SCIENCE IN SWIMMING VI

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PREFACE

If we think about it, we cannot help the feeling that no interlocutor can ever surprise us with any general knowledge learned in school, from books, family or, generally speaking through social interaction if we accept, a priori, the emergent methodology of constructing scientific hypotheses devised by K. Popper, T.S. Kuhn and P. Feyerabend, which could be described as one based on “deducing from context and negotiating with context”. We are not talking about a guessing or quizzing game meant to do away with independent thinking. It simply lays the basis for greater stability, coordination, fluid and synchronized action necessary to achieve precise hand movement, including graphomotor skills, as well as improved gross motor skills. Independent thinking is the domain of science while verifying the veracity of a hypothesis bears testimony to methodological expertise and the ability to word concepts. Our “Science in Swimming” monography is entirely destined to students AND unquestionable figures of authority. And that changes everything. Its greatest upside is that it approaches knowledge or even its verification quite amenably. The “Great Ones” have always stated their willingness to extend a helping hand to the young and the latter have accepted it gladly. All we wish for is for things to go on that way. Judging from previous results – the work already published – we are quite sure that the initial idea lingers on.

We take this opportunity to tank all the authors who contributed to these papers. A special thanks goes to the reviewers. We would also like to express our gratitude to the sponsors.

Prof. Krystyna Zatoń
CHAPTER I

PHYSIOLOGY AND BIOMECHANICS IN COMPETITIVE SWIMMING
What is expectable from VO2 kinetics at different swimming intensities?

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ABSTRACT

Oxygen uptake (VO2) kinetics at diverse exercise intensities has already been described before but mainly centred on laboratory conditions (treadmill running and cycloergometry), not during swimming in a regular pool. A detailed description of the VO2 kinetics at low-moderate, heavy, severe and extreme swimming intensities will be presented, focusing on its parameters (amplitude, time delay and time constant), as well as relating it with blood lactate concentrations and heart rate. It will be shown that when swimming at (or under) the anaerobic threshold, VO2 rises in an exponential fashion and then reaches stabilization (as the blood lactate concentrations and heart rate do). However, when swimming intensity increases, and a physiological steady state is no longer observed (the blood lactate concentrations rises exponentially evidencing a relevant anaerobic participation), VO2 primary component speeds up and a VO2 plateau does not appear anymore, emerging a VO2 slow component. When swimming even faster, the VO2 trend is similar but it will lead to a more expressive amplitude of the VO2 slow component, allowing reaching VO2max values. When swimming above the VO2max intensity, on typical anaerobic intensities spectrum, VO2 kinetics only present a (very) fast rise that ends abruptly due to exhaustion. Here, swimmers are not able to reach their VO2max, but attain very high blood lactate concentrations. We consider this knowledge very important for obtaining more objective training programmes (particularly when building training sets) and evidence the importance of systematic training control and swimmers evaluation and advice.

Key words: swimming, VO2 kinetics, exercise intensity domains

INTRODUCTION

Swimming is a complex, continuous, cyclic and individual sport, where physical conditioning has an evident contribution in achieving high level performances. As
Olympic events last between ~20 s to 15 min, it is evident that competitive swimming in general depends on both aerobic and anaerobic energy delivery (Gastin 2001). Therefore, the assessment of the energy available for muscular work is a very important measure to help increase the efficiency of training methods and to achieve high standard goals. Swimmers’ energy expenditure should be examined, evaluating both aerobic and anaerobic energy sources (Fernandes et al. 2006), the former by assessing oxygen uptake (VO₂) and the latter by determining blood lactate concentrations ([La−]). The assessment of the ATP-CP contribution has no tradition in swimming, since the phosphagen stores have reduced capacity (with low relevance in most of the competitive events; Capelli et al. 1998), but also because a muscular biopsy is a very invasive procedure and hard to accomplish on regular basis.

The specific VO₂ dynamics at low-moderate, heavy and severe exercise intensity domains has been described before, but mainly in well controlled environments, particularly using recreational sportsmen exercising in laboratory, i.e., on treadmill and cycloergometer (see Carter et al. 2000 for a review on the topic). The extreme intensity domain was much more recently described (Hill et al. 2002) but VO₂ related studies conducted in field are very scarce. Knowing that swimmers outcome is directly dependent on their total energy input (di Prampero et al. 1974; Pendergast et al. 1977) and that it varies in-between land/aquatic environments, vertical/horizontal body positions and type of musculature used, we will conduct a physiological characterization of a large spectrum of intensities when swimming freely in a swimming-pool. This will be done by presenting the VO₂, [La−] and heart rate (HR) kinetics along rectangular and incremental protocols conducted in standard swimming pools, using preferably populations of front crawl high-level swimmers.

DEVELOPMENT

VO₂ assessment in swimming was only implemented on a regular basis in the 1970s due to previous methodological difficulties like the incapacity to follow the swimmer along the pool, the heavy and hard to carry equipment and the increased drag imposed by the respiratory snorkel and valve systems (Sousa et al. 2014a). In the pioneer studies, expired air was collected in Douglas bags, a procedure which was used to a great extent in the 1980s but remaining still operational in our days. However, these devices have several limitations, once they are very difficult to handle during free swimming and the complexity of the posterior analysis of the relative O₂ and CO₂ concentrations. The necessity for better evaluation techniques that could be used during swimming training and competitions has led to the development of VO₂ assessment portable and automated systems, allowing less demanding procedures. These new apparatus also permit obtaining values in real time during the exercise, not only during the recovery phase after exercise (a common practice when using fixed oximeters; see Laffite et al. 2004). As a result, researchers have a better control of what is going on and can give immediate feedback to the coaches and swimmers.

As few VO₂ kinetics related studies were conducted using portable telemetric systems that allow breath-by-breath analysis of well-trained swimmers performing in ecological swimming conditions, our research group has focused on measuring its expression (concurrently with the HR) over the whole duration of swimming exer-
exercise. This has been done in the last 20 years by evaluating swimmers of different levels and genders in swimming conditions similar to those of training and competition since we believe that laboratory testing procedures are inadequate to estimate the specific swimmers’ physiological characteristics (Fernandes et al. 2013). In our first studies (Fernandes et al. 2003a; Fernandes et al. 2003b), we used a computerized metabolic system fitted with a mixing chamber, giving 20 s time averaged values for respiratory variables, that ran on a special chariot that accompanied the swimmer along the swimming pool. This approach was based on the PhD study of Vilas-Boas (1993), divulged to the technical and scientific swimming communities at the 10th FINA World Sport Medicine Congress in Kyoto (Vilas-Boas and Santos 1994; Figure 1), who assessed the energy cost of different breaststroke swimming variants, probably the first attempt in the world to assess VO2 during free swimming in a pool (not in a flume) without using the Douglas bags.

Afterwards, to avoid the discomfort of the weight of the oximeter and its pulling along the swimming pool side, the equipment was upgraded, becoming automated portable VO2 measurement devices with a telemetric portable gas analyser available nowadays (Figure 2).

This enabled monitoring of VO2 (and other ventilatory parameters) at smaller intervals, allowed collection of breath-by-breath data and led to a better examination of small changes in VO2 compared to measurements with lower sampling frequencies. The K4b² has been used frequently in the last decade or so, but the new K5 (the 4th generation of the most popular wearable metabolic system, both from Cosmed, Rome, Italy) seems to be a breakthrough in the field of exercise physiology and human performance assessment. Firstly, the K4b² was transported by the researchers walking on the lateral wall following the swimmer along the pool, but nowadays it is suspended over the water in a steel cable, allowing a more effortless VO2 assessment and minimizing the disturbances of the normal swimming movements (Fernandes et al. 2012; Sousa et al. 2011).

The gas measurement devices were attached to respiratory snorkel and valve systems, with the inspiration and expiration tubes situated in the front of the head,
not adding significantly to the total drag of the swimmer (as recently confirmed by Ribeiro et al. 2015a, in opposition to popular non-confirmed believes). In our first studies, we used Toussaint’s respiratory snorkel and valve system (Toussaint et al. 1987), but afterwards we changed to an upgraded swimming snorkel and valve system that enabled breath-by-breath data collection in ecological conditions (Keskinen et al. 2003). Then, we started to use a new Aquatrainer II snorkel and valve system (Cosmed, Rome, Italy), which is nowadays probably the most used instrument for real time expired gas acquisition during swimming (De Jesus et al. 2014; Sousa et al. 2014a; see Figure 3). This apparatus was partially developed, tested and validated in our swimming pool and laboratory, allowing great precision and better temporal resolution (Baldari et al. 2013).

HR assessment in swimming has been done for a long time, mainly for the training sets intensity control, being most frequently assessed through palpation of the neck.
or wrist during the first seconds of recovery (Maglischo 2003). As the carotid and radial arteries are not easily found through palpation, the pulse rate is hard to count accurately (when beating more than one time per second) and some rest periods are very short, HR began to be assessed during swimming through telemetry. First attempts by our research group were conducted in the 1980s using ECG telemetric systems (Vilas-Boas 1990), but the advent of easy to wear and low-cost telemetric HR monitors rapidly allowed for new opportunities. When assessing simultaneously both VO₂ and HR, we started to record continuous HR data every 5 s (Fernandes et al. 2005), with these parameters being nowadays better paired by using a Polar chest belt connected to the K4b² portable unit (Baldari et al. 2013; Fernandes et al. 2012).

During some decades, VO₂ and HR were considered the best parameters for characterizing swimmers’ endurance capacity, but some researchers pointed out that these were not sufficient for the overall physiological assessment (Maglischo 2003; Olbrecht 2000). Therefore, since an anaerobic specific indicator was missing, [La−] determination has started to be frequently used for evaluating swimming performance and training control since the 1970s (Mader et al. 1978), although for many years enzymatic test procedures and analyses were reserved for big laboratories. The first study of our group was exactly with these more traditional chemical procedures (Vilas-Boas and Duarte 1991). In the 1980/1990s, portable automated lactic acid analysers were available, allowing a larger number of swimmers to take advantage of the tests. Our group has considerable experience in assessing [La−] in the final of rectangular tests and in-between steps of incremental intermittent protocols, using portable (e.g. Fernandes et al. 2010; Neiva et al. 2011) and enzymatic analysers (e.g. Barbosa et al. 2006; Fernandes et al. 2008). The hand-held analysers are purchased and operated at lower cost, requiring a smaller quantity of blood sample from the fingertip or earlobe and giving faster final results than the enzymatic analysers, but the latter have a broader measurement range.

Trying to overcome the limitation of having only the post-exercise [La−] at their disposal, di Prampero et al. (1978) proposed to observe the [La−] expression throughout an entire bout by performing the selected partials of a specific test distance, for example, repeating the 50, 100 and 150 m partials at the specific pace of a 200 m event (Figueiredo et al. 2011). This method was designated as blood lactate increasing speed (Vilas-Boas and Duarte 1991) and used as an indirect indicator of [La−] kinetics during swimming (Lafite et al. 2004). We find this approach truly interesting since it allows expressing the values of lactate released from the working muscles during swimming, permitting more accurate assessment of some determinant performance influencing parameters as the swimming energy cost (Barbosa et al. 2006; Capelli et al. 1998; Fernandes et al. 2006).

In swimming related books and coach manuals, exercise intensity is frequently defined by means of a single parameter of physiological function, particularly by using the % of VO₂max (or HRmax). In our opinion, this is an inadequate strategy since it is well known that the % of VO₂max at the anaerobic threshold varies widely (McLellan and Gass 1989; Messonnier et al. 2013). Thus, studying physiological responses to exercise at, for instance, 85% of VO₂max might result in some swimmers exercising below the anaerobic threshold and others at or above it. Therefore, we prefer (and suggest) the use of the dynamic behaviour of pulmonary gas exchange (especially VO₂) and [La−] during constant-load exercise to well define and
establish the low-moderate, heavy, severe and extreme exercise intensity domains (Burnley and Jones 2007; Hill et al. 2002).

