regard to crawl and butterfly events, whereas, the findings for breaststroke event did not support the results of this researcher in respect of breaststroke event. The discrepancy of findings in this part can be attributed to the method of return in 50 m backstroke and breaststroke used in the present study. The results of the research in regard to wearing Fast-Skin in endurance swimming event are in agreement with those reported by Cordain and Kopriva (1991) and the result in crawl event with Fast-Skin confirmed the research by Toussaint et al. (2002). On the contrary, the results in this regard did not confirm the result of the study reported by Roberts et al. (2003) who concluded that using Fast-Skin had no significant effect on free style swimming at sub maximal level. This conflicting finding may be attributed to the difference in the intensity of swimming activities. The results of the data analysis also demonstrated that wearing Fast-Skin resulted in the highest improvement of swimming record in all type of events in 50 m events of female swimmers for crawl (5.66%) to breaststroke (0.90%). However, the effect was not statistically significant for 50 m breaststroke. The change

TABLE 4. Results of Benferroni test define the significant mean differences in fast and sub-endurance four swimming styles records in 0.008 level of significance

Swimming style		Front crawl	Backstroke	Breaststroke	Butterfly
Fast (50 m)	front crawl				
	backstroke	*			
	breaststroke	* ☼			
	butterfly		* ☼	* ☼	
Semi-endurance (200 m)	front crawl				
	backstroke	*			
	breaststroke	☼	☼		
	butterfly		* ☼	☼	

☼ is related female, * is related male

of record for male swimmers following the use of Fast-Skin was most noticeable in backstroke (2.06%) and least present in crawl (0.50%). The decrease in swimming record of 50 m butterfly and crawl was not significant. The possible cause for this result in 50 m breaststroke of female swimmers could be attributed to the limitation imposed on knee joint due to the Fast-Skin (SA) and lack of habituation in using the Fast-Skin (the female swimmers in this research used the Fast-Skin for the first time). The most pronounced effect in all swimming events for female swimmers using Fast--Skin was observed in butterfly swim as high as 3.14% and the least effect was recorded in breaststroke which was approximately 0.59%. But, in male swimmers, the highest effect due to using the Fast-Skin was recorded for crawl swim which was 5.54% decrease and the least effect was noticed in backstroke swim which was 1.47%.

The results of the analysis in regard to comparison the effect of wearing SK and SA indicated that the records of swimmers following the use of such swimsuit significantly decreased. This decrease in female swimmers following wearing SA and SK was 2.38 and 1.42%, respectively. However, the difference in result while wearing SK versus wearing SA was 0.98% which was not statistically significant, whereas, such a decrease for a male swimmer wearing SK versus SA was 2.94 and 5.94% which was statistically significant. The result of this research for female swimmers did not support the findings of Mollendorf et al. (2004) who concluded that wearing SA is more effective than wearing all other types of swimming whereas the results for male swimmers were in agreement with those reported by this author. The reason for such a discrepancy may be attributed to the swimmers' gender, since roughness and softness of skin and hair covering the skin surface in the two gender is different. Therefore, it seems that SA has more beneficiary effect in male swimmers.

The reason for including the SK and SA of Fast-Skin in this study in endurance event (400 m) was to test the assumption. Some elite international swimmers claim that wearing SA at distances exceeding 200 m imposes excessive load on them and

TABLE 5. Central tendency and variability statics of using swim suit types in 400 m freestyle swimming and the effect comparison of them by ANOVA test in 0.05 level of significance

	Swim suit type	Mean (SD)	Range	Sources	Sum of squares	Variance	F value	P value
Girls	normal suit	322.23 (0.97)	1.90	between groups	89.01	44.50	52.54	0.002
	SK suit	314.57 (1.07)	2.12	within groups	5.08	0.85		
	SA suit	317.67 (0.67)	1.34	total	94.09			
Boys	normal suit	328.58 (1.26)	2.41	between groups	573.91	286.95	141.40	0.000
	SK suit	318.92 (1.65)	3.15	within groups	12.17	2.03		
	SA suit	309.03 (1.31)	2.85	total	586.10			

TABLE 6. Results of Benferroni test define the significant mean differences of using different swim suit types in 0.016 level of significance

Swim suit type	Normal suit	SK suit	SA suit
Normal suit	–		
SK suit	* ☼	–	
SA suit	*	* ☼	–

☼ is related female, * is related male

leads to impairment of their performance. This may be one logical explanation for the superiority of SK versus SA in female swimmers. The results of the analysis of comparing the records of swimmers in speed, semi-endurance and endurance event following the use of Fast-Skin indicated that the records at 50, 200, and 400 m distances decreased. These results also indicated that the effect was more pronounced in speed versus semi-endurance and endurance events, however, for male swimmers, the effect of Fast-Skin was more in endurance event versus semi-endurance and speed swims. One possible explanation is that the form of waves can have an important effect. The form of waves has a direct effect on propelling force (McGinnis 2004). Generally, in low speeds, the form is layer like, whereas in high speed, the form changes to turbulent type (Mortimer, Beckerle 2005). Even though, there is insufficient research in this area, and further research seems to be needed, but there is the possibility that the type and the condition of distribution of adipose tissue in body (gender difference), in addition to the speed influence the form of wave and consequently change the propelling force. Finally, it is suggested that the form of currents surrounding the swimmers (layer and turbulent type) be the subject of further research and the effect of wearing swimsuit be evaluated under such circumstances. In addition, it is suggested that exercise physiologists pay closer affection to the possible alteration of muscle fiber activation due to wearing these outfits. Finally, the effects of wearing these swimsuits in short distance competitions (25 m) versus longer distances (50 m long pool) are recommended.

CONCLUSION

The results of this study demonstrated the effectiveness of wearing Fast-Skin in all types of swimming events at various distances. Also, the effect of wearing these swimsuits, SK versus SA, was shown in endurance swimming. Although the results of this study showed that the swimming outcomes of all four events decreased due to the use of Fast-Skin. However, the decrease in 50 m breaststroke in female swimmers and 50 m of crawl and butterfly of male swimmers was not statistically significant.

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Motivation of Young Swimmers of Both Sexes

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ABSTRACT: The main aim of the paper was to look for dependences between sex, sport experience and motivation to practise swimming. Fifty-seven people (28 girls and 29 boys) who practice swimming at Szkoła Mistrzostwa Sportowego and KS Jordan, Kraków, were examined. Terry and Fowless motivation questionnaire (1985), adapted by Sterkowicz was used as the research tool. In the statistical report, calculations of mean values with range correlation for the motive hierarchy were used. In the two-factor ANOVA correlation with interaction, sex (K, M) and training time (shorter 'S' ≤ 6 years; longer 'L' > 6 years), were independent variables, whereas swimming motives made up dependent variables. These included: 1) Excellence, 2) Affiliation, 3) Stress, 4) Independence, 5) Power, 6) Extrinsic success, 7) Intrinsic success, 8) Health and fitness, 9) Aggression. In all the cases the values of the motives of older swimmers, with a longer training time were higher than in the case of the younger ones, which proves a larger importance of motivation among more experienced swimmers of both sexes.

KEY WORDS: practising swimming, motivation, diversities

INTRODUCTION

Practising any sport is always accompanied by motivation to do it, usually connected with the specific character of the discipline. Motivation is one of the most vital factors influencing the decision of practising any sport. Further, motivation also influences the development of the sportsmen and their sports achievements. The key factor in the motivation to practise a sport is understanding sportsmen's needs and helping to fulfil them (Czabański 1998). "Motivation in sport comes from two basic sources. One of them is located in human biological structure and the other operates on the principle of double intensifying, using the 'lure' of sport ideals and effects of being fit. These two basic sources are processed by an 'individual' filter of personal and situational conditions, thus creating specific motivation for achievements" (Kosińska 1991). 'The motive in sport is a timeless and extra situational and individual readiness to act intentionally in sports situations. Motives in sport are current cognitive (e.g. waiting, evaluation) and emotional (e.g. hopes, fears, joy, disappointment) processes, which appear before, during and after sports activities' (Röthing

1983). Numerous tests show that a large number of different factors attracts people to active practising sport and these include mainly ambition, i.e. a desire to be successful and to show one's value (Czajkowski 1989), winning social applause, the pleasure which exercise and effort give, love for a specific sport, health reasons, keeping fit, social reasons and fulfilling different (often not realized) psychological needs, such as dominance, aggression, friendship or acceptance, etc. Wankel and Kreisel observed (1985) that the sources of motivation in sport are the following: 1) internal factors, i.e. joy from practising sport, personal achievements, acquiring new skills, 2) social factors (being in a team, being with friends) were slightly less valued, 3) external factors, results and effects of sports activity, winning, winning a prize, giving pleasure to others (coach, family, friends) were placed at the end. After examining a large group of top sportsmen, Nawrocka (1984) discovered the following motives: 1) a desire to be successful, showing one's value, fulfilling one's ambition, achieving social applause (51% of the examined), 2) a necessity of active way of life and the pleasure connected with it (25%), 3) a need for the activity of a given sport and overcoming its difficulties (16.4%). Also, other motives, such as health reasons, aesthetic experiences and material gains appeared. According to Scanlan and Lewshwaite (1986) martial arts are chosen because of aggressiveness, competitiveness, a need for achievements, recognition and social status, a desire for self-improvement and improving one's fitness and ability. In the case of ice hockey (Atkinson, Feather 1984) the main motives were: a need for social acceptance, being in a group, a need for friendship. Also, the following appeared: a need for one's excellence (competence), a stress (stimulation, tension), a need for achievements (recognition), aggression (dominance), a need for power (the possibility of leading others) and a need for independence (the possibility of independent activity).

From the above studies it can be seen that most often the success is the main and direct aim of sports activity. On the other hand, practising sport as such, as one of the equal forms of human self-fulfillment means accepting not only advantages but also hazards which result from its practising. Therefore people who practice sport professionally and want to be better than others or exceed their own limitations incur a certain risk (loss of health) resulting from practising a given sport (Grabowski 1999).

THE AIM OF THE PAPER

The main aim of the paper was to look for dependences between sex, sport experience and motivation to practise swimming. The basic research questions were: What kind of motivation is the most important incentive to make swimmers practise regularly and if the training time is a factor which differentiates the swimmers in terms of their motives?

MATERIAL AND METHOD

Fifty-seven people (28 girls and 29 boys) who practice swimming at Szkoła Mistrzostwa Sportowego and KS Jordan, Kraków, were examined. Training time and age correlated highly ($\delta = 0.89$; $p < 0.001$) and were connected with the sports class of the subjects ($\delta = -0.49$ and $\delta = -0.48$; $p < 0.001$). It was assumed then that age (from 13 to 19), training time (from 3 to 10 years) and sports class (from 3 to 1) could be treated as experiment factors. No diversities between sexes were noticed among the variables mentioned above.

Terry and Fowless motivation questionnaire (1985), adapted by Sterkowicz was used as the research tool. The meaning of 27 statements, each introduced by 'I practise swimming because…' was evaluated. The answers on a scale from 0 (unimportant) to 10 points (very important) were grouped in 9 motives according to a special key. In the statistical report, calculations of mean values with range correlation for the motive hierarchy were used. In the two-factor ANOVA correlation with interaction, sex (women 'W', men 'M') and training time (shorter 'S' ≤ 6 years; longer 'L' > 6 years), were independent variables, whereas swimming motives made up dependent variables. These included: 1) Excellence, 2) Affiliation, 3) Stress, 4) Independence, 5) Power, 6) Extrinsic success, 7) Intrinsic success, 8) Health and fitness, 9) Aggression.

RESULTS

When trying to answer the main research question, detailed analyses of the correlation between the variables: sex, age and training time, and swimmers' motives to do this discipline were done.

a) **Profiles and hierarchy motives among male and female groups**
   Figure 1 shows motivation profiles in sub-groups according to sex.
   As can be seen (Fig. 1), the following motives prevail among women swimmers: Health and fitness (8), Independence (4), and Affiliation (2), whereas for men the most important motives are: Excellence (1), Affiliation (2), and Health and fitness (8). Aggression is the least important motive in both groups. The profile configuration of 'W' and 'M' groups is very much the same ($\delta = 0.84$; $p = 0.004$). Figure 1 also reveals diversities in the motive intensity of both groups. We can see that 'W' group dominates 'M' group in Independence and Power motives, whereas 'M' group dominates in Excellence and Stress.
b) **Profiles and hierarchy motives among groups of different training time**
   Figure 2 shows motivation profiles in sub-groups according to training time.
   For people with shorter training time 'S' the most important motives were (Fig. 2) Health and fitness (8), Affiliation (2), and Excellence (1), whereas for people with longer training time the most important ones were: Excellence (1), Extrin-

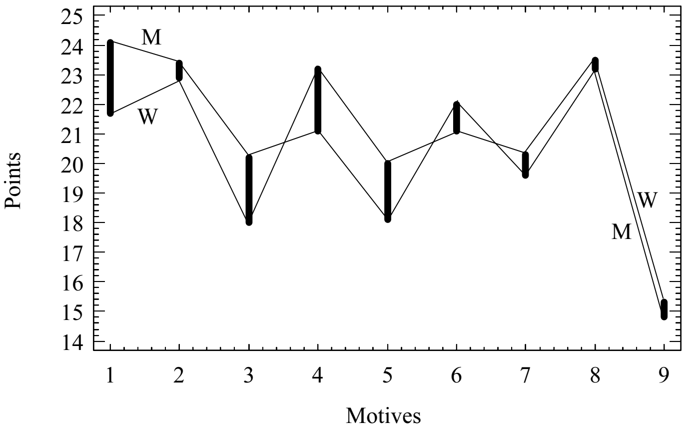

FIGURE 1. Motivation profiles in groups according to sex (W and M)

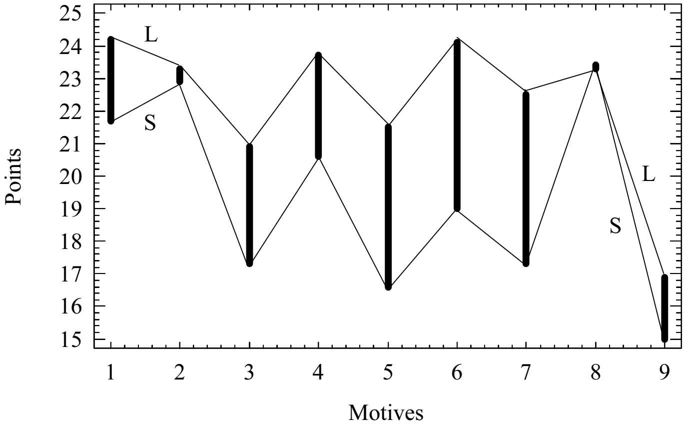

FIGURE 2. Motivation profiles in groups according to training time (S; L)

sic success (6), Affiliation (2), and Health and fitness (8). These profiles are very much the same, because the correlation coefficient is high ($\delta = 0.83$; $p = 0.006$). Figure 2 clearly shows that people with longer training time can be characterized by a higher level of Power (5), External (6) and Intrinsic success (7). The Stress (3) and Independence (4) are less important.

c) **Sex and training time vs intensity of swimming motives: interactions**
Excellence (1) was weaker among women than men (3.48; $p = 0.07$), for more experienced 'L' swimmers it was stronger than in the 'S' group ($F = 3.82$; $p = 0.06$). A statistically significant interaction of sex and training time factors influencing the intensity of excellence ($F = 6.40$; $p = 0.02$) was stated. This interaction is given in Figure 3.

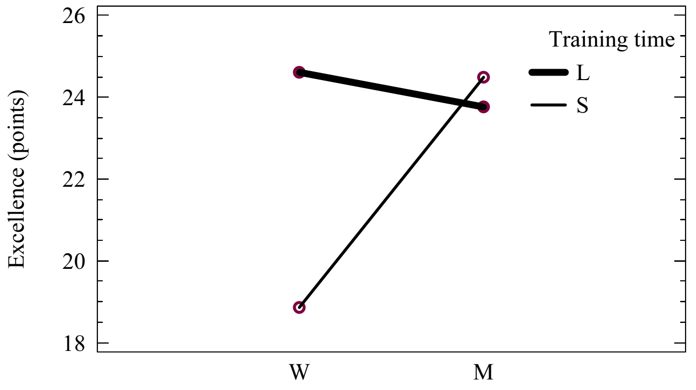

FIGURE 3. Interaction of sex and training time factors and excellence motive (sex, training time, category)

In ‘W’ group a significant dominance of swimmers with longer training time ‘L’ over girls with shorter training time ‘S’ was observed.

Affiliation (2) depended neither on sex factor (F = 0.12; p = 0.72), nor on training time (F = 0.06; p = 0.081). A statistically significant interaction of the above mentioned factors (F = 1.15; p = 0.29) was not stated.

Sex did not influence Stress (3), which results from competitions (F = 1.40; p = 0.24). In intensifying the Stress (3), diversities among groups tended to appear (F = 3.86; p = 0.06). In ‘W’ group with shorter training time ‘S’, the stress tended to be lower than in ‘L’ group. No interaction of sex and age factors with the stress (F = 1.12; p = 0.29) was stated.

In ‘W’ group, the value of Independence (4) was higher than in ‘M’ group (F = 2.00; p = 0.016). Training time clearly modified the value of this motive (F = 3.94; p = 0.052). Shorter training time was connected with the lower value of Independence (4) with the interaction statistically negligible (F = 0.02; p = 0.89).

Power (5) values did not vary ‘W’ and ‘M’ group means (F = 0.91; p = 0.34). This motive was more important among boys and girls with longer training time (F = 6.30; p = 0.02). No significant interaction effect in this motive caused by the mutual interaction of sex and training time was stated (F = 0.02; p = 0.89).

In the values of Extrinsic success (6) no statistic diversities connected with the swimmers sex were observed (F = 0.24; p = 6.62), however, these diversities were significant in the case of training time (F = 7.29; p = 0.01). The interaction of sex and training time factors was statistically insignificant (F = 0.86; p = 0.36).

A similar type of dependence concerns Intrinsic success (7), i.e. sex does not influence the value of this motive significantly (F = 0.13; p = 0.72), on the other hand, training time significantly differentiates the compared groups statistically (F = 7.52; p = 0.01). The interaction is statistically unimportant (F = 1.12; p = 0.29).

The analysis of the variance of Health and fitness (8) demonstrated that swimmers are a homogenous group in this respect (F = 0.04; p = 0.84). Training time does not influence the intensity of this motive (8) (F = 0.01; p = 0.93). No interaction of the above mentioned factors was spotted.

Aggression (9) does not discriminate the subjects in terms of sex (F = 0.10; p = 0.75). Still, there is a statistically significant dependence of this motive's intensity (9) on training time (F = 4.04; p = 0.049). The interaction is statistically unimportant (F = 0.00; p = 0.98).

DISCUSSION

The basic aim of the paper was to specify the most important motives, which guided young sportsmen when choosing swimming. Apart from successes, this often requires numerous sacrifices, effort, complying one's lifestyle with the selected discipline, also suffering from unfavorable results (e.g. health or psychological problems, connected with the failure), which are the aftermath of taking a sport. The determination of the interaction between swimming motivation and such variables as sex, age or training time was also important.

The results of the research showed that the motives of the swimmers are similar to those of other sportsmen (Nawrocka 1984; Wankel, Kreisel 1985; Dybińska 2006). Internal factors, such as health and fitness, excellence, independence and affiliation prevailed.

While analyzing the research material, motivation profiles in sub-groups of swimmers selected in terms of sex and training time were crossed out.

With these results it was stated that in females the following motives are most important: health and fitness, independence and affiliation. For males the most important factors are achieving excellence, affiliation and health and fitness. The hierarchy of motives proved to be highly correlated in both groups.

Among people with a shorter training time the most important motives to swim were: health and fitness, affiliation and achieving excellence, whereas for swimmers with a longer training period achieving excellence, extrinsic success, affiliation and health and fitness were the most important. Both ratings are highly correlated.

Training time (index of sports experience) turned out to be a variable, discriminating the subjects in terms of motives. Depending on training time, statistically significant diversities referred to such motives as: power, intrinsic success, extrinsic success and aggression.

CONCLUSIONS

The results analysis indicates that:

1. Age and training time turned out to be variables discriminating swimmers in terms of motivation to do swimming.
2. There is a similarity in the motivation of boy- and girl-swimmers. However, the rating of the motives was the discriminating factor for both sexes.

3. In all cases the values of the motives of older swimmers with a longer training time were higher than in the case of the younger swimmers, which proves a larger importance of motivation among more experienced swimmers of both sexes.

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Moving the Body to Swim

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ABSTRACT:
Purpose: The aim of movement research is that humans live in onmoving process states. The body-in-process is an active electromagnetic field (living matrix alive).
Basic procedures: the scientific basis is transformed into experimental design and goes back to theory.
Results: high competition sport is a field of a risky coherent state.
Conclusions: the work in the field of competition sports affords a diagnostic background of coherent lifestyle.
KEY WORDS: ordering regulation, coherence, electromagnetic field

INTRODUCTION

We found that motion activity is structured on different levels. There is an onmoving ground state as vibrant motion. There is a muscular state of tasked-tensional motion ‘under stress’. There is a social and cultural state of movement as ‘locomotion’ in defined situations of ‘sporting life’ (like techniques of swimming).

In the first place we examined the whole activity-spectrum under strategic and fundamental regulating display of order in an electromagnetic body-field (living matrix). Under these premises swimming is an informational task of sucking order (to get frequency-information while moving). To live in frequency information is basically well known as living in Schuman-resonance (Oschman 2000). This life triggering earth field together with sunlight (Schrödinger 1999) constitutes a human body as dissipative-expanding structure in continuous but discrete states of microvibrations (Rohracher, Inanaga 1969; Randoll, Hennig 2003). This vibrant state also exists in the living cell (Rensberger 1996).

In a life constituent 24 h cycle the body modulates ‘activity’ (and stress, exertion/effort, load/strain as well as relaxation, fun, joy). We found out that for diagnostic, performing, exercising and training reasons we must fully understand any task – and swimming – in the context of far reaching life cycles. The basic motion cycle is a 24 h cycle of coherent life management. We need data from all activities over a 24 h daytime. Then we are able to do a profound diagnosis and training control. The theoretical frame presented here is a result of our experimental work and is based at least upon over 12 million single data. They gradually formed the ‘picture’ lined-up as follows.

MATERIAL AND METHODS

Sachs (1969) found out that statistical measurement data from living systems fits into a log-normal distribution. What does this mean? All data reflect the coherent state of a ‘whole body’s’ life processing motion! It has been proved by Zhang (2006, 2007) that in a coherent state all processing elements (cells, organs) do their independent work-out and at the same time are fully in contact and cooperation as a processing whole. Log-normal distrubution is an index of coherence and order. An ideal Gaussian distrubution then stands for chaotic and maybe disturbed, damaged or severe ill states.

When monitoring work-out states in training we can use data of the electromagnetic bodyfield – in positive (supporting) or negative (helping, changing methods) intend.

Biological parameters of living systems are permanently in change. Therefore it has been important to us to extend our research to a 24 h cycle of coherent life management and ordering regulation of the body itself. The general importance of such a research-frame is underlined in Smolensky’s and Lamberg’s (2001) work on the so called ‘body clock’.

We concentrated our explorations on a 24 h cycle of order-sucking activity during ‘daytime’, as a general upright walk-state and night-time as a lay-down state in sleep.