The low-moderate exercise domain includes all swimming intensities below (and at) the anaerobic threshold that is defined as the highest sustained intensity of exercise for which measurement of VO\textsubscript{2} can account for the entire energy requirement and the rate at which lactate appears in the blood will be equal to the rate of its disappearance (Stegmann et al. 1981; Svedahl and MacIntosh 2003). At this intensity spectrum, VO\textsubscript{2} attains a steady state after the initial fast kinetics phase and there is no change (or only a transient increase) in [La\textsuperscript{−}] (Sousa et al. 2011). In fact, the anaerobic threshold is a boundary that represents the highest exercise intensity during which the balance between production and removal of lactate occurs, also known as lactate threshold and lactate turning point (Brooks 1985), expressing the development of the swimmers aerobic capacity (Heck et al. 1985; Simon 1997).

In Figure 4 it is possible to observe that when swimming at the intensity (or under) corresponding to the anaerobic threshold, VO\textsubscript{2} rises exponentially – the VO\textsubscript{2} fast component – taking 2–3 min to stabilize and then assuming a plateau for the rest of the exertion (de Jesus et al. 2015). This is the typical behaviour when undertaking training sets at the aerobic capacity training zone, particularly when carrying out continuous and extensive workouts.

When the swimming intensity exceeds the physiological steady state and the body is not able to maintain its homeostasis, VO\textsubscript{2} primary component speeds up and the VO\textsubscript{2} plateau is no more observed (Figure 4). This is a poorly known training zone, as it is situated between the anaerobic threshold and the VO\textsubscript{2max} intensities, representing the heavy and severe intensity domains. Some researchers suggest (e.g. Jones et al. 2010) that there is a well-defined boundary separating the heavy from the severe intensity domains – the critical power – but, by definition, as it represents the exercise intensity that can be sustained without fatigue (exhaustion occurs after about 30 to 60 min of exercise; Hill 1993), we find it much more related with the anaerobic threshold, i.e. the moderate intensity. So, the heavy intensity domain displays power outputs above the anaerobic threshold, starting to cause a significant accumulation of [La\textsuperscript{−}] over time and a notable VO\textsubscript{2} slow component leading to an elevated VO\textsubscript{2} response (Sousa et al. 2014a; De Jesus et al. 2015).

![Fig 4](image.png)

**FIGURE 4.** Illustration of the VO\textsubscript{2} kinetics at different swimming intensities
appearance of this VO₂ slow component phenomenon, superimposed upon the fast component, is probably due to the activation of fast twitch glycolic fibers (Zoladz and Korzeniewski 2001), but this needs yet to be further studied to have a solid confirmation, particularly in swimming.

In the severe intensity domain, the exercise intensity is much higher than at anaerobic threshold and neither blood lactate nor VO₂ values can be stabilized (Gaesser and Poole 1996), showing a pronounced VO₂ and a greater [La⁻] compared with the previous intensity (Burnley and Jones 2007; Pringle et al. 2003). During constant pace exercises at this intensity, after an exuberant VO₂ fast component caused by the need of oxygen by the body as the exercise proceeds, it continues moderately to increase until the point of exhaustion. Here, the VO₂ slow component has larger magnitude compared to the heavy intensity domain, allowing reaching VO₂max values (see Figure 4), reason why this exercise intensity domain is also known by aerobic power training zone. In fact, the VO₂ slow component has been commonly reported for heavy (Reis et al. 2012), but mainly for severe swimming intensities (Billat 2000; Rodriguez et al. 2003; Fernandes et al. 2008; Sousa et al. 2014b), where its magnitude can exceed 1 l · min⁻¹ and represent ≥ 25% of the total VO₂ increase above the pre-exercise baseline (Poole et al. 1994). As said in the previous paragraph, the cause of the slow component is still a matter of debate, with several different hypothetical causes for its origin although the selective recruitment of type II fibres gains more agreement.

When swimming above the VO₂max intensity, at the extreme domain – also known as the anaerobic capacity training zone – VO₂ kinetics only present a fast component, which rises in a very fast way and ends abruptly due to exhaustion (Ribeiro et al. 2015b). This fourth exercise intensity domain was proposed recently, accounting for short duration and very high intensity efforts at power outputs at which exhaustion occurs before VO₂max is attained (Hill et al. 2002). Here, there is not enough time for swimmers reaching VO₂max (see Figure 4), although the VO₂ values obtained are of a relevant magnitude for such short exercise durations. This intensity domain is very scarcely studied in swimming, which is odd since performing 50 to 200 m events (in-between ~20 s – 2 min efforts) involves the use of different metabolic pathways compared to those involved in longer swimming events (Olbrecht 2000). Two pioneer studies characterized the VO₂ kinetics at the 100 m (Rodriguez et al. 2003) and 200 m (Sousa et al. 2011) front crawl, being suggested that, even for short duration swimming events, there is a relevant aerobic energy contribution (Figueiredo et al. 2011; Peyrebrune et al. 2014). The [La⁻] are much more expressive than in lower intensity domains, with values that can reach 16 mmol · l⁻¹ at the 100 and 200 m events in anaerobically trained swimmers (Olbrecht 2000; Vescovi et al. 2011), expressing the use of the glycolysis at its maximal rate.

CONCLUSIONS

Although the physiological mechanisms responsible for the kinetics of VO₂, [La⁻] and HR, along the swimming intensities used in training and competition remain somehow obscure, we consider its understanding very important for reaching higher objectivity in training programmes, particularly in the construction of training sets.
REFERENCES


Effects of specific muscle strength development on the crawl swimming technique of physical education students

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ABSTRACT

The goal of the study was to verify the effect of three types of exercise training programs on the front crawl technique in non-professional swimmers. Participants, divided into three exercise groups: dry-water group (n = 3), water group (n = 3), dry group (n = 3), attended supervised exercise sessions twice a week for three months. Dry-water group improved stroke length in 25 m test by 2±0.1% and in 50 m test by 6±0.18%, stroke frequency in 25 m test by 3±8.0%, speed in 50 m test by 5±8.7%, strength of the upper limbs in 10 strokes test by 21±0.57%, and 50 strokes test by 16±0.12%. Water group improved speed in 25 m test by 7±0.9% and in 50 m test by 12±2.0%, strength of the upper limbs in 10 strokes test by 10±0.04% and in 50 strokes test by 18±0.05%. Dry group improved the strength of the upper limbs in 10 strokes test by 21±0.58% and in 50 strokes test by 31±0.29%. We suggest that a combination of dry-land and water exercise leads to development of crawl technique and upper limbs strength; dry-land exercise leads to the development of upper limb strength but deteriorates technical parameters in front crawl, and water exercise leads to an improvement in overall speed but deterioration of technical parameters in front crawl in non-professional swimmers.

Key words: biokinetic, strength training, stroke length, stroke frequency

INTRODUCTION

Muscle strength and endurance are the primary requirements for swimming performance. On the one hand, swimming performance is affected by the swimmer’s movement skill level (technique) and on the other hand by his or her movement abilities. The transfer of muscle strength into swimming locomotion and precisely into the swimming technique plays an important role in swimming performance, affecting the parameters of swimming stroke (stroke length, stroke rate and the speed of movement). The creation of propulsion in water always leads to a loss in mechanical force that is transferred as kinetic energy from the swimmer to the water. This means that during maximum performance, strength is used both to overcome the resistance of the environment and to propel the swimmer forward. It is also necessary to study the effects of strength training performed on land or in the water on swimming technique (Scott and Scott 2015; Hofer et al. 2012).
Many experts deal with the issue of the transfer of muscle strength and its influence on the swimmer’s overall performance. Their research has been primarily focused on measuring the swimmer’s specific strength while swimming or on the effect of dry-land strength training on swimming performance. Strength training on land primarily affects the general level of physical fitness. Strength training in water affects both performance and parameters of swimming techniques. The development of strength on dry land requires specific training; it means that the power exercise on dry land must resemble the movements carried out in the water. A strong swimmer may not be the fastest. Strength is a necessity, but not a sufficient condition for guaranteeing maximum performance (Cronin et al. 2007; Vorontsov et al. 2006; Gambetta 1999). Those studies indicate that dry-land training is related to performance over very short distances, but not over distances that require a great amount of aerobic energy consumption. Some studies have proven its minimal effect on monitored variables such as the distance swam over one movement cycle (Crowe et al. 1999).

Traditional strength training may be a valuable adjunct to the exercise program followed by endurance runners or cyclists but not swimmers since they need more specific forms of strength training to realize performance improvement (Tanaka et al. 1998). Further studies have confirmed that the effect of dry-land strength training is less significant than the effect of strength training performed in water. This means that these studies investigated the degree of specificity of individual exercises on the development of muscle strength that is closely related to swimming performance (Cronin et al. 2007; Breed et al. 2000; Cossor et al. 1999; Tanaka et al. 1998). Also, there is evidence that overall muscle capacity is related to swimming performance, especially to 100 m freestyle in female swimmers (Garrido et al. 2012). The importance of strength exercise on land is clear, but only the combination of strength specific exercises on land and water has the greatest impact on swimmer’s speed in events up to 200 m (Tanaka et al. 1998).

Tanaka and Swensen (1993) consider that the general development of muscular strength on land or combined muscle strength on land and in the water does not increase swimming performance in untrained swimmers. Based on this finding, we would like to determine the influence of dry-land strength training and water strength training on the speed of swimming and selected technical parameters of front crawl in the case of students attending the Faculty of Physical Education and Sport at Charles University (FPES CU) who did not have a long swim career. For our purposes, we distinguish three categories of exercise: non-specific exercises (on land, where the position of the body and stroking movements are not consistent with the body position and stroking movements of swimmers), semi-swim-specific strength exercises (on land, where the degree of specificity-body position and stroking movement is as close as possible to the motion stereotype of a given swimming technique, like “Biokinetics”), and specific exercises (in water, where the position of the body and stroking movements are similar to a given swimming technique).
MATERIAL AND METHODS

Twelve students (21 yrs., SD = 0.5; 77.9 kg, SD = 4.4; 180.6 cm, SD = 5.3) were selected from first-year male students (N = 60) of the FPES CU. Participants were divided into four groups on a random basis: dry-water, water, dry, and control (each one with N = 3). Informed consent was obtained from the participants, after a detailed description of the measurements was provided. Approval was granted by the University Ethical Committee. Anthropometric measurements were taken and are shown in Table 1.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age [years]</th>
<th>Weight [kg]</th>
<th>Height [cm]</th>
<th>LBM [kg · m−2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-water (n = 3)</td>
<td>20.6 ± 0.4</td>
<td>75.1 ± 7.5</td>
<td>176.7 ± 8.2</td>
<td>66.0 ± 7.5</td>
</tr>
<tr>
<td>Water (n = 3)</td>
<td>21.6 ± 0.4</td>
<td>81.9 ± 1.0</td>
<td>181.7 ± 2.0</td>
<td>70.9 ± 0.9</td>
</tr>
<tr>
<td>Dry (n = 3)</td>
<td>20.6 ± 0.4</td>
<td>81.4 ± 7.1</td>
<td>187.8 ± 3.2</td>
<td>71.2 ± 6.1</td>
</tr>
<tr>
<td>Control (n = 3)</td>
<td>21.3 ± 0.9</td>
<td>73.2 ± 5.5</td>
<td>176.5 ± 5.3</td>
<td>64.6 ± 3.9</td>
</tr>
<tr>
<td>Total N</td>
<td>21.0 ± 0.5</td>
<td>77.9 ± 4.4</td>
<td>180.67 ± 5.32</td>
<td>68.17 ± 3.37</td>
</tr>
</tbody>
</table>

Protocol contained two swim performance tests, 25 m and 50 m front crawl, which were measured by stop watch in (s). Further, we measured swim velocity in (m · s−1, V), stroke length (m · cycle−1, SL) and stroke rate (cycles · min−1, SR), using a manual stroke watch. The start was performed in water and by whistle. Subjects repeated the same tests prior to and after intervention. During testing, a video recording of swim motion above and below the surface of the water was made in the sagittal and transverse planes. The crawl technique was recorded on Sony Handycam HDR digital cameras. All tests were performed in a 25 m pool. For the recording of other variables, we marked a visible 10 m distance from the edge of the pool.

We also focused on monitoring and comparing swim performance and technique parameters related to SR and average swim velocity achieved in the test. As these variables are included in swim step calculation, we are capable of determining SL and thus the efficiency of a given swim technique (Counsilman 1973; Maglischo 2003; Hofer et al. 2012).