But sleeping does not mean inactivity. During sleep, the coherent state is modulating itself (for the sake of order in the living matrix) as repair and restoring: to get ready for the coming daytime cycle. During the daytime cycle we must suck-in order that is realized in night-time, respectively sleep.

To fully understand the 24 h cycle we must pay attention or take into account the phases of ‘rest’ or ‘siesta’, of pause, inhibition or meditation in daytime. These are phases where the body tries to ‘hold’ coherent states even under ‘pressure’ for example of work or other tasks. In stress states order is more reacted out, coherent states are disturbed or damaged.

The basic assumption of our present scientific research is outlined as follows: 1) the human body is a body-alive and living vibrational matrix; 2) within the display of classical movement (locomotion), quantumphysical ‘onmoving’ in discrete spacetime and biophysical ‘motion’ of living-matrix regulation we centered our concept in ‘ordering regulation’; 3) ordering regulation takes place within an electromagnetic field; 4) the ordering process is coherent-vibrational and holistic; 5) the order of the body-alive can be examined as a log-normal distributive ‘power’ in relation to Gauss-

-distribution; 6) in coherent onmoving the body-alive works as a multiplicative generator of kinetic aliveness and life; 7) the order is modulated in everyday life and does not depend on special tasks or events: it is a relational order.

The nature of 'ordering process' is consequence of living bodies constantly moving on 'far from equilibrium' while minimizing entropy (Popp 1999, 2000; Schrödinger 1999).

To live in an onmoving state of life and to stay alive is a great challenge of modern times. Since 'everything is in vibration' we have to find out how vibration is encoded in the frequencies of the body. There are numerous interesting hypotheses: the work of DNA on the basis of biophotons (Popp 1999) the DNA as wave generator (Gariaev 2005), Schuman resonance in combination with the geomagnetic earth field; cosmic light cycles; electric patterns of life (Burr 2000), microvibration of the muscle and so on. What we know about life and movement is very much. But what are we willing to do with all these 'facts and figures'?

Here we do not follow biomechanical or biochemical paths. And we do not think that we can find a universal form as s method for successful living. We just want to read a little bit more the text of normal everyday life. We want to find out what we can do to be intimately 'in touch' with kinetic aliveness, to be in touch with joy, happiness, longevity, wellbeing...

For the purpose of education, training, and performance we find some approaches to successful interventions we call 'aliveness support' of the ordering regulation.

Central theme of our theoretical and experimental works is the topic of biophysical coherence in the way (Ho 1996, 2003; Schrödinger 1999; Popp 2000; Zhang 2007) gave fundamental input to this approach. We want to research the ordering regulation of life in everyday life cycles and we want to understand self-knowledge and self-ordering processes of the body-alive. So it might be possible to understand the range of motions in swimming as coding tools of coherent qualities.

RESULTS

Everything in life and what we do or the way we move does affect the living matrix, the body, the organs, the cells, because 'life' is a 'superposition' of onmoving state (Schrödinger 1999) or permanent movements'. There is no escape from moving on. Therefore it is easy to say that movement is living, or better: life exists in motion. But what is the real way of life and 'living' as the processing order? It is the idea of coherent-ordering in the the whole range of movement possibilities in the name of this order, in the name of aliveness (vibration; pulsation; tension). Because the body lives out of this order.

'Coherent vibrations recognize no boundaries, at the surface of a molecule, cell, or organism – they are collective or cooperative properties of the entire being. As such, they are likely to serve as signals that integrate processes, such as growth, injury repair, defense and the functioning of the organism as a whole. Each molecule, cell, tissue and organ has an ideal resonant frequency that coordinates its activities' (Schrödinger 1999).

We outline 'coherence' as connectivity in multiplication within an electromagnetic field and not as addition of different electrical values (Zhang 2006, 2007). Whenever the body is active, doing something, it is an activation of coherence as modulation of the ordering regulation. From frequency to physical form the body orders on behalf of information in the wide range of frequencies (Gariaev 2005).

Movements in everyday life possess 'matter and wave' structure. Fortunately, the wave structure is not only in the realm of atoms, cells or DNA. It is also in the 'flesh' as 'pulse' of life (Kuriyama 1999) or in the microvibrational order of muscles (Randoll, Hennig 2003).

'In the living body, each electron, atom, chemical bond, molecule, cell, tissue, organ (and the body as a whole) has its own vibratory character. Since living structure and function are orderly, biological oscillations are organized in meaningful ways, and they contribute information to a dynamic vibratory network that extends througout the body and into the space around it' (Oschman 2000).

The recordings can be 'seen' in an electromagnetic picture of coherence. And the picture tells us the story of quality in ordering aliveness. The body-alive can generate, recognize, modulate coherent information. When measuring and producing 'results' there has always been intervention before (either spontaneous or induced). Now we make a difference in interpretation of the results: either the intervention is supporting coherence (supporting value) or it is not supporting coherence (ordering regulation in Gauss distribution).

When measuring the electromagnetic body, we get mathematical 'pictures'. The pictures are unique and tell a story within the frame of theoretical arrangements of interpretation and diagnosis. The process of onmoving is recorded as the processing of everyday-life: including exercise, training, physical education or movement-therapy; working, resting, breathing, sleeping, eating and thinking. As the onmoving body moves as 'a whole', the field of aliveness is coherent as a multiplicate processing state (and not an isolated addition of particles or integration of parts). Biophysical research of human movement is research of the aliveness-field as dissipative (expanded) and connected moments of vibrations, waves and informational displays. The 'entire living matrix forms an electronic and a photonic network' (Oschman 2000).

The body never 'sleeps'. The electromagnetic field is a non-stop regulation in coherence. While the classical body-in-motion 'stops' and changes activities, the body-alive is moving on in the so-called 'wake state'. We examine the non-stop regulation in relation to activity, that means 'coherence' comes first. In transformation of Siemens and Ohm formula, Zhang (2007) has shown that we examine an electromagnetic field and not skin resistance with associated conductivity. The 'electric body' (Becker 1994) is dynamic and thus always electromagnetic. The mathematical configuration of a log-normal distribution (connectivity and cohesion) is a well elaborated experimental access in sports-scientific research. The instrument does not follow a statistical 'norm' of a 'population'. The measured values are worth for the moment and significant for the measured person only.

The scientific device is called SAM 2. It enables us to explore the electromagnetic field of the body. In a further developed form the device may be used in everyday life 'monitoring' the state of order. The actual device is constructed to measure the electromagnetic matrix following 'conductivity' and field qualities of skin electricity.

With the help of 128 electrodes in form of small 'needles' the field is examined.

A positive electrode serves as a counter part. We can measure every second and even offline we can take 2000 measurements. The distribution of values follows mathematical rules of Gauss distribution and log-normal distribution als field of multiplicate values of living matter!

There is observed a 'good' coherent value. It means that coherence is well supported and the ordering regulation is in a 'harmonic state'.

DISCUSSION

What we measure is a 'moment' in the manner-of-living that is actually and always modulated by activity: maybe working, always breathing, thinking or doing sports and so on. The onmoving state thus is a state of frequencies and the actual way of doing is a form of 'sucking in frequency-coded order' (Schrödinger 1999).

'Order' in this way of regulation is a 'floating' and discontinuous order; therefore there does not exist a norm, only coherence!

The living matrix is order in vibration and resonance. The body never comes back to a former state, but always moves *into* aliveness. In a course of a physical time-structure it seems that the body 'comes back'. That phenomenon is very interesting, because it is a special form of time-path in reverse (Prigogine, Stengers 1981). So the body gets old in the real sense of the word: is grows and develops and sometimes seems to be 'younger than ever'. The body-alive is a non-local organizser. It generates, filters, recognizes and distributes the ordering potential (of coherence/in coherence). Our everyday life is an ordering regulation-response. In living (to rest; to work; to sleep; to think; to breathe; to eat; to drink; to 'move') we are automatically (while onmoving) and systematically (practising sports for example) imposing 'activated frequencies' on the body and thereby we are 'feeding' the ordering regulation.

CONCLUSIONS

In our approach[1] to the body-alive we can distinguish a multiple frequency opening life-process from a more mechanistic 'locomotory' confining process (a primarily entropic state of decay).

The log-normal distribution in the 'storing' (from latin 're-staurare', to make new) function of order is an indicator of coherence and of 'good life' (since 'good' means nothing else than... coherent!). We now step into a science concerned with measurements of processing life in a holistic and coherent way. We can no longer 'trust' in locomation alone or in the pictures of concrete movements.

We now 'see' the unseen and our experience can be expanded. That is a problem when we leave diagnosis and try to give practical advice **how** to move and **what** to do.

The scientific device can be developed to an appropiate diagnostic tool in sports exercise, training and movement-therapy. But it is still difficult to interpret values and distribution in a non-psychological and non-physiological manner. We do no psychological or medical work.

NOTE

[1] We therefore distinguish the following states of the body-alive: the **morphic** state (see classical morphological-phenomenological approach), the **flesh and muscle** state (physiology; biomechanics), the **mind-control** state (physiology; psychology; neuroscience), the **electrical** state (neurophysiology) the **biomolecular** state (biochemistry; molecular biology), the **electromagnetic** state (biophysics) and the **biophotonic** state (biophysics; quantumphysics).

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PART FIVE

WATER SPORTS AND HISTORY OF SWIMMING

SCIENCE IN SWIMMING II, 2008, 171–176

Fin Rib Influence on Mechanical Parameters

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ABSTRACT: Mechanical response of a fin in use mainly depends on material and architecture designs. In this way, different mechanical approaches have been proposed over the last years. This paper focuses on a mechanical damped string mass model to study influence ribs and structural holes on dynamic oscillation response for different fin designs. A specific test bed has been realised to record vertical oscillation of a fin with a SIMI motion capture device in order to determine specific mechanical parameters such as fin stiffness and viscosity. Then, these parameters have been computed to characterise fin blade reaction to a specific flexion position corresponding to upper and lower foot kicking during a normal finswimming activity. Main results of this study highlight that hole designs reduce not only fin stiffness but also its viscosity. Moreover, influence of rib lengths on stiffness is characterised.

KEY WORDS: finswimming, stiffness, mechanical parameters, design

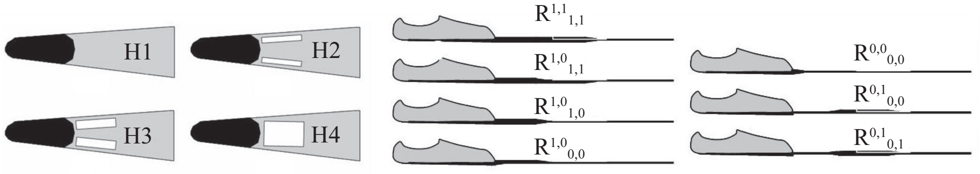
INTRODUCTION

Material and technology in fin swimming are improved constantly, modern fins are designed using the combination of two or three different materials. However, it is still the main fin structure which governs fin response in downward and upward kick. Actually, two solutions for acting on fin dynamical response are available. The first one is based on carbon or aluminium fiber in order to raise fin stiffness (Bideau et al. 2003) and thus improve response. The second one is more used in fin industries and consists in improving fin rib designs. The aim of ribs or flanges is to rigidify specific parts of the fin to improve propulsion of the fin swimmer. Many solutions have been developed to quantify fin stiffness. One is to measure flexural rigidity (Pendergast et al. 2003). It consists in putting weights on the fin's blade and measure the vertical deflection. Flexural rigidity is computed by using the following mechanical equation: $EI = PL^3/(3\delta)$ (Gere, Timoshenko 1990), where P (N) represents added masses, L (m) masse distance and δ (m) the deflection. This method employs a static description, but another work has carried out this problem. The other method employs a dynamical approach (Bideau et al. 2003). For a maximal ankle flexion, and extension, during respectively lower and upper kicks, fin flexions are maximum. For upper and lower kick positions, the fin is released and the whole structure modifies its curvature. At this moment, blade oscillation creates a vortex propelling the finswimmer (Arellano 1999). It is in this mind the quick release method has been developed following the same logic. It consists, on a bed test, in putting fins in flexion and releasing quickly the blade to visualize oscillations with a motion capture device. These oscillations can be considered as the response of a damper spring masse system. Mechanical equations help us compute mechanical properties such as stiffness (K) and viscosity (υ). The aim of this study is to demonstrate the influence of design on dynamic mechanical parameters.

MATERIAL AND METHODS

In order to study the dynamic release of a fin during the upper or lower stroke, different fin architectures have been tested. There are two kinds of modifications on fin architecture: one is the modification of ribs, and the other one is the presence of different size hole in structure (Fig. 1). For a better understanding of hole and rib modifications, a specific notation has been adopted. Figure 1a shows the presence of different holes in fin structure in terms of size and locations and different fin ribs architectures are presented in Figure 1b. Hole modifications are respectively named H1, H2, H3, H4 and classified as a function of the hole size. Rib modifications are denoted $R^{i,j}_{k,l}$, where (i, j) represent the first and second parts of upper ribs and (k, l) the lower rib.

The test method used is similar to damped spring mass model of Bideau et al. (2003). A foot last is firstly positioned in the foot pocket of the fin. Then, the last is fixed on the test bed on a free axis corresponding to the ankle joint location (Fig. 2c). The procedure consists in applying a flexion to the fin between ankle axis (A) and the end of the fin structure (B) (Fig. 2a), until the projected fin length is reduced by twenty percent of the total fin length (L). The ankle axis is free in rotation to permit a curve deformation of fin. To be in oscillation a motor permit to rotate the fin



a b

FIGURE 1. Scheme of different holes (a) and scheme of fin ribs architectures (b)

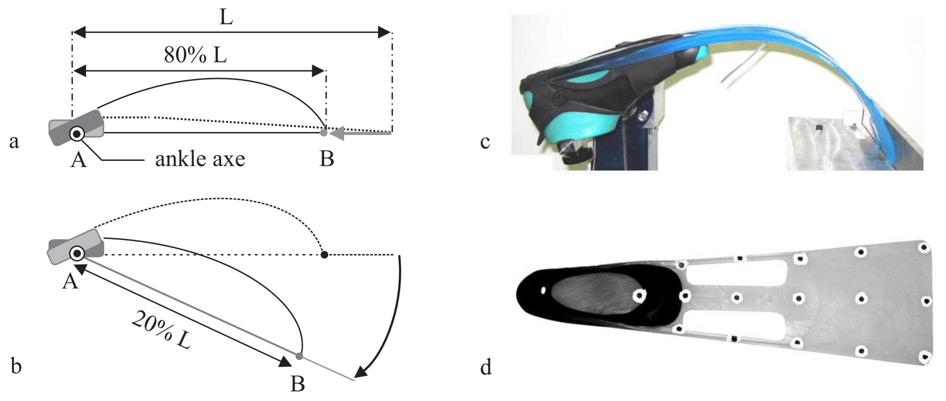


FIGURE 2. Scheme of protocol method with the 20% compression step (a, c) and rotation to horizontal foot position (b) and a photography of fin markers (d)

around ankle until foot is in a horizontal position (Fig. 2b). At this moment the ankle axis is locked and fin can be released. Two high frequency cameras (1000 Hz) are used to record fin blade oscillations by computing 3D coordinates of 16 markers (∅8 mm – Fig. 2d) with SIMI-Motion software.

Mechanical coefficients are deduced from oscillation measurements by using this mechanical model (Bideau et al. 2003):

$$K = \left(2\pi / T_n\right)^2 \cdot m \qquad\qquad \upsilon = \xi^2 \cdot \sqrt{K \cdot m}$$

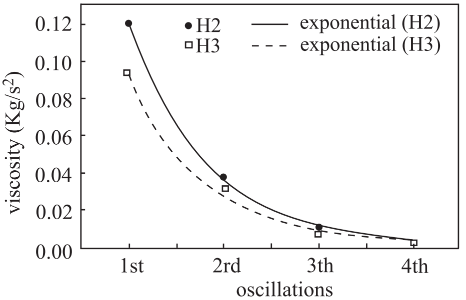
with

$$\xi = \sqrt{\frac{\Delta^2}{\Delta^2 + 4\pi^2}} \quad , \quad \Delta = \ln\left(z_i / z_{i+1} \right)$$

z_i is the vertical coordinates of the i^{th} oscillation peak, and T_n is the first period of time. So, a high stiffness value is related to the fin capacity to have quick oscillations, and a high viscosity value is related to a quick damping of these oscillations.

RESULTS

Hole designs influence. Concerning stiffness (Fig. 3b), results show a noticeable difference between H1 and H2 which is certainly due to the presence of holes in fin structure. Figure 3b represents the evolution of stiffness *K* and viscosity υ for different hole sizes. A linear decrease of stiffness is highlighted if hole size is increased from H2 up to H4 whereas viscosity behavior is not linear. For larger holes, H3 and H4 viscosity values strongly decrease (Fig. 3b). Finally, fin panel could be cut into



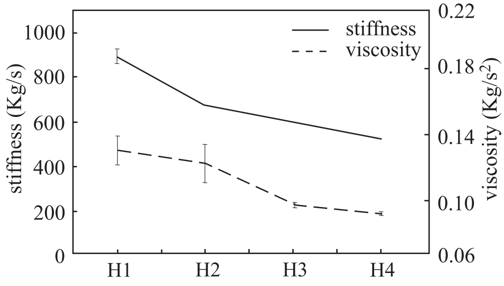


FIGURE 3. Evolution of viscosity as a function of oscillation numbers for two fin H2 and H3 (a), evolution of *K* and υ parameters for different fin with hole size variations (b)

two: on the first hand {H1, H2} couple which have the same level of viscosity, and on the other hand {H3, H4}. In addition to this, for each set, damping time evolution is the same. So, only H2 and H3 mechanical behaviour, representative of each group, are shown in Figure 3a. Viscosity parameter decreases faster for a more important hole size, whereas for a smaller hole viscosity comportment is quite similar to the whole fin.

Ribs design influence. Fin stiffness evolves as a function of rib designs. Fins with complete ribs ($R^{1,1}{}_{1,1}$), half ribs ($R^{1,0}{}_{1,0}$) and without ribs ($R^{0,0}{}_{0,0}$) can define a mean line (Fig. 4 – dotted line). Nevertheless, asymmetric fin designs ($R^{1,0}{}_{1,1}$, $R^{1,0}{}_{0,0}$) are upper or respectively lower to the mean line.

DISCUSSION

First of all, we grant that the material has the more great influence on dynamic response. But in our experiments the material is always the same and only blade architecture is modified. For consider the a hole effect, if material quantity is reduce at the bass of blade, the mechanical response will very likely tend to a slower and longer oscillation. We agree for stiffness because a linear influence of hole size is observed. However it is not the same evolution for viscosity parameter. Indeed, if hole size becomes too high, then viscosity really decreases (Fig. 3b). So for a higher hole, oscillation is less damped at a higher frequency. This is probably due to vibration phenomenon more than a real oscillation mode. Because, for small hole size, time response is similar to H2 response (Fig. 3a) whereas, for larger hole size, response change of mode and became less damped.

Designing a hole on a fin, has certainly an advantage but if its size is too high, mechanical parameters are damaged. In order to balance this effect, ribs seem to be a solution. Ribs influence has been studied in this way.

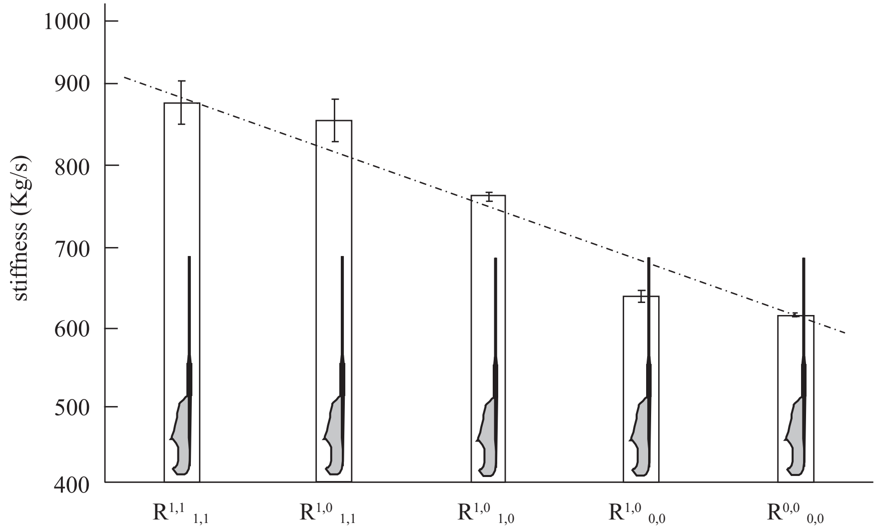


FIGURE 4. Stiffness evolution for different ribs design

Ribs have a real impact on stiffness parameter. As results show the effect of rib on stiffness, more long ribs have higher stiffness intensity. They permit a quicker release of fin blade with a higher oscillation frequency. Stiffness seems to be well correlated with the length of ribs. But for asymmetric designs, values are not on the mean line. This is probably due to the test bed protocol. Because, if ribs below the blade are longer, stiffness is higher; and if ribs above the blade are longer, stiffness is lower than mean line. In the bed test, fin is positioned with hell up, in this way, fin has a preferential oscillation. For the oscillation, start blade position is determinant; and as fin blade is deformed in one direction, explanation is probably here. Before the release, at the initial position, up-ribs are in compression mode and down-ribs are in traction mode. This explains the different response for dissymmetrical design. In this way, asymmetric designs should be investigated in future study to optimize asymmetric response.

CONCLUSION

It is proved that lower and upper kick do not have the same kinematic and intensity, even more for novice (Arellano 1999). So we can specify upper and lower design in order to cancel this biomechanical deficit. With specific blade shape, different mechanical response can be obtained and probably help swimmer to balance a muscular power lack.

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≋ SCIENCE IN SWIMMING II, 2008, 177–182

The Effectiveness of Time-out for Feedback in Water Polo Game with ‘Extra Man’

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ABSTRACT: One of the most decisive situations of the water polo game is the exclusion of a defensive player, resulting in the superiority in number of the attacking team. Coaches attempt to maximize the percentage of success on the ‘extra man’ situation. In some cases, specifically at the crucial moments of the game, they opt for the timeout solution right after the exclusion, regarding it as beneficial feedback of information for the team. The objective of the study was to explore whether the solution of time out at the ‘extra man’ actually benefits the team that calls for it or not.

KEY WORDS: man up, timeout, feedback

INTRODUCTION

A commonly recurring situation of the water polo game which is assumed to play a significant role to the formation of the final result of a game is the situation where one of the two teams plays with an extra player, due to the exclusion of a player of the opposite team after a serious error. This situation is described by the term ‘extra man’ and the team plays in the game with an extra player for 20 s (FINA 2002). At this point, defense is not press defense but for the situation to be encountered, it tries to cover its gaps by filling in the space or playing zone defense (Rajki, Gallov 1985). On the other hand, the attacking team tries various combinations to find one of the six players free so as to pass him the ball to shoot, with the opposite goalkeeper being out of position, if possible. Due to the importance of this situation, coaches spend a great deal of training time with teams, to improve the technique and the method of the ‘extra man’. It is important for the teams to pay attention to this recurring situation, since between two teams equal in force, most of the goals are scored when this situation is exploited. A research on 99 games in International and European Championships has shown that a percentage of 40.2±22.7% of the goals has been accomplished during the ‘extra man’ situation (Platanou 2004). Coaches attempt with their method to maximize the percentage of success on the ‘extra man’ situation. In some cases, specifically at the crucial moments of the game, they opt for the time-out solution right after the exclusion, regarding it as beneficial feedback of information for the team. The aim of the feedback is to co-ordinate the players of the attacking team and the coach to give the appropriate instructions, so as for the players to break the opposite defensive set up and score a goal. The question arising is in which case the percentage of success in the 'extra man' situation is greater. Is it in the case where the athlete functions according to the inner feedback, in other words, his own judgment without a pause and a given time-out or is it in the case where the athlete functions after an outside feedback from his coach, given at a time-out after the pause of the game? The objective of the study was to explore whether the solution of time-out at the 'extra man' actually benefits the team that calls for it or not. In addition, it was examined whether there are differences in the number of games played with an 'extra man with a time-out' and 'without a time-out', and in the number of goals scored in both cases, in between the 4 periods of the game.