All participants performed 10 strokes and 50 strokes test on Biokonetic which is closely related to arm movement characteristics of 25 m and 50 m crawl. Setting the load for 10 strokes test was on level 3 and for 50 strokes test on level 4. The participants pulled at maximum speed with a controlled length of the pull. Measurements focused on the overall power (W) and power to weight ratio (W · kg−1) (Horčic et al. 1994). The intervention lasted 3 months and all participants had a single 45-minute training session twice a week. The dry group and water group did regular training in the first 25 min of the swimming lesson. The dry-land strength training of dry-water group started 25 min before the swimming lesson, and then continued in water. The water group and dry-water group swam with a parachute attached.
to the swimmer’s waist at the following load: $3 \times (4 \times 25 \text{ m})$ rest – 30 s, 2-minute rest between series (training on Tuesday), $3 \times (4 \times 50 \text{ m})$ rest – 30 s, 1.5-minute rest between series (training of Thursday). The intensity was set at maximum. Biokinetic strength training was set at the following load: $3 \times (4 \times 20 \text{ s})$ rest – 30 s, 2-minute rest between series (training on Tuesday), $3 \times (4 \times 40 \text{ s})$ rest – 30 s, 2-minute rest between series (training on Thursday). The intensity was set at maximum. We tried to logically set the duration, repetition, and intensity of exercise on land, in order to best fit the exercise carried out in the water. Means ± standard deviations were calculated for all variables. For results evaluation, scatter analysis was employed ($2 \times 4$) with repeated measurements for individual dependent variables. The intra-group factor was the effect of the intervention and the inter-group factor was the training type. Statistical significance was set at $P < 0.05$. The “partial eta squared” effect coefficient was used to evaluate the effect size. The effect was interpreted as follows: 0.04 – minimum practical effect, 0.25 – moderate effect and 0.64 as a strong effect (Ferguson 2009).

RESULTS

Performance characteristics are shown in Table 2. Statistically significant improvement occurred in all participants at performance test over 25 m and 50 m swim, stroke frequency over 50 m and in 10 strokes and 50 strokes tests.

The test results for 25 m all-out swim test show high improvement in swim times in water group, approximately about 7% in the 25 m all-out test. Their swim times in the 50 m all-out swim test also improved by 12%. The dry group and dry-water group did not improve in the 25 m all-out swim test, but improved in 50 m all-out swim test (dry group by 3% and dry-water group by 5%).

The inquiry also controls parameters of crawl technique. From the results of all-out tests, we calculated the frequency and length of the strokes. Table 2 shows an apparent increase in a number of strokes in water group by 19% and reduction in the number of strokes in dry-water group by 3% in all-out swim test over 25 m. The changes of frequency occurred also in the 50 m all-out test. The frequency in water group increased by 16% and in dry group by 4%.

We also calculated results of SL in the 25 m and 50 m all-out tests. SL of water group was shorter by 8%, SL of dry group was shorter by 5% and SL of dry-water group was longer by 2% in 25 m test. In the 50 m all-out test, SL of water group did not change, SL of dry group was shorter by 2% and SL of dry-water group longer by 6%.

In the 10 strokes test, water group improved by 10%, dry group improved by 21%, and dry-water group improved also by 21%. In the 50 strokes test, water group improved by 10%, dry group by 31%, and dry-water group by 16%.

DISCUSSION

The main purpose of the study was to determine the influence of specific and semi-swim-specific exercise on overall performance over 25 and 50 m crawl and...
TABLE 2. Performance characteristics of pre-test and post-test intervention.
Data are represented as a mean ± standard deviation

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 m [s]</td>
<td>50 m [s]</td>
<td>25 m [f]</td>
<td>50 m [f]</td>
<td>25 m SL [m]</td>
<td>50 m SL [m]</td>
<td>10K [W · kg⁻¹]</td>
<td>50K [W · kg⁻¹]</td>
</tr>
<tr>
<td>DW (n = 3)</td>
<td>16.8 ± 3.55</td>
<td>38.0 ± 11.1</td>
<td>54 ± 3.28</td>
<td>48 ± 5.0</td>
<td>1.53 ± 0.26</td>
<td>1.59 ± 0.29</td>
<td>2.8 ± 0.52</td>
<td>2.0 ± 0.27</td>
</tr>
<tr>
<td>W (n = 3)</td>
<td>16.4 ± 0.96</td>
<td>37.0 ± 2.08</td>
<td>47 ± 3.81</td>
<td>45 ± 3.46</td>
<td>1.73 ± 0.03</td>
<td>1.67 ± 0.46</td>
<td>2.2 ± 0.27</td>
<td>1.6 ± 0.11</td>
</tr>
<tr>
<td>D (n = 3)</td>
<td>16.3 ± 1.92</td>
<td>36.5 ± 4.6</td>
<td>46 ± 4.11</td>
<td>43 ± 1.8</td>
<td>1.80 ± 0.12</td>
<td>1.84 ± 0.20</td>
<td>2.7 ± 0.28</td>
<td>1.6 ± 0.29</td>
</tr>
<tr>
<td>C (n = 3)</td>
<td>16.9 ± 0.77</td>
<td>37.1 ± 0.65</td>
<td>44 ± 4.32</td>
<td>41 ± 1.78</td>
<td>1.84 ± 0.17</td>
<td>1.91 ± 0.10</td>
<td>2.6 ± 0.35</td>
<td>1.6 ± 0.18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Post-test</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 m [s]</td>
<td>50 m [s]</td>
<td>25 m [f]</td>
<td>50 m [f]</td>
<td>25 m SL [m]</td>
<td>50 m SL [m]</td>
<td>10K [W · kg⁻¹]</td>
<td>50K [W · kg⁻¹]</td>
</tr>
<tr>
<td>DW (n = 3)</td>
<td>16.6 ± 3.2*</td>
<td>36.1 ± 8.7*</td>
<td>52 ± 8.0</td>
<td>48 ± 7.4</td>
<td>1.56 ± 0.1</td>
<td>1.69 ± 0.18</td>
<td>3.3 ± 0.57*</td>
<td>2.4 ± 0.12*</td>
</tr>
<tr>
<td>W (n = 3)</td>
<td>15.2 ± 0.9*</td>
<td>32.6 ± 2.0*</td>
<td>55 ± 1.0</td>
<td>51 ± 1.1*</td>
<td>1.59 ± 0.08</td>
<td>1.68 ± 0.08</td>
<td>2.5 ± 0.04*</td>
<td>1.8 ± 0.05*</td>
</tr>
<tr>
<td>D (n = 3)</td>
<td>16.1 ± 2.1*</td>
<td>35.3 ± 4.7*</td>
<td>46 ± 6.3</td>
<td>44 ± 6.6*</td>
<td>1.72 ± 0.29</td>
<td>1.79 ± 0.25</td>
<td>3.2 ± 0.58*</td>
<td>2.1 ± 0.29*</td>
</tr>
<tr>
<td>C (n = 3)</td>
<td>15.6 ± 0.9*</td>
<td>34.1 ± 1.0*</td>
<td>44 ± 4.9</td>
<td>42 ± 3.0*</td>
<td>1.89 ± 0.2</td>
<td>1.92 ± 0.12</td>
<td>2.8 ± 0.19*</td>
<td>2.0 ± 0.28*</td>
</tr>
</tbody>
</table>

|               | 0.001    | 0.000    | –         | 0.020    | –         | –         | 0.002    | 0.000    |
|               | 0.79     | 0.82     | -         | 0.51     | -         | -         | 0.71     | 0.82     |

DW – group intervention both on dry land and in water; W – intervention in water; D – intervention on dry land; C – control group;
25 m and 50 m [s] – the length of swim and time in seconds; 25 m and 50 m SL[m] – the length of swim and distance of stroke length
in metres; 25 m and 50 m [f] – the length of swim and frequency of stroke per minute; 10K and 50K test with 10 and 50 strokes
on the Biokinetic in [W · kg⁻¹] – power per kilogram of weight; * – results statistically significant for \( P < 0.05 \); \( \eta^2 \) – degree of effect size
whether this training positively affects crawl performance parameters, such as frequency and length of strokes, in CU FPES students who are not competitive swimmers. Given the small number of respondents, we cannot fully say that the intervention confirmed the objective of work, but from the results, we may assume that specific exercise in water (water group) positively affected the changes in an overall speed test over 25 m and 50 m crawl. According to the results, changes occurred also in stroke frequency and length but were adverse – higher stroke frequency and shorter stroke length, which indicates a deterioration of technical parameters. The differences between effective and ineffective crawl technique are clear: an effective technique is defined as the one that maintains high swimming speed, with the increasing stroke length, low frequency and optimal stroke rate (Counselman 1973; Graig and Pedergast 1979; Maglischo 2003; Hofer et al. 2011). Based on the results, we can say that the specific exercise had a positive effect on the overall swimming speed of untrained participants in water group, but with an unwanted increase in stroke frequency and reduced stroke length. Results of the test of the upper limbs strength on Biokinetic in water group shows that the muscle strength was lower than in the other tested groups, and we think that it was due to the specificity of the load. The results are not statistically significant in comparison with the control group because the control group improved in some variables too. Additionally, at the end of the research we found that all the members of the control group were swimming and improving the muscle strength outside the conducted research.

Previous studies (Cronin et al. 2007; Breed et al. 2000; Cossor et al. 1999; Tanaka et al. 1998) consider that the effect of semi-swim-specific exercise is less than the effect of specific exercise in water. Also, Tanaka et al. (1993) has suggested that the general development of muscular strength on land or combined muscle strength on land and in the water does not increase the swimming performance of untrained swimmers. Semi-swim-specific exercise had less effect on the overall speed test over 25 and 50 m crawl and also a minimal effect on the stroke frequency. The results indicate that increased muscle strength in dry group influenced the length of the stroke, which was shorter than in the dry-water group. In comparison with the results of upper limbs strength test on Biokinetic, the values were higher than in the other groups, and we think this was due to the better adaptation to the strength training on Biokinetic.

In contrast to other studies (Cronin et al. 2007; Vorontsov et al. 2006; Gambetta 1999), we have created another group of participants who completed the intervention both in specific and semi-swim-specific exercise in water and on land. The dry-water group improved in the overall speed test over 25 and 50 m crawl. The values were higher if compared to dry group and lower if compared to water group. It is also evident that the dry-water group improved the parameters of technique. We could see lower stroke frequency in 25 m crawl and longer stroke length in 25 m and 50 m crawl. Also, the values of the upper limbs strength test on Biokinetic were higher than in water group. Dry-water group was the only one that had positive changes in speed, technical parameters and also in the strength test. Values of stroke length in 50 m crawl test were higher even if the stroke frequency remained stable.
CONCLUSIONS

From the above results we can say that specific exercise positively influenced the overall speed over 25 m crawl and 50 m crawl and negatively influenced the length and frequency of the stroke. We have also noticed positive influence in the strength of upper limbs. The semi-swim-specific exercise positively influenced the overall speed on 25 m and 50 m crawl. The stroke frequency was without changes but the stroke length decreased. The strength of the upper limbs increased. A combination of semi-swim-specific and specific exercise influenced the overall speed, stroke length and frequency. Also the changes were evident in upper arm strength. Data showed that we cannot agree with Tanaka et al. (1993) that the combination of semi-swim-specific and specific strength training does not increase swimming performance in untrained swimmers.

Further research would be needed to perform on a larger sample size and with a greater emphasis on monitoring external variables in control group.

ACKNOWLEDGEMENT

This project was supported by PRVOUK P38.

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Effects of 8-week dry-land special functional training on core stability in young swimmers

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ABSTRACT

The main purpose of this study was to determine the effect of the application of 8-week dry-land functional training on the core strength, stability, balance and neural and muscle control improvement in young swimmers. The study involved fourteen young male (7) and female (7) competitive swimmers (age: 14.25 ± 1.5 years) from the same local swimming club. To assess dynamic stability of the lower and upper part of the body in female and male swimmers, the Star Excursion Balance Test (SEBT) and the Range of Motion (ROM) test were applied twice: before the planned 8-week core functional training session and after eight weeks. To assess the upper part of the body’s dynamic stability, external and internal rotation of the shoulder was applied, the muscles of the rotation group of the shoulder were tested, and blade stability was assessed. The 8-week dry-land functional training programme for swimmers proved to have significant effects related to core stability and core muscle strength (SEBTs) as well as neuro-muscular control and balance of the body.