MATERIAL AND METHODS

For the purpose of the research 26 games were analyzed from the European championship of Beograd in 2001 (13 games) and the European championship of Budapest in 2006 (13 games). The number of cases where the game was played with 'extra man' was recorded per period. The number of cases where the game was played with 'extra man' when the team asked for a time-out or did not ask for one was also recorded. Furthermore, the number of goals scored in each of the former cases was recorded.

Statistical analysis. Descriptive statistics with percentages and average numbers were used to describe the variables. For the comparison of the number of cases with an 'extra man with a time-out' and 'without a time-out' presented and the goals scored respectively, a t-test with independent samples was conducted, while for the comparison between periods ONE WAY ANOVA (was conducted) followed by Tukey's *post hoc* analysis. The statistical analyses were made with the use of the SPSS program. The level of statistical significance was set at $p < 0.05$.

RESULTS

The average number of the cases of the 26 games with an 'extra man' per period, the total number of the cases and the total number of goals per period are shown in Table 1. The number of the total of goals in the 4 periods (198) was 42.85% of the total of the cases with an 'extra man' (462).

The total number of time-outs and no time-outs and the average number of the 26 games per period are shown in Tables 2 and 3. The total number of time-outs in the last period, as can be seen in Table 2, is significantly bigger than the number of time-outs in each one of the other three periods ($p < 0.05$).

TABLE 1. Average number and total of the 'extra man' and goals per period in 26 men's water polo games

Periods	Average number 'extra man'	Total 'extra man'	Total goals in 'extra man'
1	4±2	108	38
2	4±1	110	56
3	5±1	124	54
4	5±2	120	50
Total number of cases with 'extra man' in the 4 periods		462 times	198

TABLE 2. Average and total number of time-outs per period in 26 men's water polo games

Periods	Average time-outs	Total number of time-outs
1	0	2
2	0	10
3	1	16
4	1	36
Total number of time-outs in the 4 periods		64
Percentage % of the total of cases with a 'man up'		13.85%

TABLE 3. Average and total number of 'extra man' without a time-out per period, in 26 men's water polo games

Periods	Average without a time-out	Total number without a time-out
1	4±2	106
2	4±1	100
3	4±1	108
4	3±2	84
Total number without a time-out in the 4 periods		398 times
Percentage % of the total of cases with an 'extra man' (462)		86.15%

In Tables 4 and 5, the total number of goals with a time-out and the total number of goals without a time-out, as well as the average number of goals in the 26 games per period, are depicted. The total number of goals (14) in the last period of the cases with a time-out is significantly bigger ($p < 0.05$) than the number of goals in each one of the other three periods (Tab. 4).

DISCUSSION

This study has examined to what extent feedback given during the time-out in the 'extra man' situation in a water polo game, functions in favour of the team asking for it.

TABLE 4. Average and total number of goals with time-out in 26 men's water polo games, per period

Periods	Average number of goals	Total number of goals
1	0±0	0
2	0±0	4
3	0±0	2
4	1±1	14
Total number of goals with a time-out in the 4 periods		20 goals
Percentage of the total of cases with an 'extra man' (462)		4.32%
Percentage of the total of goals (198)		10.10%
Percentage of goals in the 64 cases with an 'extra man' with a time-out		31.25%

TABLE 5. Average and total number of goals without a time-out in 26 men's water polo games, per period

Periods	Average of goals without a time-out	Total number of goals without a time-out
1	1±1	38
2	2±1	52
3	2±2	52
4	1±1	36
Total number of goals without a time-out in the 4 periods		178 times
Percentage of the total of cases with an 'extra man' (462)		38.53%
Percentage of the total of goals (198)		89.90%
Percentage of goals in the 398 cases with an 'extra man' without a time-out		44.7%

The results demonstrate that the time-out and the feedback given to the players of the team asking for the time-out do not finally act beneficially in scoring. As it is widely known, the result of a game depends to a high degree on the effectiveness of the teams in the 'extra man' situation (Platanou 2004). It is important for the teams to pay attention to this recurring situation, since between two teams equal in force, most of the goals are scored when this situation is exploited. In the current research, examining the results of 26 games in two European Championships, the 'extra man' situation was exploited by 42.85%, since the goals scored were 198 in total, against 462 cases of the 'extra man' situation. Proportional results have been presented in another previous research (Platanou 2004). Therefore, it is obvious that there is significant room for the percentage of success in this situation to be improved even more. At the crucial moments of the game, coaches attempt to opt for the time-out solution right after the exclusion, regarding it as beneficial for their team that has the advantage in the number of players. In the first place, the study has managed to demonstrate that the number of cases where the teams played with an 'extra man without a time-out' was significantly bigger than the number of cases where the teams played using a time-out (64). This can be explained on the basis of the water polo regulations, since the number of time-outs that the coach can use during the game is limited (2 time-outs every 7 min). It has been observed yet that the percentage of the goals scored by the teams when playing without a time-out was significantly bigger (44.7%) than the percentage of the goals observed when the teams were using the time-out (31.25%). Giving feedback to the team with the numerical advantage aims at co--ordination of the players and appropriate instructing from the part of the coach, so as for the players to break the opposite defensive set up. These instructions constitute the outside information that a player receives from the surroundings which he utilizes. So, the team starts playing in the 'extra man' situation, knowing the way or the ways to score a goal. This can certainly be assumed as an advantage. However, the study hasn't proved this knowledge to result in scoring of goals. This could be possibly explained if it is taken into consideration that feedback is not only given to the players of the team with the numerical advantage (offensive team) but to the players of the defensive team as well. The players of the defensive team also receive information needed to counteract the offensive systems. Therefore, it is possible that when an offensive team asks for a time-out, it gives the chance to the defensive team to rest and organize itself. This works as an advantage for the defensive team. The players, now refreshed, can play more effectively, having a clear head. The offensive team, when asking for a time-out, loses its rhythm and the possibility of catching the defensive team of its guard, with a sudden shot, the moment when the defensive players are getting the appropriate positions. Moreover, the possibility of the offensive players to develop individual initiatives is lost. The player often functions according to his instinct, receiving information that derives from his own self. Therefore, in the case of the 'extra man' situation without a time-out (outside feedback), the offensive player can surprise with his own initiatives, if he judges that the conditions are in favour of him, for example if he finds the defense absolutely unprepared. The moment of inspiration that the offensive player may have, can be interrupted by a time-out and it should be kept in mind that in lots of cases the momentary initiative of a player can change the balance of a water polo game. Furthermore, a relaxed defense carries less anxiety when facing the offensive team. Another important point is that the coach of the defensive team has the opportunity to make appropriate changes in the team.

The comparative analysis of the variables between periods has demonstrated that coaches ask for much more time-outs in the 'extra man' situation and score more goals at the last period in comparison to the other three periods. This possibly happens because the most usual coach method is to ask for a time-out at this period, which is the most crucial part of the game, when the players are most tired and need time to rest. No important differences were observed between the periods in the total of cases with an ‘extra man’, the number of cases with an ‘extra man without a time-out’ and the goals with an ‘extra man without a time-out’.

CONCLUSION

1. The time-out solution that coaches follow in order to maximize the percentage of success at the ‘extra man’ situation seems not to benefit much the offensive team (team that asks for the time-out) but to benefit more the defensive one.
2. Most of the time-outs are asked for by the coaches in the fourth period. The reason for this is that the most usual coach method is to ask for a time-out in this period, since it is the most crucial part of the game and the players are most tired.

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Comparative Assessment of Sports Level in Junior Women Swimming in Poland and Germany in 2004 and 2007

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ABSTRACT: The aim of the paper was to compare the level of sports results achieved by 14-year-old girls in 2004 and 2007. The results of the final events in freestyle and backstroke gained during the Junior Polish Championship in the category of the 14-year-olds and the German Championship in the same age category in 2004, and the Junior Polish Championship in the category of the 17–18-year-olds and the German Championship in the same age category in 2007 were used as the material in the paper.

KEY WORDS: swimming, junior women, sports level

INTRODUCTION

Many factors have an influence on the achieved result, among others there are the following: genetic predispositions of a competitor, applied training program, methods and means of its realization, nutrition, climatic training, diagnosis of health of competitors during training units and means that hasten the process of biological regeneration.

A high level of swimming and intensifying competitive fight for leading positions require many closely connected activities, procedures and means carried out during the long-term process of training. The increase in the result level in modern sports depends to a large degree on undertakings directed towards the search for the most talented competitors that in the future can achieve significant successes.

The proper choice of individuals of peculiar qualities and abilities that have a high potential of physical and motor possibilities is important. The selection of talented young swimmers is based, first of all, on the assessment of the most stable indexes, whose measurements at the beginning of the training allow one to predict their further development. The indexes are: somatic parameters (height, body weight, the length of the upper limb, the length of the hand and foot), indexes of mobility of the articular and ligamentous system and sports results gained at long distances that determine the oxygen possibilities (Płatonow 1997; Bartkowiak 1999; Sachnowski et al. 2005). Nowadays Polish competitors achieve very good results in sports competition in swimming and that is why it seems important to follow, collect and analyze results obtained both by world class competitors and juniors. A coach as a main organizer of the training process must properly determine the training direction, the tempo of development and the formation of sports results. It can not be achieved without the knowledge of factors that decide about the development of a given sports discipline, without collecting information about our sports results and sports results of our opponents as well as the analysis of the tempo of their development.

The aim of the paper was to compare the level of the sports results gained by the 14-year-olds in the chosen swimming events in 2004 and next to make the repeated comparison of the results in the same age group after a 3-year-training in 2007.

In the paper the author has tried to answer the following questions:

1. What differences can be observed in the sports level among the German and Polish female competitors in 2004?
2. Are there any important changes in the disproportion of the achieved sports results among female swimmers in 2007?
3. What disproportions are there in the sports results in the examined ranges: the winners, the medalists and the finalists?

MATERIAL AND METHOD

As the study material the author used the results of the final events in freestyle and backstroke gained during the Polish Championship of the 14-year-olds and the German Championship in the same age category in 2004 as well as the Polish Championship of the 17–18-year-olds and the German Championship in the same age category in 2007. The results were taken from the official internet pages:

– The Polish Swimming Federation (www.polswim.pl),
– The German Swimming Federation – Deutscher Schwimm – Verband (www.dsv.de).

The present author conducted a comparative assessment of the results achieved by the female competitors in three groups: the winners, the medalists and the finalists in the particular events in 2004 and two groups (due to the lack of the data concerning the results of the full final of the German female competitors): the winners and the medalists in 2007.

The data was processed and the arithmetic mean and the standard deviation were estimated. Moreover, the formulae for calculating the differences in seconds and percentages were applied.

RESEARCH RESULTS

FREESTYLE

In 2004 at the distance of 50 m in freestyle the German female swimmers achieved better results in all three analyzed groups that is the winners, the medalists and the finalists. The advantage of the German junior women amounted to respectively 2.33% in the finalist group, 2.47% in the medalists group and 2.20% in the winners. The distance of 100 m in freestyle is characterized by the same high advantage of the German female swimmers over the Polish ones. The observed difference amounted to about 2.1% in the winners and medalists, whereas in the finalists it amounted to 3.34%. It should be emphasized that the average time of the German medalists at the distances of 50 and 100 m in freestyle was better than the result of the Polish winner in this event (Tab. 1).

TABLE 1. The comparison of the level scores of female juniors Polish and German in 2004 – freestyle

Competition	Place	Poland	Germany	Comparison	
		$\bar{x}$ (sec)	$\bar{x}$ (sec)	d (sec)	d (%)
50 m	1	27.88	27.28	0.60	2.20
	1–3	28.18	27.50	0.68	2.47
	1–8	28.60	27.94	0.65	2.33
100 m	1	1:00.12	58.84	1.28	2.18
	1–3	1:00.56	59.37	1.19	2.00
	1–8	1:02.41	1:00.39	2.02	3.34
200 m	1	2:06.70	2:07.71	1.01	0.79
	1–3	2:09.17	2:09.77	0.60	0.46
	1–8	2:13.25	2:11.85	1.40	1.06
400 m	1	4:30.59	4:28.52	2.07	0.77
	1–3	4:35.83	4:30.45	5.38	1.99
	1–8	4:41.79	4:34.68	7.11	2.59
800 m	1	9:21.42	9:10.48	10.94	1.99
	1–3	9:34.06	9:19.13	14.93	2.67
	1–8	9:45.34	9:26.63	18.71	3.30

In 2007 the same tendency was observed. The German female competitors gained better sports results at the distances of 50 and 100 m in freestyle in both examined groups. The biggest difference was noticed among the medalists in the event of 50 m in freestyle, where it amounted to 2.9%, a little bit smaller in the group of the winners – 2.3%. At the distance twice as long, these differences were smaller and amounted to 2.1% both in the winners and medalists. The observed disproportion in the event of 50 and 100 m is smaller in comparison to the difference observed in 2004, but the

German female swimmers still at both analyzed crawl distances achieved definitely better results (Tab. 2).

In 2004 the Polish female swimmers were the best at the distance of 200 m in freestyle. The advantage of the Polish winner over the German junior amounted to 1.01 sec (0.79%), whereas in the group of the medalists the difference was smaller (0,46%). Among the finalists of this event the German women were better coming 1.4 sec before the Polish women (Tab. 1). In 2007 similarly as 3 years ago the Polish gold medalist achieved a better sports result. The difference was 0.5%. In the competition of the medalists in this event the female swimmers from Poland scored a slightly better results (0.1%) (Tab. 2). Analyzing the race at the distance of 400 m in freestyle in 2004 a regularly increasing difference in the sports level of female swimmers of both countries was observed. In all analyzed groups, the German 14 year-olds were better. Their advantage amounted to 0.77% among the winners of the event, 1.99% in the group of the medalists and 2.59% in the group of the finalists.

Assessing the level of swimming of the female competitors taking part in the event of 800 m in freestyle, a stronger dominance of the German junior women was manifest. The biggest disproportion was revealed in the group of the finalists (3.3%) (Tab. 1). Assessing the event of 400 and 800 m in freestyle in 2007, an inverse tendency was observed. The Polish junior women achieved definitely better sports results in comparison to the German females. The difference among the gold medalists in the event of 400 and 800 m in freestyle amounted to respectively 1.35% and 2.3%. However, among the medalists these differences were slightly bigger and amounted to 1.8% at the distance of 400 m and 2.42% at the distance of 800 m. It is worth mentioning that the average time of the Polish female medalists in the described events was better than the result gained by the German female winners (Tab. 2).

TABLE 2. The comparison of the level scores of female juniors Polish and German in 2007 – freestyle

Competition	Place	Poland	Germany	Comparison	
		$\bar{x}$ (sec)	$\bar{x}$ (sec)	*d* (sec)	*d* (%)
50 m	1	27.1	26.5	0.6	2.30
	1–3	27.7	26.9	0.8	2.90
100 m	1	58.2	57.5	0.7	1.20
	1–3	58.6	57.9	0.7	1.20
200 m	1	2:04.2	2:04.9	0.7	0.50
	1–3	2:06.0	2:06.1	0.1	0.10
400 m	1	4:19.7	4:23.2	3.5	1.35
	1–3	4:22.1	4:26.8	4.7	1.80
800 m	1	8:58.1	9:10.5	12.4	2.29
	1–3	9:05.9	9:19.1	13.3	2.42

BACKSTROKE

Analyzing all the backstroke events in 2004, the biggest difference at the sports level was observed among the finalists taking part in the distance of 50 m. It amounted to 3.68% to the advantage of the German female competitors. In the medalist group this distance decreased, although still remained quite significant. Among the examined female competitors the winners presented the smallest differences. The Polish swimmer was better coming 0.03 sec before the German one. The smallest difference in the gained results was observed at the distance of 100 m in backstroke; the German gold female medalist lost to the Polish junior woman by the difference of 0.04 sec (0.06%). In the other examined groups, the better results were achieved by the German women, among the medalists the disproportion amounted to the value of 0.37% and among the finalists 0.75%. At the distance of 200 m in backstroke the Polish female competitors achieved better results in the group of the winners and medalists, where the difference amounted to 1.77% and 0.66% respectively (Tab. 3).

TABLE 3. The comparison of the level of the sports of female juniors Polish and German in 2004 – backstroke

Competition	Place	Poland	Germany	Comparison	
		$\bar{x}$ (sec)	$\bar{x}$ (sec)	*d* (sec)	*d* (%)
50 m	1	31.32	31.35	0.03	0.09
	1–3	31.83	31.40	0.43	1.37
	1–8	32.99	31.82	1.17	3.68
100 m	1	1:07.12	1:07.16	0.04	0.06
	1–3	1:08.13	1:07.87	0.25	0.37
	1–8	1:09.77	1:09.25	0.52	0.75
200 m	1	2:21.68	2:24.23	2.55	1.77
	1–3	2:24.65	2:25.61	0.96	0.66
	1–8	2:29.32	2:27.59	1.73	1.17

In the analysis of the results carried out in 2007 it was noticed that in all the examined events in backstroke the German female competitors prevailed. The biggest disproportions were visible among the gold female medalists throughout the event. The difference in the scores of the gold female medalist from Germany amounted to 2.6% at 50 m, 3.2% at 100 m and 3.9% at the distance of 200 m in backstroke respectively. The disproportions among the medalists are smaller and do not exceed 2% (Tab. 4). However, it should also be emphasized that the average time of the medalists at all the distances in backstroke was better or similar to the results gained by the Polish female winners in this event. Such a big difference at the sports level between the junior women from Germany and Poland indicates a small improvement of the results among the Polish female representatives in the period of three years of training.

TABLE 4. The comparison of the level of the sports of female juniors Polish and German in 2007 – backstroke

Competition	Place	Poland	Germany	Comparison	
		$\bar{x}$ (sec)	$\bar{x}$ (sec)	*d* (sec)	*d* (%)
50 m	1	30.6	29.8	0.8	2.60
	1–3	31.1	30.8	0.3	1.00
100 m	1	1:05.8	1:03.7	2.1	3.20
	1–3	1:06.8	1:05.9	0.9	1.30
200 m	1	2:21.9	2:16.3	5.6	3.90
	1–3	2:22.4	2:19.9	3.9	1.77

SUMMARY

Analyzing all the freestyle events in 2004, a strong disadvantage at the sports level of the German female swimmers in comparison to the results gained by the Polish female competitors was noticed. It is most visible at the distances of 50, 100, 400 and 800 m, where the average time of the German female swimmers occupying the places 1–3 appeared to be better than the results of the Polish female winners of these chases. The Polish junior women only in the group of the winners and medalists of the 200 m event in freestyle show a better sports level than the German junior women. In the analysis of the results 2007 year it was manifest that the German female swimmers achieved a better sports level only at the distances of 50 and 100 m in freestyle. The biggest differences were seen at the shortest distance in both examined groups. However, at the distances of 200, 400 and 800 m in freestyle, the Polish female competitors achieved a remarkable advantage in sports results. This dominance was observed especially at the distance of 800 m, where the disproportion between the Polish and German female competitors exceeded 2%.

Comparing the results gained at 50, 100 and 200 m in backstroke in 2004 it was noticed the advantage none of the team. The Polish women appeared to be better in four groups out of the nine under study, whereas the German female swimmers in five groups. The biggest advantage gained the Polish junior women at the distance of 200 m, where among the winners the difference separating both female competitors amounted to 2.55 sec (1.77%). The comparison of the results made in 2007 showed that the German female competitors dominated in all the examined events in backstroke. The biggest differences were observed among the gold medalists in the whole event. The results gained by the Polish junior women reflect, unfortunately, the poor performances of the Polish competitors in backstroke on the international arena.

The presented research indicates the advantage of the German junior women in typically fast events (sprint), in which oxygen-free sources of gaining energy predominate. The German women dominated definitely at the distances of 50 and 100 m in freestyle and backstroke. It seems that it is worth making an analysis of training plans and programmes followed by competitors specializing in the distances of 50 and 100 m, in which certain changes should probably be introduced. For years (apart from the performances of Bartosz Kizierowski, who trains in the USA) we have not gained successes in the international competition in fast events. For the last years we have gained significant successes in longer distances (200, 400 m), which confirms the performances of Otylia Jędrzejczak and Katarzyna Baranowska. In the present comparative assessment similar tendencies can be also noticed because the examined group of the female competitors gained definitely the better results at the longer distances. It allows one to expect successful performances in the sports competition of female swimmers specializing in the distances of 200, 400, 800 m in freestyle.

CONCLUSIONS

1. Both in 2004 and 2007 the lower sports level of the Polish junior women was noticed in the most analyzed events.
2. The biggest differences between the German and the Polish female competitors were observed at the distances of 50, 100 and 800 m in freestyle in 2004.
3. In 2004 in backstroke the higher sports level of the gained results among the Polish junior women in the group of the winners and the medalists was noticed, but these differences at the sports level of the female representatives of the compared countries were negligible.
4. In 2007 the German female swimmers gained definitely better results in all backstroke events.
5. In 2007 the Polish junior women dominated at the distances of 200, 400 and 800 m in freestyle.

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Modelling Leg Movements and Monofin Strain Towards Increasing Swimming Velocity (Preliminary Attempt)

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ABSTRACT: The aim of the study was to analyse leg segments displacement and monofin strain in terms of propulsion efficiency. It was assumed that the application of Artificial Neural Network enables one to determine precisely brackets within which the leg segments displacement and monofin strain will achieve optimal scope to gain maximal swimming speed. The response of network pointed 10 parameters. Those chosen for the analysis are: foot flexion angle towards shin, proximal fin part flexion angle towards foot, attack angle of the distal fin part, attack angle of fin surface. The comparison of network response graph with the results of the real movement analysis validates the results in the modelling sense. Vast network capabilities in developing the analysis with new cases allow one to apply the model to monofin swimming technique assessment.

KEY WORDS: swimming, monofin, modelling, Neural Networks, kinematics

INTRODUCTION

The study is to establish an efficient and economical monofin use in gaining maximal swimming velocity. The essence of monofin propulsion has been explained with the use of kinematic (Colman et al. 1999) and dynamic (Rejman et al. 2003) analyses. Kinematic (Shuping, Sanders 2002) and dynamic (Rejman 1999) criteria of the monofin swimming technique have been specified. Wu (1971) among others created models of the analysed technique. Only partial applicability of those works created a need for a functional model of monofin swimming technique. Model construction is based on the results generated by Artificial Neuronal Network (Rejman, Ochmann 2007). The utility of the Neural Network as a modelling method is based on the correlation between describing and described variables in dynamic processes of probabilistic nature. This makes it a useful tool in sports research. Neuronal Networks were used in modelling traditional swimming technique (Edelmann-Nusser et al. 2001). Two-dimensional structure of propulsive movements where monofin is the only source of propulsion (Rejman 1999) facilitates modelling of the monofin swimming technique.