Key words: core strength, stability, neural and muscle control, upper and lower part of the swimmer’s body, dry-land training programme

INTRODUCTION

The review of the literature shows a multitude of definitions for the core. Richardson (1999) defines the core as a “box of muscles” which consists of: the abdomen muscles at the front, the spine muscles and the gluteal muscles at the back, the diaphragm as the roof, and the pelvis and waist belt as the bottom. According to Letuun et al. (2004), the core is a lumbar and pelvic system that consists of the lumbar spine, the pelvis, the hip joints and the active and passive tissues that trigger or inhibit movement of this system. Fig (2005) stated that the core encompasses the whole anatomy between the sternum and the knees, especially the abdominal area, as well as the lower area of the back and the hips. Kibler (2006) and Akuthota (2004) appear to have proposed the most accurate definition of the human core, stating that the core are all the muscles that protect the spine, ensure stability, distal mobility and represent the centre of the integrated kinetic chain during execution of movements.
Stability, force and strength are essential elements in the training of the core. To make the core stable, muscle activity in the lumbar section of the spine is necessary (Akuthota, 2004). The core strength is the capacity of the muscle system to produce force from the contractions and pressure in the abdominal cavity (Santana et al. 2005). The core strength along with stability constitute the capacity of the core to control the position of the body and the movement of the core about the pelvis, ensuring optimum production of force being transferred as well as controlling the other segments of the body involved (Kibler 2006).

Progress in core training mostly depends on: controlling stability of the movement system, training of core strength and systematic strength training (Comerford 2007). Some authors propagate the idea that enhanced strength of the core for controlling the position of the body may improve athletic achievements, but the scientific environment indicates imperfections of this theory (Sharrock et al. 2011). According to Hibbs et al. (2008) lack of results observed in many studies related to sports achievements may be caused by non-functional core training programmes that do not translate into better sporting achievements due to a poor understanding of the role of the individual muscles during the exercises.

Presently, core stability and strength training constitute a popular trend in the world of sport and fitness. The multitude of varied training programmes available results in the lack of clear training effects (Willardson 2007; Hibbs 2008). Some scientists support the effectiveness of core training, but rather in the field of preventing injuries and in rehabilitation. However, these authors express uncertainty in this respect when the straining of core muscles are related to sports achievements (Behm 2002; Sharrock 2011). However, Myer (2005) reported that the benefits related to balance of the body and neural and muscle control are related to core training and sports achievements.

Therefore, the main purpose of the study was to determine the effect of the application of 8-week dry-land functional training on the core strength, stability, balance and neural and muscle control improvement in young swimmers. Based on earlier studies concerning the core stability in swimming, it was hypothesized that an 8-week of functional training intervention can have positive effects on the process of strength transfer between the upper and the lower parts of the body, in consequence, affecting swimming performance.

**MATERIAL AND METHODS**

The study involved 7 girls (aged 14.3 ± 0.74 years, body height 169.00 ± 5.12 cm, body mass 56.48 ± 5.23 kg) and 7 boys (aged 14.1 ± 0.62 years, body height 175.65 ± 3.81 cm, body mass 59.78 ± 7.42 kg) representing a high level of swimming skills in their age group (record holders and medal winners at the swimming championships). In the 2-year-period before the test, all subjects had trained regularly 8–10 times a week and had participated in Championships. The swimmers had been involved in regular training for a minimum 4 to 6 years (7.9 ± 0.9 h/week). The subjects declared a lack of pain in the lower section of the spine within the preceding 12 months and a lack of pain in the shoulder joint. All participants were prepared physically for the dry-land special functional training with a 6 month training
programme in the scope of “core training”. The subjects and their parents signed
an informed consent form and were instructed in the procedures and protocol for
the experiment prior to the testing. The test protocol followed the guidelines of
the Declaration of Helsinki of 1975. The research project was approved by The
Bioethics Commission at the Regional Medical Chamber, Krakow, no. 118/KBL/
OIL/2012.

In order to assess the level of stability of the subjects’ body, specialised tests
were applied. To assess the dynamic stability of the lower part of the body in female
and male swimmers, according to the article referenced Olmsted 2002, the Star Ex-
cursion Balance Test SEBT was applied twice: before the planned 8-week functional
training session of the core muscles and after its completion (after eight weeks).

To assess the dynamic stability of the upper part of the body, assessment of
external and internal rotation of the shoulder joint was carried out twice (Radwan
et al. 2014). The so-called “internal factor” of reliability of the test was estimated
on the basis of the correlation factor and (for the SEBT) amounted to 0.86–0.96
(Hertel et al. 2000, 2006; Gribble et al. 2004).

SEBTs for female and male swimmers were prepared bilaterally (left and right)
and set in 4 directions (for each side), beginning with 0° to 45°, 90°, 145°, 180°.
Achievements by the subject of the relevant distance (measured in mm) were the
sum of each of the sides separately (Figure 1).

To assess the dynamic stability of the upper part of the body, assessment of
external and internal rotation of the shoulder joint was carried out twice (Radwan
et al. 2014). For this purpose, the muscles of the rotation group of the shoulder
were examined and shoulder blade stability was assessed.

EBTs were conducted as follows: the subject placed a bare foot at the centre of
the cross marks on the floor. The path of movement of the lower limb was set with
eight 150 cm long lines (marked out with an adhesive tape affixed to the floor) set
at recurring 45° increments from the centre of the prepared grid (Fig. 1). The geo-
metric centre of the subject’s foot was aligned with the so-called “cross”, and the
other foot was to reach the furthest point possible without touching the floor. The

![Figure 1](source: Hertel et al. 2006)

**FIGURE 1.** The testing grid for the Star Excursion Balance Tests. The directions are
labelled based on the reach direction in reference to the stance limb
(source: Hertel et al. 2006)
position of the lower limb in contact with the floor required: dorsal flexion of the ankle joint, flexion of the knee joint, flexion of the hip joint. The other foot was to touch the line as far away as possible with minimum contact with the floor and without significant support in maintaining the vertical position of the body. The subject then returned to the centre of the grid maintaining full balance. The observer marked the point on the line touched by the subject and then manually measured the distance (in mm) from the centre of the grid. The result was then normalised to the length of the subject’s lower limb measured from the anterior superior iliac spine to the external part of the medial ankle (Gribble et al. 2003).

The range of mobility (the ROM test) of the shoulder joint was checked using a camera (SONY Cyber-shot DSC-RX 10) and the “Kinovea 08.15” free software program, which is used for analysis, comparison and assessment of the range of passive and active mobility (of the shoulder joint) and is used in sport and physiotherapy. Reliability of assessment of the ROM test has been confirmed by other researchers (El-Rahem et al. 2015). The protocol of exercises included the following procedures:

1. Induction of the subject to the session,
2. A short warm up (on land).

The ROM test was prepared bilaterally: to the right and left arms.

The employed functional training protocol for core muscles on land, applied to female and male swimmers, covering the period from week 1 to week 8 (October, November 2014) are presented in Tables 1 and 2. Twice a week dry-land training programme was performed. Duration of dry-land training was approximately 45 minutes each.

During the first two weeks, the subjects adjusted their organisms to the training procedure. Training always included 6 different exercises. During the first two weeks, 6 exercises were done in three series of 12 repetitions each (Tables 1, 2). The subjects executed the exercises with only a slightly advanced degree of difficulty (stable exercises, static work of muscles, eyes open); the subjects prepared their bodies with warming up and stretching throughout the time.

**TABLE 1. The protocol of dry-land functional training**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Week 1–4</th>
<th>Week 5–6</th>
<th>Week 7–8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of series of exercises</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Number of repetitions</td>
<td>12</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Level of instability</td>
<td>stable: work on a mat</td>
<td>relatively stable: Bosu</td>
<td>unstable: Fitball / balancing board</td>
</tr>
<tr>
<td>Work of muscles</td>
<td>static</td>
<td>dynamic</td>
<td>dynamic with increased speed</td>
</tr>
<tr>
<td>Movement speed</td>
<td>slow</td>
<td>mean speed</td>
<td>fast</td>
</tr>
<tr>
<td>Moment of using strength</td>
<td>rest</td>
<td>using strength, work with a partner</td>
<td>use of strength, tubing cord</td>
</tr>
<tr>
<td>Visual impressions</td>
<td>eyes open</td>
<td>eyes open</td>
<td>eyes closed</td>
</tr>
</tbody>
</table>
During the period from week 1 to week 4, the subjects (Tables 1, 2) executed every exercise 3 times each in 12 repetitions, on stable ground. The work of muscles was static with slow movements, without using strength and with open eyes to facilitate the exercise.

During the weeks 5 and 6, the number of the executed exercises was increased to 4 series of 15 repetitions; the ground was also modified during the exercises with the Bosu ball, which is a double-sided device – one side of the device is a pneumatic dome that responds to every movement of the subject, the other side is flat and rigid. Speed of movement was also increased, and some exercises were supported by a partner. The subjects had their eyes open during these exercises.

The training in weeks 7 and 8 was considerably more intense and more difficult. The number of the executed exercises increased to 5 series of 20 repetitions. The exercises were executed on unstable ground, with a balancing board, or the so-called FitBALL® (a large inflated exercise ball), which require commitment of all muscles that stabilise the body, that are related to the need of maintaining balance during effort. Tubing cords were used for exercises, which required dynamic work of muscles with increased speed. Speed of movement increased, and the subjects had their eyes closed to make the exercise more difficult.

Additionally, during the study, in order to ensure the proper determination of training effectiveness (progress), the level of fatigue of the participants (in their opinion) was tested according to the Borg scale (Borg 1982). It is the scale of subjective perception of physical effort according to the Borg Rate of Perceived Exertion (RPE scale). The study took place after each completed training session. Table 3 presents the scale of subjective perception of physical effort according to Borg, where the maximum effort is 10, and the complete lack of perception of effort is 1.

### Table 2. The protocol of the exercises during dry-land functional training

<table>
<thead>
<tr>
<th>Exercise #</th>
<th>Week 1–4</th>
<th>Week 5–6</th>
<th>Week 7–8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static twist</td>
<td>normal</td>
<td>on one leg on the “Bosu” ball</td>
<td>a balancing board was used in this exercise</td>
</tr>
<tr>
<td>Dynamic twist.</td>
<td>one leg on stable ground</td>
<td>1 kg ball and standing on the “Bosu” ball</td>
<td>“Bosu” ball, with both hands pushing the tubing cord</td>
</tr>
<tr>
<td>Push ups.</td>
<td>stable: feet and hands on a mat</td>
<td>hands positioned on the balancing board</td>
<td>hands on the balancing board, the feet on the “Bosu” ball</td>
</tr>
<tr>
<td>Side plank</td>
<td>the body in the side position</td>
<td>one leg raised</td>
<td>raising one leg and one arm</td>
</tr>
<tr>
<td>Crunches.</td>
<td>normal</td>
<td>“Bosu” ball in the pectoral-lumbar-sacral section</td>
<td>“Bosu” ball is replaced with the Fit-ball to raise the body higher</td>
</tr>
<tr>
<td>One Leg Supine Bridge</td>
<td>normal</td>
<td>foot placed on the “Bosu” ball</td>
<td>foot on the Fit-ball.</td>
</tr>
</tbody>
</table>
TABLE 3. Borg Rate of Perceived Exertion Scale, as determined by participants

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale 1–10</th>
<th>Effort</th>
<th>%HR_max*</th>
<th>% VO2max**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Resting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Very easy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Easy</td>
<td>52–60</td>
<td>31–50</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Moderate</td>
<td>61–85</td>
<td>51–75</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Difficult</td>
<td>86–91</td>
<td>76–85</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Very difficult</td>
<td>89–92</td>
<td>85–90</td>
</tr>
<tr>
<td>7</td>
<td>6–7</td>
<td></td>
<td>&lt; 93</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td></td>
<td>&lt; 93</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Extremely difficult</td>
<td>&lt; 93</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Maximal</td>
<td>&lt; 93</td>
<td>&lt; 90</td>
</tr>
</tbody>
</table>

* Percent of maximum pulse  
** Percentage of maximum oxygen consumption

The paired t-test was executed in order to assess the effects before and after the training in the groups of girls and boys. In order to compare the effects of the functional training (in both groups), for both the right and left sides of the body, the ANOVA analysis (time ´ group ´ exercise) was applied to the SEBTs and the ROM test. The level of significance p ≤ 0.05 was assumed for all the results achieved.