Functional model of the monofin swimming technique (Rejman, Ochmann 2007) was represented by physical formulas and described the kinematic parameters and their combinations which determined the maximal monofin swimming speed in the aspect of using in the training technique.

The aim of the study is to develop a functional model as a tool in monofin swimming technique assessment by assigning numerical form to certain technique parameters. A precise determination of optimal feet displacement and monofin strain points towards a model aspect to increase monofin swimming efficiency. Optimisation criteria will be connected with propulsive movement modification to gain maximal speed during both movement cycle phases and limit velocity decrease in the movement cycle. The obtained high level of intra-cycle velocity stabilisation will create the basis for maximal swimming speed.

MATERIAL AND METHODS

The research was carried out in two stages. Eleven volunteer male swimmers took part in both of them. They were 15–18 years old and displayed a high level of swimming proficiency. At the first research session swimmers swam 25 m underwater at a maximum speed. At the second one they covered 50 m. During both sessions the swimmers were filmed underwater, with the assumption that they move only in the lateral plane (Rejman et al. 2003). Kinematic analysis of the movements was carried out using the SIMI® Analysis System (Rejman, Ochmann 2007). The results represented leg and monofin flexion angles and angles of attack of the monofin surface parts (and their derivations). The data were used as input variable for the Neural Networks. Horizontal velocity of the swimmer's body mass centre in a separated cycle was calculated. The first 23 variables were used to define model relations against the output variable (Horizontal velocity of the swimmer) (Rejman, Ochmann 2007). After the second stage the input variables were reduced to 16 parameters pointed out by the network in the first stage. The network chose all of input parameters but only 10 were associated with monofin swimming speed. The following parameters were chosen for a further analysis on the account of significant influence on swimming speed and convenient measurement and interpretation: foot flexion angle towards shin (α_{ankle}) proximal fin part flexion angle towards foot (α_{tail}), angle of attack of the distal part (β_{distal}) and angle of attack of the entire surface of the monofin ($\beta_{surface}$).

The same procedure was employed for the Artificial Neural Networks construction in both stages of modelling the monofin swimming technique. In the selection of a genetic algorithm Generalized Regression Neural Networks and Probabilistic Neural Network (Speckt 1991) were used. From several tested models the best one, with the fewest mistakes, was chosen. The model's development was based on multi-layer perception (Bishop 1995). The network's training process was based on a back propagation algorithm (Patterson 1996). Based on the training set, the neural net model was constructed. The validation set was a basis for the network's 'learning' results check. The testing set enabled one to assess network quality. For the preliminary interpretation of the network model, sensitivity analysis and regression statistics were used. Response graphs were used to display graphically particular correlations between input and output variables.

RESULTS AND DISCUSSION

Standard deviation values indicate the division boundaries within which the angle changes regarding leg segments displacement and monofin strain take optimal values in terms of possibilities of gaining maximal swimming.

The same group of swimmers was examined in both stages of the experiment; under the same conditions with the use of the same research tools like Neuronal Network of identical construction. The network used in the present study generated very similar results indicating the same parameters as in the first version. The results of network answers (Fig. 1) correspond with the swimmer's movements record and its kinematic characteristics (Fig. 2) Thus, there is a basis for verification of the applied method.

The results specifying the optimal scope of feet displacement (α_{ankle}) signal that in order to gain maximal velocity during the upward movement phase it is essential to decrease the dorsal feet flexion (–20^{o}) from its parallel position towards the shin

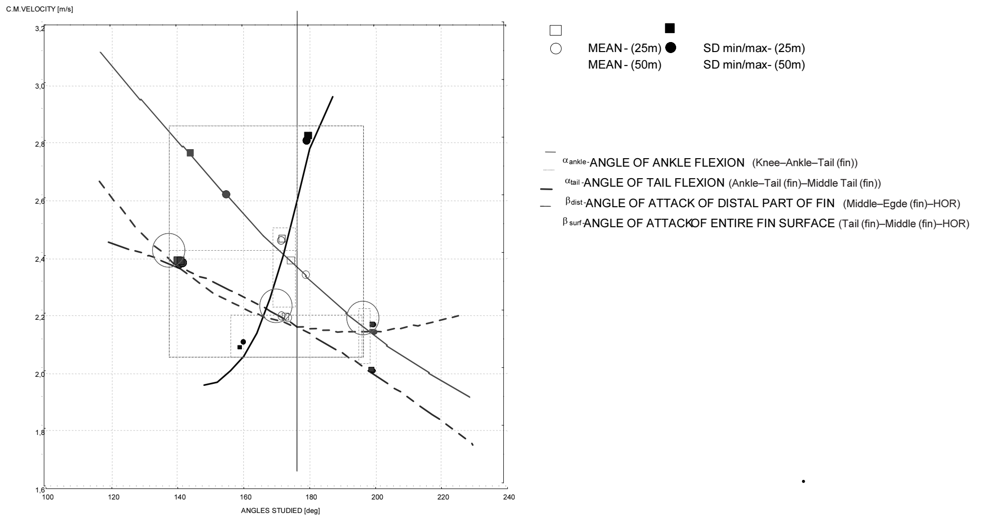
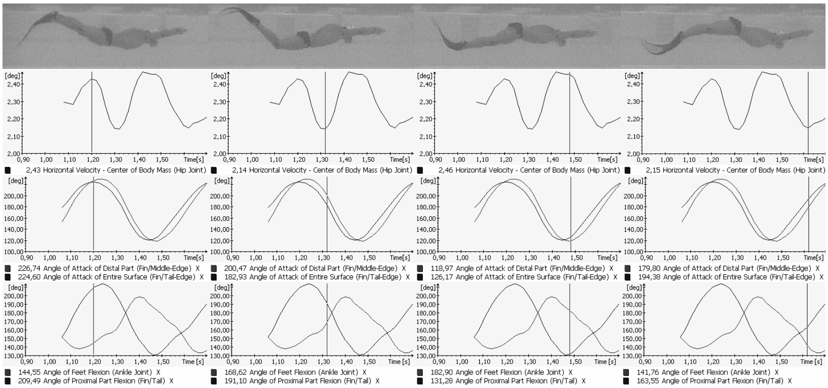


FIGURE 1. Network response diagrams illustrating borderlines (marked by the standard deviation values) in which the analysed angular parameters of leg segments displacement and monofin strain take optimal (model) values in terms of possibilities of gaining maximal swimming speed



A B C D

FIGURE 2. Real swimmer's movement illustration recorded during the research and corresponding characteristics of the analysed angle leg displacements and monofin strain in the fragments of movement cycle essential in terms of swimming velocity

(180^{o}). Whereas during the downward movement plantar flex should not exceed 180^{o}. In both propulsive movement phases maximal swimming velocity corresponds with placing the monofin segments in one line at optimal attack angle (Fig. 2ACD). Thus, maximisation of the monofin surface at optimal attack angle decides about propulsion efficiency. Standard deviation values point at the following optimal monofin segments strain: α_{tail} 35^{o} in the downward movement phase and (–)27^{o} in the upward movement phase, β_{distal}, $\beta_{surface}$, 37^{o} in the downward movement phase and (–)26^{o} in the upward movement phase.

The results interpretation towards maintaining maximal velocity within the cycle requires from the swimmers earlier initiation of the feet upward movement (with knees straightened) in order to avoid monofin position parallel to swimming direction. The only way to maintain maximal velocity in the upward movement phase is the optimal extension of leg lift time (with knees straightened) at optimal feet dorsal flexion.

Positioning the monofin at a proper angle of attack influences swimming speed. The comparison of the monofin and fish movements confirms the importance of lift and thrust in effective propulsion (Wolfgang, Anderson 1999). In unsteady flow, the trajectory and the shape of the fin is dominated in inducing vortices (Ungerechts et al. 1999). The angle of attack is an important factor determining the direction of movement of added water mass. When pushed backwards this creates an additional source of propulsion (Colman et al. 1999) favouring maintaining high swimming velocity. Minimal velocity in the subsequent cycle phases appear when the tail and the edge are connected with a straight line parallel to swimming direction (Fig. 2BD). There is no basis to generate propulsion in such conditions. The least favourable monofin position from the propulsion efficiency point of view takes place during transition from upward to downward movement phase and vice versa (Colman et al. 1999). The minimal velocity in the movement phase is also the lowest velocity in the cycle. Unfavourable monofin position in this phase is accompanied by shin flexion at the knee joint which facilitates laminar water flow over the monofin. Additionally, upward shin movement (the same as swimming direction) arouses resistance.

Gavilán et al. (2006) confirms suggestions as to velocity decrease limit in the movement cycle. He proved that as a result of undulatory movements accompanied by wave resistance, the shape of the fin surface changes causing a negative phenomenon. In order to minimize this, it is necessary to minimize the amplitude of monofin movements while increasing stroke length. Minimising movement amplitude results also in reducing time of positioning the monofin in streamlined position. Delay in starting the knee flexion helps to minimise swimming velocity decrease in the upward movement phase (Rejman 2006).

Feet displacement and monofin strain in order to generate propulsion can be interpreted by analogy with fish movement. Eel-like movements are characterised by sinusoidal trajectory of all body segments displacement (Vilder 1993). In model sense equal propulsion forces proportions are maintained during both cycle phases (Rejman 1999). 'Perfection' of fish swimming ability credits the postulate to optimise kinematic propulsive movement structure towards stabilisation of high intra-cycle velocity which is a condition to gain maximal swimming speed.

CONCLUSIONS

Reliability of the applied methods and reality of the results achieved on the basis of Artificial Neural Network justify model interpretation of the selected monofin swimming technique parameters. Large calculation network potential in developing the analysis with new cases is the point of departure for applying model solutions in monofin swimming technique assessment. The results focus on the need to minimise feet movement in the ankle joint during propulsive movements in order to maximise swimming speed. Monofin segments strains reduction during the downward movement and increasing the upward movement scope with straightened knees correlates with minimising propulsive movement amplitude. In such conditions there exists a basis to gain constant high intra-cycle velocity being the condition of maximal swimming speed.

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Overload of the Ankle Joints during Mono-Fin Swimming – Mechanism and Diagnosis

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ABSTRACT: The aim of the study is to diagnose a potential foot adaptation mechanism leading, in certain circumstances, to development of chronic joint illnesses in the ankle joint area. The mono-fin straining forces, flexion changes in the ankle joints in one movement cycle were recorded. Additionally, feet maximal plantar flexion on land was measured ($N = 36$). The maximal straining of the mono-fin evokes increasing the angle of foot plantar flexion which leads to the overload of the tendons and joints stabilising muscles. These large loads during mono-fin swimming stimulus adaptation phenomena can appear in the ankle joints. The simple elements of the strategy leading to limiting the risk of overload in the ankle joints while mono-fin swimming, were pointed out.

KEY WORDS: swimming, mono-fin, ankle joints, overloads

INTRODUCTION

The mono-fin swimming technique constitutes, according to the rules, activity in water aiming at the efficient and economical use of the fin surfaces, being the source of propulsion. Mono-fin swimming technique consists of performing oscillating movements by particular body segments, on one's chest, in the sagittal plane. The scope of these movements increases towards the centre of the swimmer's body mass, and further in the direction of the legs (Rejman 2001).

The ankle joints constitute the transfer axis of the muscle torque to the mono-fin, which is the source of propulsion (Rejman, Ochmann 2007). Because of the fin surface size as well as the propulsion structure, the ankle joints are exposed to substantial overload. Therefore mono-fin swimming is an example which clearly shows the threats resulting from irrational and unreasonable usage of the loads in this swimming event. The control of swimming training aimed at prevention of the ankle joint overload is omitted in practice. Thus, the aim of the study is to diagnose a potential feet adaptation mechanism leading in certain circumstances, to development of chronic joints illnesses in the foot and especially in the ankle joint area.