RESULTS

Figure 1 shows that the mean values for the SEBTs in female swimmers increased from 398.2 mm to 412.4 mm and from 389.4 mm to 402.1 (the right foot and left foot, respectively) after application of the 8-week special functional training pro-

FIGURE 1. Summary of results of the SEBTs in the female and male groups before and after the dry-land functional training (ANOVA)
The effects of 8-week dry-land special functional training on swimming performance were evaluated. It means that SEBTs results increased by about 3.7% for the right foot and 3.3% for the left one. In turn, male swimmers reached bigger improvement in both SEBTs: 8.1% and 12.2% (for the right and left foot, respectively).

On the basis of the upper body ROM test analysis (Figure 2), the internal rotation (IR) of the (right and left) shoulder joint in both groups was slightly improved after participation in 8-week dry-land functional training. However, the improvement was higher in the female group than in the male group (p < 0.05). In turn, the external rotation (ER) of the (right and left) shoulder joint showed much higher improvement than IR in both groups, and also female swimmers reached higher values than male swimmers.

![Figure 2: Summary of results of the ROM TEST in the female and male groups before and after the dry-land functional training (ANOVA)](image)

Table 4 indicates that in the group of female swimmers, the difference between internal rotation of the right and left shoulder joints (IR_P vs. IR_L) increased after the intervention of 8-week training period. In the group of male swimmers, the difference was already significant at baseline, and increased after the training. In the female group, the difference of external rotation of the right and left shoulder joints (ER_P vs. ER_L) dropped from 3.23 to 0.98, whereas it increased in the male group from −0.77 to 1.2.

Table 5 shows that the mean level of fatigue, as perceived by the subjects, during the execution of the dry-land functional training programme ranged from 2.98 to 6.27 for females and from 3.45 to 5.98 for males, increasing in both groups from week to week. The results in the female group were slightly lower from Week 1 to Week 5 of the exercises, and slightly higher during the weeks 6 through 8, when compared to the male group.

**DISCUSSION**

The main objective of this work was to assess the effect of the dry-land functional training implemented in swim workout (for both female and male swimmers), mostly in the area of core muscles, in the phase of specialised training.
TABLE 4. The mean (mean ± SD) and the difference of the results in the ROM test before and after the 8-week dry-land training for female and male groups

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Girls before training</th>
<th>Girls after training</th>
<th>p &lt; 0.05</th>
<th>Boys before training</th>
<th>Boys after training</th>
<th>p &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR-P</td>
<td>53.5</td>
<td>56.28</td>
<td>0.764</td>
<td>43.17</td>
<td>47.56</td>
<td>0.98</td>
</tr>
<tr>
<td>IR-L</td>
<td>52.1</td>
<td>53.71</td>
<td>0.951</td>
<td>37.36</td>
<td>41.32</td>
<td>0.89</td>
</tr>
<tr>
<td>ER-P</td>
<td>100.68</td>
<td>104.65</td>
<td>0.918</td>
<td>97.45</td>
<td>102.45</td>
<td>0.947</td>
</tr>
<tr>
<td>ER-L</td>
<td>97.45</td>
<td>103.67</td>
<td>0.816</td>
<td>98.22</td>
<td>101.25</td>
<td>0.805</td>
</tr>
<tr>
<td>IR_P vs IR_L</td>
<td>1.4</td>
<td>2.57</td>
<td>0.789</td>
<td>5.81</td>
<td>6.24</td>
<td>0.994</td>
</tr>
<tr>
<td>ER_P vs ER_L</td>
<td>3.23</td>
<td>0.98</td>
<td>0.654</td>
<td>-0.77</td>
<td>1.2</td>
<td>0.543</td>
</tr>
</tbody>
</table>

IR_P: internal rotation of the right shoulder joint, IR_L: internal rotation of the left shoulder joint
ER_P: external rotation of the right shoulder joint, ER_L: external rotation of the left shoulder joint
IR_P vs IR_L: difference between internal rotation of the right and left shoulder joints
ER_P vs ER_L: difference between external rotation of the right and left shoulder joints

TABLE 5. The mean level of fatigue of the subjects after each training session (in the opinion of the subjects)

<table>
<thead>
<tr>
<th>Week</th>
<th>Females (x)</th>
<th>Males (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.98</td>
<td>3.45</td>
</tr>
<tr>
<td>2</td>
<td>3.12</td>
<td>3.87</td>
</tr>
<tr>
<td>3</td>
<td>4.25</td>
<td>5.16</td>
</tr>
<tr>
<td>4</td>
<td>4.72</td>
<td>4.86</td>
</tr>
<tr>
<td>5</td>
<td>4.92</td>
<td>5.28</td>
</tr>
<tr>
<td>6</td>
<td>5.78</td>
<td>5.02</td>
</tr>
<tr>
<td>7</td>
<td>6.45</td>
<td>6.25</td>
</tr>
<tr>
<td>8</td>
<td>6.27</td>
<td>5.98</td>
</tr>
</tbody>
</table>

After the 8-week dry-land training, both groups achieved better results in the SEBTs, although slightly higher results (improvement in core stability) were found in the female group compared with the male group. However, differences were demonstrated in the results of the right foot test in both groups (p ≤ 0.03). ANOVA proves significant differences between the groups for both sides: SEBTs for the right foot and SEBTs for the left foot (p = 0.03). Similar results were obtained by Scibeck et al. (2001), where they show improved core stability but no effects on swimming performance in collegiate swimmers. Strength exercises used during the training sessions positively affected neural and muscle control as well as balance. The rela-
relationship between SEBTs and core stability has been investigated, for example, football players (Nesser et al. 2008), young male athletes (Stanton et al. 2004) collegiate healthy people (Okada et al. 2010). SEBTs are a set of clinical tests used in order to detect functional deficits in the lower limb work. These tests are used in both physiotherapy in subjects with lower limb dysfunction as well as in healthy persons practising physical activity and sport (Hertel et al. 2000, Gribble et al. 2004). SEBTs are both economic and precise in measuring dynamic stability of the lower parts of the body. The better results achieved in the female group may be related to the learning effect or benefits related to the specific physical activity of each of the subjects. Focusing on the global trend with specific progress may be a good way to improve functionality and dynamics of exercises. Such examples can be found among others in the works of Sharrock et al. (2011) who found a relationship between core stability and a med ball throw among college athletes and that of Saeterbakken et al. (2010) who showed an increase in maximal throwing speed in high school female handball players.

To achieve the optimal motor ability development in swimming, the swimmer should implement training stimuli both on land (in the gym) and in water. The belief that strength, stability and endurance of the core may be improved by executing standard exercises throughout the season, e.g. in the gym, is definitely wrong. Most of swimming training programmes feature various training stages during the season. These most often include various stages of execution of endurance, but also strength, power and speed, which is the reason why specialised training should be also conducted on land. It is recommended to include in the specialised swim training on land, execution of exercises on each side of the body (right and left), just like during training in water. The developing trend of various training proposals will provide every swimmer with different training methods, both on land and in water. Execution of new, varied exercises may prove difficult for male swimmers. Internal rotation (IR) of the (right and left) shoulder joint in both groups was significantly improved, but finally it was higher in the female group (41.25°) than in the male group (36.74°). External rotation (ER) of the (right and left) shoulder joint proved to be higher in both groups of subjects after the 8-week period of the dry-land special functional training but was higher in the female group (105.28°) than in the male group (101.25°). Walker et al. (2012) found there was an increased risk of shoulder pain with limited or excessive ER. Bak and Magnnsson (1997) recommended activating chest muscles to increase rotation (IR limited). Fatigue of the shoulder and core musculature might initiate the development of pain in the swimmer’s shoulder (Stocker et al. 1995), and improved strength and endurance of the core muscles might protect against shoulder pain in adolescent athletes (Auvinen et al. 2008). Our findings are in line with those of Tate et al. (2012), who found that none of the other age groups swimmers (12–14 years old) showed a difference in flexion ROM between swimmers with and without shoulder pain. Theoretically, swimmers with reduced flexion ROM could have a reduced stroke length and, therefore, need additional strokes compared with swimmers with greater mobility, incurring greater shoulder load. However, since older swimmers exhibit shoulder hypermobility (Beach et al. 1992) and stretching has been reported to aggravate shoulder symptoms (McMaster et al. 1993) careful consideration should be given when evaluating potential merits of shoulder elevation stretching.
We found that the mean level of fatigue perceived by the subjects during the execution of the dry-land functional training programme increased in both groups from week to week. This is consistent with reports of other authors that land-training for experienced competitive swimmers is irrelevant for competitive swimming performances (Bulgakova et al. 1987; Breed et al. 2000; Costill et al. 1983; Crowe et al. 1999; Kucia-Czyszczoń et al. 2013; Tanaka et al. 1993). If fatigue from land-training is carried into swimming practices, it is likely to be detrimental to swimmers’ practice performances. Brent S. Rushall (2014) reported that effort levels will be reduced, techniques will be compromised, the experience of swim training will be negatively affected, and the volume of swim training will be reduced in every affected training session. Despite the negative association between land work and pool work, coaches and swimmers “buy” the land-training drivel and false claims and relate any coincidental improvements to it and ignore its influence when analyzing failures.

The achieved results in the SEBTs and ROM test after application of the 8-week dry-land functional training programme (implemented with the procedure of a gradual increase of training loads and properly stimulated neural and muscle systems) that the properly developed strength of core muscles may positively affect transferring between the arms and the core, and may also bring about effects in the proper control of the position of the body. Therefore, these results are consistent with reports of other authors (Barbosa al. 2010b; Silva al. 2007; Schmidt and Ungerechts 2008; Kucia et al. 2014), saying that morphometric characteristics of male and female swimmers tend to be uniform and very similar to each other. It seems to be, consequently, a legitimate assumption to make joint analysis of the correlation between the sports performance and the core muscles for both genders. On the one hand, a review of the literature indicates that the data mediums in the range of values are similar in terms of gender, chronological and biological age. Thus it appears that the study hypothesis was positively verified. These initial data show that functional training programmes on land for swimmers have positive and beneficial results and that further studies on larger groups and different age groups will further verify these initial findings so that these training programmes may be successfully implemented in swim training at each stage of sports training.

CONCLUSIONS

The dry-land functional training programme for swimmers, at the stage of directed training, proved to have significant effects related to core stability and core muscle strength (SEBTs) as well as neuro-muscular control and balance of the body.

The results of the ROM test (stability of the upper part of the body) related to internal rotation (IR) and external rotation (ER) of the (right and left) shoulder joint after the 8-week training programme on land were significantly improved in both groups. However, the difference proved to be higher in the female group. Furthermore, our study is able to provide a basis for other researchers to investigate: core endurance, internal and external shoulder stretching, and dry-land programme for swimmers in limiting or preventing shoulder injury, and finally the relationship between swimming performance and SEBTs and ROM test.
Practical implication:
The SEBT could be commonly used to assess core stability and core muscle strength among swimmers and the ROM test might determine shoulder injury risk. Nevertheless, new testing batteries as well as movement ranges of joints and biomechanical parameters for swimmers should be improved to assess and screen the swimming performance.

ACKNOWLEDGMENTS

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Effectiveness of interval training on changes in young swimmer’s physiological parameters and swimming speed

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ABSTRACT
The purpose of this study was to examine some physiological responses to interval training in terms of maximal oxygen uptake (VO₂max), minute ventilation (VE), heart rate (HR), and front crawl swimming speed over 25, 50 and 100 meters. Seventeen primary school age swimmers (9 females and 8 males, aged 11.73 ± 0.45 years) were randomly allocated to a control group (n = 8) and interval group (n = 9) and took part in six-week interval training cycle. The Wilcoxon non-parametric test for comparing two related samples was performed in this study. The result of this experiment implies that interval training is a very efficient method to improve several physiological parameters, such as maximal oxygen uptake and minute ventilation. This study also confirms that interval training is a better method to increase swimming speed in comparison with the standard training method, even in children.