Biomechanical analysis allows one to monitor the process in which the force of water resistance on the mono-fin affects the foot and its flexibility. The research (Rejman et al. 2002; Rejman, Wiesner 2006; Rejman, Ochmann 2007) shows that there is a close correlation between the force of the mono-fin surface straining and the angular scope of foot plantar and dorsal flexion. The resources also give a vast amount of information about the influence of the scope of flexibility in the ankle joints on the swimming efficiency in the case of standard swimming techniques (Soons et al. 2003). On this basis, it is possible to assume that in the swimming sports and in case of the mono-fin swimming in particular, the forces of water resistance affecting the feet (the fin) as the result of the propulsive movements increase the scope of flexibility in the ankle joints.

Periodically increasing overload in the training process can lead to pathological conditions, resulting from the developing instability in the joints. There are numerous arguments confirming that ankle joint instability is a pathogenic factor in the problem of frequent sprains or twists. These minor injuries are often disregarded. The awareness of the results of negligence in the treatment of minor injuries is quite low among the competitors, their parents and trainers, and it is manifested by applying only temporary first-aid treatment designed to keep the swimmer in the training process. Desisting from specialist treatment in this overload stage leads to deeper pathological changes such as ankle joint osteochondrosis dissecans, which leads to damage of the joints hyaline cartilage. Having reached that stage, specialist treatment is inevitable and consequently a break in training is also required. Belittling the threat, late diagnosis or the overload of treatment inattention can lead to deepening pathological changes and development of degenerative changes in the ankle joint area. The irreversible character of those changes terminates individual sportsman's career.

MATERIAL AND METHODS

Research material was collected in experiments carried out with the participation of members of Polish Mono-fin Swimming Team (*N* – 36). Swimmers from the same group, characterized with similar body composition (Tab. 1), age and swimming experience took part in all trials. The research task was the swimming of one lap (50 m) by each swimmer at a subjectively appointed maximal speed.

TABLE 1. The data describing the organisation of experimental tests constituting the basis for analysis (the numerical data of groups and similarity of the somatic parameters defined on the basis of standard deviation)

Experimental trial	Number of subjects	Body mass	Body high
I	16	Av. 76.3 kg	Av. 1.845 m
II	11	SD 6.2	SD 0.043
III	9		

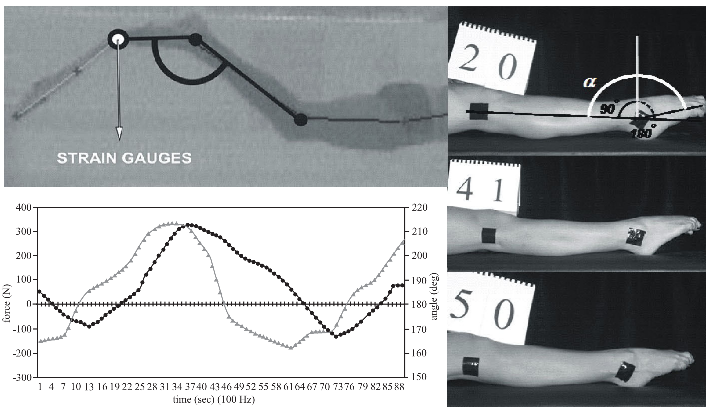
The tracking of measurements allowed the register of real time data on the dynamic parameters of the mono-fin movements as well as the kinematical parameters of the leg segment movements. The force of the mono-fin's straining in the reaction to water resistance was registered by means of strain gauges placed at the fin's tail (Fig. 1) and coupled with a multichannel bridge and computer. The gauge signal was processed into a record of the mono-fin straining force in the time function (Rejman et al. 2002). The kinematical data was obtained by underwater filming of the swimmers and analysis of the digital picture in the movement analysis system (SIMI®) (Fig. 1). The parameters of the camera as well as the filming procedure corresponded with standards of such analyses (Rejman et al. 2003). Records of changes in the ankle joint flexion in the time function during swimming were used in the study.

The basis for analyses were records of the mono-fin straining force, synchronised in time, as well as record of flexion changes in the ankle joints area in one movement cycle. Additionally, measurements of feet maximal passive plantar flexion on land were taken from the swimmers. The flexion scope of the ankle joints was measured in regular conditions (before training) and after the joint loads (Fig. 1).

All experiment trials were carried out under the same conditions and with the use of the same equipment. Reliability of the results reached in individual trials can be confirmed by the similarity of the correlation coefficients average between recorded forces and flexion in the ankle joints as well as between the considered angles and the horizontal components of the velocity of the centre of the body mass while swimming (Tab. 2).

A

B



C1

C2

C3

FIGURE 1. A – Procedure of the mono-fin straining force record in the reaction to water resistance. Illustration of the strain gauges location and illustration of the measurement of the scope of angular changes in the ankle-shin joints. B – Synchronised in time records of the mono-fin straining force (darker line) and angular changes in the ankle-shin joints (lighter line) in one movement cycle. C – The procedure of marking maximal scope of plantar flexion in the ankle-shin joints (C1), maximal scope in regular conditions (before training) (C2), and after training load of the ankle-shin joints (C3)

RESULTS

TABLE 2. The value of correlation coefficients illustrating proportional relationships appearing between the mono-fin straining force in the reaction to water resistance and the ankle-shin joints flexion. The value of correlation coefficients between the considered angles and the horizontal components of the velocity of the body mass centre movement while swimming completed with the cross correlation value for the considered parameters and the quotient value of the standard deviation calculated with the use of artificial neural networks. The value of maximal foot plantar flexion while swimming and when measuring the passive plantar flexion on land – before training and after training load

Ankle joint angle – swimming velocity							Ankle joint angle – dry land test	
Experimental trial	Av. correlation C. Force–velocity	Av. correlation C. Force–angle	Av. correlation C	Av. cross correlation C	Ann quotient	Av. maximal ankle joint angle swimming test	before training session subsequent swimmers	after training session subsequent swimmers
I	0.5	0.75	0.52		6.333	187°		
II	0.64	0.73	0.63	0.69		191°		
III	0.6	0.64	0.56			190°	172°–174°–176° 173°–174°–173° 174°–174°–172°	176°–177°–176° 176°–175°–175° 174°–176°–176°

DISCUSSION

The results of the biomechanical analysis allow one to form a conception of a potential adaptation mechanism in the ankle joint area, which is conductive to overloads being the result of irrational, unreasonable coaching of mono-fin swimming.

Table 2 shows the crucial relationship between swimming velocity increase and the growth of force generated on the mono-fin. Uncritical interpretation of this relationship in the context of gaining maximal swimming speed means striving for maximisation of muscle torque transferred from the feet onto the mono-fin. Utilising water drag makes it much easier to generate a large propulsion force in the case of downward fin movement (Rejman 2001). The maximal straining of the mono-fin evokes reactions such as: increasing the angle scope in foot plantar flexion which leads to the overload of the tendons and ankle joints stabilising muscles. Here it is necessary to point out that large foot flexibility is an important factor in gaining maximal swimming speed. This is confirmed by analyses based on cross correlation coefficient determination (Tab. 2). Calculations received with the use of neural networks have similar significance. The high value of the standard deviation quotient stresses the meaning of the angle describing ankle joint flexibility during propulsion generation (Rejman, Ochmann 2007).

It seems that large loads on the ankle joints during mono-fin swimming are unavoidable, and as a consequence of periodic training, stimulus adaptation phenomena can appear in their area. What is more, comparison of maximal passive foot plantar flexion value (before training) in the case of the competitors examined, with the results of similar tests carried out on the population of swimmers and non-swimmers, provides information about that adaptation (Tab. 2).

The values recorded during the present research (172°–176°) correspond with the values recorded in the group of highly rated breaststroke swimmers (167°–176°) (Soons et al. 2003). The lack of significant differences with regards to ankle joint flexibility, suggests the similar character of the adaptive nature of them in mono-fin, as well as breaststroke swimming. The extent of adaptation in the ankle joints area becomes visible only with a comparison of the scopes of maximal passive foot plantar flexion between the groups of mono-fin swimmers and non-swimmers (140°–150°) (Soons et al. 2003). The results of the comparisons presented bear a question as to whether the scope of foot flexibility in the plantar flexion observed in the group of mono-fin swimmers is a manifestation of functional adaptation, or should be considered as a pathogenic factor caused by overload.

Many scientists conclude that almost all joint hyperflexibility syndromes can lead to joint instability. In the case of the ankle joint, instability is usually caused by plantar hyperflexion. In a situation, where mono-fin movements constantly increase the plantar flexion, the work conditions of muscles, tendons and ligaments are changing. Consequently, the neurological mechanisms of movement-control are disturbed. There are changes in reflex muscle activity and, in consequence, ligaments take on the main role in joint stabilization. The chronic state described above leads to changes in the elasticity and geometry of the ligaments. This instability increases the frequency of ankle sprain incidents. Additionally it overloads the rear segment of the joint surface. This situation is very rare under normal conditions. This overloading (stress) often leads to damage of joint hyaline cartilage – for example osteochodrosis dissecans or chondromelation. These diseases are very often career ending.

As far as we know, there are very few publications about ankle joint injuries in swimmers, and there are none describing mono-fin swimmers. Probably this can be due to the relatively small population of people involved in this sport. The fact is that in this type of activity, the forces acting on the feet are very strong and change the biomechanical conditions of the ankle joint. Ankle hyperflexion is an example of an adaptation process but sometimes it can also become a pathogenetical factor.

Implementation of the studies' objectives entails the necessity of forming concrete prophylactic activities eliminating the risk of ankle joint overload in mono-fin swimmers. Suggestions applying to rationalisation of technical training in the direction proposed are a result of the conviction that aiming to achieve maximal mono-fin straining, does not directly determine maximal swimming velocity. Research on the dynamic criteria of the quality of mono-fin swimming technique proved that the model curve depicting mono-fin surface straining forces in the time function is very similar to sinusoid shape (Rejman 2001). The above means that the factor deciding the quality of propulsion force technique on the fin surface, is its stability manifested in the equal values of the force generated by means of the up-and-downward fin movement, as well as equal time ratio in both phases of the movement cycle (rhythm). Implementation of the criteria quoted in respect to an overload prophylactic, where the overload results from excessive foot plantar flexion, is based on the concept of reducing forces applied in the downward fin movement and on the improving the technique of the upward fin movements, by limiting the bending of knee joints (Rejman et al. 2003). While it has been proved that the amplitude and frequency of the undulatory propulsive movements of the lower limbs correlated noticeably with large ankle joint flexibility as factors determining swimming speed (Alley 1953; Thrall 1960; Barthels, Adrian 1971; Ungerechts et al. 1998) – the unambiguous criteria of the optimisation of mono-fin movement time structure, have not been specified so far. It is common knowledge, however, that limiting the amplitude of the propulsive leg movements to 34.31–36.58% of the swimmer's body length (Gavilán et al. 2006) and maintaining an adequately high frequency of movement (Barthels, Adrian 1971; Jayne, Lauder 1995) are qualities that distinguish outstanding, highly rated swimmers.

CONCLUSIONS

It has been indicated in the study that there are simple elements of the strategy leading to limiting the risk of overload in the ankle joint areas during mono-fin swimming, along with consistent implementation of the aims connected with improvement of competitive results. These findings lead to the conviction that in the prophylaxis of ankle injury the proper construction of the training cycle and proper technique are of the utmost importance. Trainers should be responsible for this. Sports medicine physicians should focus on the identification of the endogenous factors of injuries, early diagnostics and relevant treatment. The example of mono-fin swimming shows that knowledge concerning threats resulting from irrational steering of the training loads as well as the awareness of the necessity to implement prophylactic activities constitute essential elements in the humanization of the training process.

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