Key words: swimming, interval training, oxygen uptake, young swimmers, children

INTRODUCTION

Work at high intensity, which is based on anaerobic metabolism, leads to a sudden accumulation of lactate and hydrogen ions in muscle fibers and in blood. The increase in the production of lactate is not caused by lower oxygen availability or by its pressure inside muscle cells, it is rather caused by an increase in the ATP demand which cannot be satisfied by oxidative phosphorylation. It is then a process independent of oxidative phosphorylation and of metabolites concentration change. It is stimulated by the activity of skeletal muscles and the resulting increase in the level of Ca²⁺ (Conley et al. 1998; Richardson et al. 1998; Walter et al. 1999). Tolerance to acidity is a major limitation here. It describes ability of muscles to perform contractions at a high concentration of lactate and hydrogen ions and the ability of organism to tolerate high acidity (Joyner and Coyle 2008).

Interval training cycle was evaluated in this study. Interval training is a type of physical training that involves a series of high intensity exercise workouts interspersed with rest, but not allowing full recovery. The ratio between time of work and rest in standard interval training varies from 1:1 to 1:3. Work should last from 30 seconds to 2 minutes. The number of repetitions in every set should be the same
with maximum of 5 repetitions. Each series is followed by 15–20 minutes active rest of moderate intensity. The work done in every repetition is assessed and compared with the result of previous set results with a 10% decline between the sets being a sign to finish training.

Some studies (Gibala et al 2006) confirm that interval training improves VO₂max and VE during progressive tests on the cycloergometer, and this should also be reflected in competition races. Interval training also improves muscle buffer volume, it increases the amount and size of mitochondrion, it increases the amount of muscle glycogen and economization of work at moderate intensity.

In this study, the interval training cycle was performed by children. A safer work rest ratio of 1:6 was chosen because of the young age of the children, and to avoid injuries.

During the training of children in primary school (grades 4-6) working on oxygen intensity is the crucial component. Up to the 12 years of age sports development is stimulated by mastering oxygen energy system. Child’s organism at the age of 9–12 years has a great ability to quickly adapt and endure substantial training effort.

Among training methods used in swimming, one can enumerate continuous, variable, repetitive, and interval methods.

The aim of this work was to analyze the influence of interval training on children aged 11–12 with at least 2-year training experience. In order to perform a thorough analysis, the following research questions were asked:

- Will interval training improve physiological parameters, such as VO₂max, VEmax, HRmax and La− greater than in the control group?
- Will the interval training cycle result in greater improvement than in the group following the standard training cycle where moderate (oxygen) intensities prevail?

**MATERIAL AND METHODS**

Seventeen children from primary school number 72 in Wrocław took part in the study on the influence of interval training on young swimmers. The children were divided into two groups: experimental (n = 9) and control (n = 8). One person from the control group finished training before the study concluded, due to injury. Experimental group, instead of eight trainings per week in normal training cycle had two training sessions using an interval method during 6-week period (12 training sessions). Control group continued training following the traditional cycle.

**TABLE 1. Body parameters of both groups (M ± SD, average ± standard deviation)**

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (n = 9)</th>
<th>Control group (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [yrs]</td>
<td>11,75 ± 0,46</td>
<td>11,71 ± 0,49</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>42,94 ± 6,72</td>
<td>40,48 ± 4,05</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>154,88 ± 7,94</td>
<td>155 ± 6,61</td>
</tr>
<tr>
<td>BMI</td>
<td>17,81 ± 1,61</td>
<td>16,85 ± 1,39</td>
</tr>
</tbody>
</table>
Trainings sessions took place in a 25 m swimming pool; water temperature was 27–29°C. All parents agreed to children’s participation in the experiment. All the children had two-year swim experience. Each swimmer took part in a progressive test two weeks prior to the experiment and two weeks after it finished because benefits of interval training occur after a few days of active rest with moderate intensity. The swimmers were tested in 25, 50 and 100 meters free-style, with a 15-minute break between the distances in order to monitor the swimming speed before and after the experiment.

The swimmers swam 50 meters free-style at maximum intensity and with a 3-minute break (chosen due to a young age of the subjects and to avoid overtraining in classical interval i.e. high intensity interval training HIIT), performing 4 repetitions in a series. Extending the work time by 1% in comparison to the first series signaled the end of the training for the swimmer who covered the distance at a slower pace. The interval between the series lasted 15–20 minutes and was active.

The experimental group was subject to interval training on two out of eight trainings. The swimmers trained on two tracks, starting at 10-second intervals. Each swimmer covered 50 meters free-style at maximum speed starting from water (without a dive). After covering the distance each swimmer rested for three minutes before the next distance. In each series swimmers covered four distances, 50 meters each. After each series there was an active break of 15 minutes, after which swimmers swam 200 meters back stroke as an active rest (at a very slow pace) and four times 50 meters of exercises mastering free-style technique, starting every 1 minute and 15 seconds. When 15 minutes of the previous series elapsed, the swimmers started a new series of four times 50 meters free-style.

During the interval between each repetition the swimmers performed a low intensity effort (20% VO₂max). According to Dorado et al. (2004), this should be more conducive to better efficiency of aerobic sources for regenerating ATP (higher oxygen intake during repetitions), rather than a passive break or stretching.

The swimmers performed two series at minimum. Total time of effort of the first series was a reference point to the following series. The time of each distance was measured for each swimmer. Moreover, the total sum of times of all covered distances for each swimmer was measured in a series. Aggregated times of each consecutive series were compared to the sum of times of the first series. Decrease in speed (slower pace over distances) was a clear signal to stop the training. It was assumed that an increase of 1% in the time of all repetitions in a series performed by a swimmer – compared to the first series – eliminated the swimmer from further tests. A swimmer who finished training in the interval method joined control group and continued with them.

Before the experiment and after it was concluded, both groups took part in a progressive test on cycloergometer. The following parameters were measured: (VO₂max), (VEmax), after effort concentration of lactate in blood (La–) and maximum heart rate (HRmax). Apart from progressive test, the swimmers checked their abilities in swimming distances 25, 50 and 100 meters. After each distance was covered, a 15-minute break followed. Swimming tests took part two weeks before the experiment started and were repeated two weeks after it finished. Cycloergometer was chosen to this study because every child takes part in 2-week preseason training cyclist camp and gain some cycling experience. Also there is a sports laboratory in the University
School of Physical Education in Wrocław equipped with cycloergometer and high technology devices that allow collecting accurate data.

Progressive line test on cycloergometer – LODE, Netherlands. The test started at load of 0 W, the load was linearly increased by 50W in 3-minute period (average 8,76W over 30s) The test was conducted until failure or until heart rate exceeded maximum value (220 – age in years) or when an increase in load did not increase oxygen intake. The measurement of heart rate was monitored using sport-tester S810 or RS400 by POLAR (Polar Elektro, Finland).

Recording of breath parameters started two minutes before effort and finished 5 minutes after the effort. The subject breathed through a mask and the air was analyzed by K4b2 COSMED, Italy or QUARK b2 COSMED, Italy. Analyzer was calibrated with atmospheric air and sample gases. Three minutes after the afford blood samples were taken to mark the acid–base homeostasis, concentration of electrolytes and lactic acid.

Quetelet's index (BMI) was measured on the basis of height and body mass.

Measurements of acid–base homeostasis parameters in blood were performed by taking blood samples from fingertips to a capillary tube sensor, 80 μl of arterialized blood and introduced to Rapidlab 348, Siemens Healthcare Diagnostics, Germany analyzer. The following parameters were measured: pH, partial oxygen pressure (pO2) and partial CO2 pressure (pCO2) (mm Hg), current, standard and total concentration of bicarbonates (HCO3) (mmol/L).

Marking lactic acid. Using fingertip or ear flap, blood sample was taken to a capillary tube sensor 10 μl, introduced into a vial with the test (Dr Lange 140, Dr. Bruno Lange GmbH, Germany) and marked on a photometer (LP 400 Dr Lange, Dr. Bruno Lange GmbH, Germany).

In the course of the experiment the control group conducted the training plan based on mastering swimming technique and developing endurance, working below anaerobic threshold.

Statistical methods were used to measure average and standard deviations and the Wilcoxon non-parametric statistical hypothesis test was used to measure the relevance of differences for two correlated variables (Statistica 2010, Statsoft, USA). The statistically significant difference was assumed at \( p \leq 0.05 \).

RESULTS

Sixteen children completed the experiment; one child from control group had to resign because of contusion.

These are the changes in experimental group: VO2max (47.97 ± 5.39 to 61.10 ± 12.18), VEmax (78.84 ± 19.95 to 89.52 ± 19.67), La– increased after progressive test (7.49 ± 1.84 to 9.45 ± 2.66), HR max slightly increased (195.33 ± 7.31 to 197.89 ± 6.92).

In control group VO2max, VEmax and HRmax improved but in less than in experimental group. There was a change of VO2max (51.31 ± 5.67 to 56.60 ± 4.67), VEmax (79.88 ± 10.82 to 82.76 ± 10.89), La– after progressive test (9.07 ± 2.80 to 10.61 ± 2.52), and HRmax (193.43 ± 8.22 to 196.00 ± 9.93).

Both groups took part in a swimming test 2 weeks before and after experiment because benefits of interval training occur after a few days of active rest with moderate intensity. Swimming test was performed over 25m, 50m and 100m front crawl.
Changes occurred in both groups. In experimental group, swimmers improved swimming speed at 25m from 15.21 ± 0.79 (s) to 14.56 ± 0.65 (s), at 50m from 33.87 ± 1.72 (s) to 32.04 ± 1.69 (s), and at 100m from 75.95 ± 4.40 (s) to 70.90 ± 4.81 (s).

In control group changes also occurred. Swimmers improves at 25m from 15.84 ± 0.74 (s) to 15.62 ± 0.79 (s), at 50m from 35.36 ± 2.04 (s) to 34.82 ± 1.89 (s), and at 100m from 81.43 ± 4.64 (s) to 79.07 ± 3.64 (s).

**TABLE 2.** Average changes in VO$_2$max, VEmax, HRmax, La$^-$ after effort and the time measured to swim 25, 50 and 100m free-style in experimental group before and after the training plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental group before training plan (M ± SD)</th>
<th>Experimental group after training plan (M ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_2$max</td>
<td>47.97 ± 5.39</td>
<td>61.10 ± 12.18*</td>
</tr>
<tr>
<td>VEmax</td>
<td>78.84 ± 19.95</td>
<td>89.52 ± 19.67</td>
</tr>
<tr>
<td>La$^-$ after progressive test</td>
<td>7.49 ± 1.84</td>
<td>9.45 ± 2.66*</td>
</tr>
<tr>
<td>HRmax</td>
<td>195.33 ± 7.31</td>
<td>197.89 ± 6.92</td>
</tr>
<tr>
<td>Time: 25 m free-style [s]</td>
<td>15.21 ± 0.79</td>
<td>14.56 ± 0.65*</td>
</tr>
<tr>
<td>Time: 50 m free-style [s]</td>
<td>33.87 ± 1.72</td>
<td>32.04 ± 1.69*</td>
</tr>
<tr>
<td>Time: 100 m free-style [s]</td>
<td>75.95 ± 4.40</td>
<td>70.90 ± 4.81*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*statistically significant changes (p ≤ 0,05)</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 3.** Average changes in VO$_2$max, VEmax, HRmax, La$^-$ after effort, and times over distances of 25, 50 and 100m free-style in control group before and after the training plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control group before training plan (M ± SD)</th>
<th>Control group after training plan (M ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_2$max</td>
<td>51.31 ± 5.67</td>
<td>56.60 ± 4.67*</td>
</tr>
<tr>
<td>VEmax</td>
<td>79.88 ± 10.82</td>
<td>82.76 ± 10.89</td>
</tr>
<tr>
<td>La$^-$ after progressive test</td>
<td>9.07 ± 2.80</td>
<td>10.61 ± 2.52</td>
</tr>
<tr>
<td>HRmax</td>
<td>193.43 ± 8.22</td>
<td>196.00 ± 9.93</td>
</tr>
<tr>
<td>Time: 25 m free-style [s]</td>
<td>15.84 ± 0.74</td>
<td>15.62 ± 0.79</td>
</tr>
<tr>
<td>Time: 50 m free-style [s]</td>
<td>35.36 ± 2.04</td>
<td>34.82 ± 1.89</td>
</tr>
<tr>
<td>Time: 100 m free-style [s]</td>
<td>81.43 ± 4.64</td>
<td>79.07 ± 3.64*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*statistically significant changes (p ≤ 0,05)</td>
</tr>
</tbody>
</table>
DISCUSSION

Will interval training improve physiological parameters, such as VO₂max, VEₘₐₓ, HRₘₐₓ and La⁻ more than in the control group?

The results of the study we have presented confirm the thesis that interval trainings used with children result in improvement of physiological parameters when compared to the standard training based on aerobic effort. All measured parameters improved in both groups, however the experimental group witnessed greater changes.

The increase in VO₂max from 47.97 ± 5.39 to 61.10 ± 12.18 in experimental group when compared to the increase from 51.31 ± 5.67 to 56.60 ± 4.67 in control group shows the scale in difference between the two training programs. It was also proven in the course of studies (Sperlich et al. 2010) that interval training is superior as it improves work efficiency, the time and distance covered in the course of training sessions is shorter, while the results are similar. In school environment where training time is limited, it is crucial to run a short session and to get similar results. The time saved can be used in many ways. In Sperlich’s experiment performed with children (10.5 ± 1.4 year), a group training with the HIIT method (high intensity interval training) improved their results in competitions to a larger extent that the group training HVT method (high volume, low intensity). In many studies (Helgerud et al. 2007), a substantial increase in VO₂max was documented when training in the course of studies and control groups in the amplitude of VO₂max change and in swimming speed at 200m free-style. Research by Faude et al. (2008) leads to similar conclusions. They studied swimmers of 16–17 years of age. They did not notice changes in VO₂max or in swimming speed at 100m and 400m free-style in either group. Experimental group trained 5 weeks using HIIT method. The results of research presented here document higher or similar efficiency achieved from the training that required less work time (interval method) as compared to the training with low intensity but large volume. To improve VO₂max, these methods can be used with children as young as 9–11 years of age (Sperlich et al. 2010).

In the work presented here we observed a change in La⁻ (concentration of lactic acid) after maximum effort, namely progressive blood test. In both groups, a similar increase in maximum concentration of La⁻ was observed (on average the increase was 2 mmol/l plasma), however, higher values were recorded among swimmers in the control group. This could prove that 11–12 year old children are not ready (when it comes to development and training) to achieve higher concentration of La⁻ even at maximum effort. A similar result in both groups does not point to any advantage of any of the methods in creating maximum concentration of lactic acid in blood La⁻. Research conducted by Buchheit et al. (2010) on a group of children (9.6 ± 0.7 years) concentration La⁻ after a running interval effort was...
6.6 ± 1.7 mmol/l plasma, while in the case of older children (15.2 ± 0.8 years) after the same distance covered and after intervals 11.6 ± 2.3 mmol/l plasma was recorded.

Maximum heart rate after a progressive test increased similarly in both groups. In their research, Matsuo et al. (2014) did not observe increase in maximum heart rate. However, there was a visible adaptation of maximum efforts. Sportsmen training HAIT (high-intensity aerobic interval training), while executing similar work, reached – after the training cycle – lower HRmax values coupled with the increased swimming efficiency. Compared to control group their restitution was faster. On the other hand, in the studies (Guilkey et al. 2014) conducted among children divided into groups according to gender, there were no visible differences in restitution after 1 minute once the training was over.

Will the interval training cycle result in greater improvement than in the group following the standard training cycle where moderate (oxygen) intensities prevail?

Times (25, 50 and 100 meters free-style) decreased in both groups, however only in the experimental group those changes were significant. It could then be stated that interval training is more effective than traditional training (constant) in creating speed to cover distances of 25, 50 and 100 meters. However, studies by Sperlich et al. (2010) conducted among 9–11 year old children and training according to HIIT, do not document a significant improvement in swimming speed over a 100m distance in free-style as compared to the group training according to HVT method. A significant difference was observed in the case of 2000 m free-style. The times needed to cover the distance varied. Here the children training in HIIT method had an upper hand. Also in the case of the research by Kilen et al. (2014) conducted among senior swimmers (seniors), who trained in HIIT method with volume of distance reduced by half as compared to the control group, improvements over 100m free-style were witnessed. The time to cover the distance did not change either in experimental or in control group.

In his research Schmidt (1992) documented that the effort of high intensity above the anaerobic threshold increases oxygen debt (post-exercise oxygen consumption) and its tolerance more than the effort in the aerobic zone. Børsheim and Bahr (2003) concluded that the effect of the oxygen debt increases with the intensity and time of effort. Studies comparing various training methods prove that maximum interval efforts are more beneficial than other methods (Baker and Gleeson, 1998). Oxygen debt is paid back in the process of coming back to rest state and it can be the source of effort adaptation. The excess of post-exercise oxygen consumption is, among others, the result of utilizing lactic acid. Another task of post-exercise oxygen consumption is enhancing metabolism which increases along with the body temperature during effort. It can then be stated that children swimming in the experimental group were more oxygen indebted, this resulting in higher concentration of ion La–.

Assessing the well-being of children was also a very important aspect of the experiment, though it was not the main focus of this study. The experiment was conducted among children of primary school age, and above all it was to be safe. Despite the high intensity of the exercises, the children managed well. None of the children complained about pain or other signs of overtraining. The children were very enthusiastic and did all the tasks eagerly.
The research proves that it is worth supplementing standard training with interval training in primary schools. The method is very beneficial and allows saving time. Two interval training units can be used per week to achieve beneficial changes in endurance and swimming speed. The results are very promising for the syllabi for primary schools, and it is clear that standard training should be enhanced with other training loads, such as interval training. It could be stated clearly that the interval training with children brings beneficial changes in physical endurance and swimming efficiency. Using the interval training method, swimmers can achieve results that would be out of reach for their peers who only use the standard training method.

CONCLUSIONS

The six–week interval training cycle improved to a large extent the swim times of primary school age children. A significant increase in VO₂max, VEmax, HRmax and La⁻ proves that endurance has improved.

The swimming speed over the distances of 25, 50 and 100m free-style improved. On this basis, one can conclude that interval training may be used with primary school children in a way that is safe and well-balanced (it should not lead to overtraining), which requires constant monitoring of the results.

REFERENCES


Swimming speed control using concurrent visual information during a training session

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ABSTRACT

The control of swimming speed and intensity in real time increases the chance of a more effective adaptation to the performed effort. Influencing the sensation of velocity and swimming technique simultaneously while increasing the intensity of the physical activity being performed is an important methodical goal of swimming training. The aim of the study was to determine the relationship between concurrent visual information and the velocity of swimming, as well as the role of technology in motor activity during high-intensity exercise. Swimmers were chosen as participants in the experiment (n = 12). In the study, we performed two tests in which subjects swam a test distance of 200m freestyle. The participants in both trials covered the test distances in swimming times as close to that which had been individually assigned prior to commencing the experiment. The speed of swimming corresponds to the intensity of effort in Zone IV (Pansold and Zinner 1994). In the first test, subjects had no information about their swimming speed. In the second trial, subjects received concurrent visual information that informed them about their swimming speed. The use of concurrent visual information meant that the times obtained were closer to the assumed times (T-Student, p < 0.001). The use of concurrent visual information increases the control over swimming speed. This results in an improvement in the accuracy of swim times, thereby achieving the desired intensity of exercise. This increases the chance for a more rapid physiological adaptation to the exercise, which in turn results in an improved swimming technique during high intensity exercise.

Key words: visual information, speed control, exercise intensity, swimming

INTRODUCTION

With the development of science there have been increases in the effectiveness of sports training. Through laboratory experiments, it is possible to assess training activities and anticipate the outcome of sports results. Ongoing research contributes to improve training methods which promote the advancement of swimming results. The effectiveness of sports training (swimming included) depends on many variables, so the most effective solutions for overcoming such variables are desirable (Pelayo et al. 1996; Sweetenham and Atkinson 2003).
In swimming training, the two main domains are swimming exercise tasks and technical development (Maglischo 2003). They differ from each other in the intensity of the physical exercise (Tabata et al. 1997). During training, intensity is not always adequately matched to the age and abilities of swimmers, so the assumed tasks are not carried out correctly. Occasionally there are situations in which coaches typically emphasize cardiovascular conditioning at the expense of proper stroke technique. They often focus on high training mileage in the water and ignore the correct swimming technique. They forget that the overall physical development and correct stroke mechanics are very important during the subsequent stages of swim training. This has a significant impact on the final outcome of the sport. And furthermore, skipping the development of the aerobic capacity reduces the capability of anaerobic training efforts and work at higher intensities (Wilmore et al. 2008). Ignoring some of the training tasks allows for technical errors to develop. As the swimmers try to fix the technical errors themselves, such erroneous movements are implanted in their long-term memory, making the movements difficult to eliminate (Butefisch et al. 1995).

Improving the exercise capacity and swimming technique should take place with regard to the respective intensities included in five training zones (Pansold and Zinner 1994). The intensity of the swim is expressed by the swim time in terms of a specific distance. Control over swimming speed in real-time in designated training zones allows for a quicker adaptation to the exercise and an improvement in the proper movement technique resulting in an increased intensity of the exercise (Maglischo 2003, Wilmore et al. 2008). For this reason, the development of a method to acquire and improve the ability to control the speed of swimming is an important goal in the optimization process of training (Micklewright et al. 2012; Chinnasamy et al. 2013; Scruton et al. 2015).

Coaches provide the recommended swim time information to their swimmers, however, young and inexperienced swimmers cannot always maintain the same speed and intensity of physical activity while maintaining proper technique. This leads to a situation in which another exercise ability and technique are improved but not the one planned at this stage of training. Consequently, there is a visible decrease in the quality of the movements during higher-intensity exercise (Laursen 2010).

Usually information on swim times is passed on by the coach through verbal communication. However, environmental conditions, i.e. ambient noise, the head being submerged in water, regardless of whether a swimming cap is worn, all constitute interference in the process of information exchange (Zatoń and Szczepan 2014). Over the years, numerous methods have been created to improve the quality of information, including video recordings with visual information about the executed movement (Proteau 1992) and devices for wireless verbal communication (Zatoń and Szczepan 2014). However, none of the methods indicated have supplied information in real time shaping a feeling of speed and the swimming technique while increasing the intensity of the exercise. Hence, in this paper a research problem happened to determine the significance of the simultaneous visual information to control the speed of swimming in swimming training.

The ability to control the speed or intensity of swimming can be seen as multifaceted. Firstly, it is an effort to increase the chance of a more rapid adaptation to a performance during swimming training (Costill et al. 1991; Pelayo 1995). An exam-
ple is swimming at speeds within demarcated training zones above and below the anaerobic threshold, which are used during the adaptation process of a swimmer corresponding to lactate concentration levels (Costill et al. 1991; Perez et al. 2009; Scruton et al. 2015). However, the inexperienced swimmer cannot always maintain the right speed. Hence, the implementation of speed control and its teaching allows for a quicker adaptation to the training exercises. Worth noting is the importance of speed control, for example, in training to maintain speed for the cardio workout zone, or swimming to reduce body fat (maintaining speed zone for aerobic training).

Another aspect is to improve the economization of the movement as a result of stabilizing the swimming speed. The stabilization of swimming speed results in a reduction in the cost of physiological exercise (Costill et al. 1985; Barbosa et al. 2005). It is common practice to form movements with the least physiological cost (Åstrand 2003; Wilmore et al. 2008). Control of swimming speed over a certain distance in order to stabilize the action can help minimize the energy needed to perform the exercise, in turn the swimmer is able to swim longer distances. The value of this can be seen in competitive swimming (long-distance swimming), as well as swimming for health and recreation (swimming long distances to satisfy the hedonistic and vital needs).

The third aspect is to improve swimming technique during high-intensity exercise. A proper selection of training loads, in particular, the intensity of the swimming exercise, is an important factor in mastering the technique used at a given speed of swimming. This is true not only at lower intensities, but also at higher intensities where optimum technique becomes more problematic. At faster swimming speeds optimum stroke mechanics are difficult to maintain. Hence, by controlling the swimming speed, it is possible to maintain a desired intensity, resulting in an improved technique during intense physical effort.

The fourth aspect of swimming speed control is to optimize the kinematic parameters of the swimming cycle: stroke length and stroke rate. The swimming stroke length is the horizontal displacement of the swimmer during one movement cycle (Hay 2002). Stroke rate it is the number of complete cycles of movement performed in a unit of time (Hay 2002). Many authors have considered stroke length and stroke rate as evaluative criteria for an effective swimming technique (Hay 2002; Zamparo et al. 2005). Using these parameters, with respect to swimming technique, speed is assessed using objective assessment swimming tools (Hay 2002). Evaluation and adjustment of stroke length and stroke rate is one way to improve swimming technique. An improvement in the effectiveness of swimming is expressed by the swimming speed and the economization of the technique; often expressed as the expense of physiological effort. It is recognized that shortening your stroke length in relation to a constant stroke rate is a mistake as it leads to a reduced swimming speed (Ballreich 1976; Craig et al. 1985). A decrease in swimming speed due to the shortening stroke length in turn leads to an increase in the physiological cost of the effort (Costill et al. 1985). Therefore, measures aimed at extending the swimming stroke length will result in an increased swimming speed and a reduction in the number of motor cycles, and an improvement in the economization of the swimming. It is evident that through improved control mechanisms on the speed of swimming, there is a lowering in the physiological cost or an improvement in
the economization of the action, which leads to an increase in performance and in sporting results (Costill et al. 1985).

For these reasons, development of a method to acquire the ability to control the speed is an important methodical goal in the process of optimizing competitive and recreation swimming (Micklewright et al. 2012; Chinnasamy et al. 2013). Discussed above are the benefits of controlling the speed of swimming, i.e. the execution of planned exercises, a faster adaptation to physical activity. This includes the minimization of the physical cost incurred during physiological effort in the water, as well as through improving the swimming technique during increased intensity and the optimization of the kinematic parameters of the swimmer. All of these factors constitute hard arguments for teaching speed control to swimmers. Hence the search for methods to improve control over swimming speed is an appropriate pursuit.

Most methods for improving the efficiency of motor performances, including swimming, are based on a flow of information (Anshel 1990; Lee et al. 1994; Magill 1998). Information theory states that information is received from the environment through exterior receptors (hearing, sight) and proprioceptors (vestibular receptors, muscles, joints, and skin), and are then processed in the path between the receptor and the effector. This results in the motor response, which produces locomotor activity (Schmidt and Lee 2005).

One of the roles played by trainers, instructors and teachers is to provide information while athletes are performing the movement using different forms of information, i.e. sensory, visual or verbal (Proteau 1992; Scheeler et al. 2004; Zatoń and Szczepan 2014).

The transmission of sensory information is made by using a simple practical operation. This means they are used for purpose specific tasks that provide information on the strength, speed, or range of movements (Schmidt and Lee 2005). A verbal message is the teacher’s message in the form of instructions on the structure of movement, or the correction of errors that occurred (Zatoń and Szczepan 2014). In contrast, an example of visual information is shown on land, such as a video or timer (Proteau in 1992; Pérez et al. 2009).

Due to poly-sensory reception of information it is recommended that information be provided in three forms; through actions, words and images (Schmidt and Lee 2005). Hence, it uses a combination of complementary kinesthetic, verbal and visual (practical action – words – images). The transmission of sensory information, verbal and pictorial, increases the likelihood that the student will visualize the motor activity (Schmidt and Lee 2005).

Also, the time in which the transfer of information is given is an additional important aspect with regard to improved movement efficiency. Lee et al. (1994) has identified several types of categorical information that refer to the time the information is transferred. Concurrent information delivered during physical activity is concerned with continuous information, i.e. – visual information. Immediate information is transmitted during motor activities, and refers to discrete information, such as verbal communication. Delayed information links to continuous and discontinuous information, but is passed after the motor activity is completed. The most effective forms are considered to be information that is transferred concurrently and immediately (Lee et al. 1994). The argument for their effectiveness lies in the processes of memory-related motor activity (Schmidt and Lee 2005).
Most often this information is used during the prevention and removal of errors (Lee et al. 1994; Magill 1998; Schmidt and Lee 2005). In the present study, visual information reached the participants as they performed the motor function in a manner that concurrently informed them of their maintained swimming speed.

Research has proven that the most effective means of information-transfer is verbal communication, which is prepared according to the criteria of effective teaching communication (semantics, syntax and pragmatics) which also factors in the criterion of time transmission; namely simultaneous and immediate (Lee et al. 1994).

However, ambient conditions may create distortions in the process of information exchange. When swimming – factors such as noise, whether the head is submerged underwater and the presence of a swimming cap – all interfere with the exchange of information between the student and the teacher or, the coach and the swimmer (Zatoń and Szczepan 2014). These communication barriers reduce the impact of the most effective verbal communication, as well as hinder its simultaneous and instantaneous transmission. As a response, a variety of methods to improve the quality of information flow have been created; an example of such a device is wireless communication with the swimmer (Zatoń and Szczepan 2014).

Another important aspect is visual information, which has been recognized by researchers and practitioners as a key factor contributing to the improved execution of physical activities (Proteau 1992; Seat and Wrisberg 1996). It is also proven to have a positive impact on the effectiveness of the execution of physical activities (Seat and Wrisberg 1996). Visual information is a rich source of essential information for those carrying out motor activities. In the above-mentioned research, the visual information was transmitted by means of a video recording (Proteau 1992) shown to the swimmers or a timer submerged at the bottom of the pool (Pérez et al. 2009), or gestures (Burzycka-Wilk 2010).

The above examples of visual information (video, timer, gestures) did not allow for the possibility of the real-time transfer of information which could then shape the swimmer’s sense of speed and technical form while swimming with increasing intensity. The most common means of passing on information (i.e. verbal information from the coach with reference to speed) in the water is presented with significant communication barriers. As shown earlier, an improvement in swimming speed is associated with a more efficient physical adaptation, a reduction in physiological costs, and an improved swimming technique at high intensities. Hence in this work, the research problem was to determine the significance of the concurrent visual information as a means to control the velocity of swimming in swimming training. During the experiment, a moving beam of light on the bottom of the pool was used to supply visual information to the swimmer so that he could maintain a given swimming speed. Consequently, the results of this study differ from others, highlighting the innovative character of the research.

In the current research, the focus was on the effect of using a method of delivering concurrent visual information (in real time) on the speed and technique of swimming at high intensity. The aim of the study was to determine the relationship between concurrent visual information and the speed of swimming, as well as determine the technical accuracy in motor activity during high-intensity exercise. It was assumed that concurrent visual information improves control over swimming speed. To verify the hypothesis, the following research questions were formulated:
1. How does transmission of concurrent visual information affect the control of swimming speed?
2. What is the relationship between concurrent visual information and swimming speed?

MATERIAL AND METHODS

Twelve participants (both men and women) who train in the academic swim team were involved in the study. The subjects were characterized by the following parameters: age 17.7 ± 3.4 years, body height 180.8 ± 9.6 cm, weight 68.8 ± 10.8 kg, years of swimming training 7.4 ± 1.7 years, personal record over 200m 136.44 ± 14.7s. Each participant agreed to participate in the experiment, and the ethical committee assigned their approval for the research.

Before testing each person was assigned a designated swim time for the 200m. This time corresponded with the required intensity for swimming within Pansold’s zone IV classification (1994). The fourth zone is characterized by anaerobic exercise (Maglischo 2003). Pansold Test fur Schwimmer (Mesics GmbH, DE) computer software was used to determine the intensity required. This software makes it possible to determine the data for the swim distance, which in turn correspond to Pansold’s five training zones. Swim times for each training zone are based on the swimmer’s best result over the test distance during the current season.

Before the main experiment, the resting heart rate level was recorded. Then participants performed a warm-up in the water, swam 200m front crawl within the first range of energy expenditure according to Pansold’s classification (1994); the first range is characterized by low intensity below the anaerobic threshold.

The main experiment consisted of two exercise tests in which subjects swam a distance of 200m front crawl at a speed that corresponds to zone IV by Pansold’s classification (1994). All attempts started with resting heart rate values. Each participant started his or her swim test in the water. In both trials, the participants were required to swim the test distance (200m) at a time as close as possible to the time designated by the computer software prior to the experiment, which measured the accuracy of the exercise.

In the first trial subjects were to swim the test distance without receiving real-time information on their swimming speed. In the second one subjects received visual information delivered in real time, which informed them about the swimming speed. In practice, participants followed a beam of light moving along the bottom of the swimming pool, generated by the device “Lider” (concurrent visual information). This beam of light moved at the designated time for each participant. Both trials were made within a 24-hour time period in order to minimize the impact of fatigue.

The delivery of concurrent visual information which informed subjects of their swimming speed was transmitted by means of the “Lider” device (Kuca Ltd., PL). The device sent electronically controlled LED light signals along the bottom of the pool by means of a submerged transparent hose. Light signals moved at a pre-programmed speed. The speed of the light signal reflected the individually pre-determined rate for each subject. This gave swimmers the opportunity to swim within the scope of the desired experiment intensity.
In the experiment, participants swam a distance of 200m in a time as close as possible to the time appointed before the experiment. The smaller difference between the time swam and the assumed time testified to an improved accuracy of exercise. Time was measured over a distance of 200m with the aid of an electronic starting system by the Colorado Time System (Colorado Time, USA), which measures swim time to the nearest 0.01 seconds.

The average time taken to cover the swim distance was calculated using the following formula: \( v = \frac{ms}{s} \).

Heart rate was recorded \( HR (\text{beat} \cdot \text{min}^{-1}) \) with a sport-tester POLAR (Polar Electro, Finland). The measurement was performed immediately before and after the test exercises.

For the determination of statistical differences a t-test was used for dependent samples. \( P \leq 0.05 \) was assumed as the level of statistical significance. The statistical analysis assumed a difference between designated swim time and the actual swim times under the two conditions (no feedback and the visual feedback), and the average swim speed over the test distance (Table 1). Statistical analyzes were performed using Statistica 9.0 computer software (StatSoft, USA).

### TABLE 1. Difference in time taken to swim the test distance and the resulting speed values under two conditions (without information and with visual information)

<table>
<thead>
<tr>
<th></th>
<th>Without information</th>
<th>With visual information</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Prescribed time [s]</td>
<td>Time obtained [s]</td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>144.25</td>
<td>147.15</td>
</tr>
<tr>
<td>( \pm )</td>
<td>11.77</td>
<td>10.51</td>
</tr>
</tbody>
</table>

\( \Delta t \) is the difference between the time prescribed and obtained (measured – obtained)

### RESULTS

The use of concurrent visual information resulted in the obtained times of the participants being closer to the times prescribed prior to the experiment (Table 1). The difference between values of the obtained times in relation to the allocated times decreased from \( 1.33 \pm 3.43 \) (p) to \(-0.08 \pm 0.62 \) (s). Swimming speed increased from \( 1.37 \pm 0.11 \) to \( 1.39 \pm 0.12 \) (m/s). Both changes in the assessed values were statistically significant (\( p < 0.001 \)).

When interpreting the results, it should be noted that when swimmers received a visual indication of their swimming speed, they were able to traverse the swim distance in a time closer to the time designated prior to the experiment. This reflects an improvement in the swimmers accuracy of the test exercises.
DISCUSSION

Sports swimming training is a subject of interest in many scientific disciplines, i.e. Biomechanics, Physiology, Biochemistry, Psychology and more. The growing number of scientific studies has led to increases in the effectiveness of swimming training (Pelayo et al. 1996; Sweetenham and Atkinson 2003). A clear link between the results of the recent research and performance has resulted in the advancement of the sport. Laboratory experiments that have been conducted are multifaceted since they deal with many aspects, i.e. the physics of swimming, optimization of movement force in the water, economization of exercise, the sphere of motivation, and the use of the latest available technology during training (Hay 2002; Barbosa et al. 2005; Pérez et al. 2009). Also significant developments have been made through research into the domain of training methodology (Lee et al. 1994; Zatoń and Szczepan 2014). However, while such research has been far-reaching, scientific investigation into training methods continues. Though it is not easy due to the fact that training is a long-term process. Despite this, it is worth noting that the training of swimmers is increasingly modernized through the emerging methods that are being implemented at various stages of sports training (Pérez et al. 2009; Zatoń and Szczepan 2014).

The aim of the study was to determine the relationship between concurrent visual information and the speed of swimming, as well as motor skill technique during high-intensity exercise. The proposed hypothesis was confirmed. The use of visual information transmitted concurrently improves the control of swimming speed. The participants receiving visual information covered the test distance in a time closer to the designated time at the commencement of the experiment (p < 0.001). This demonstrates a more accurate realization of the training test exercises.

In swimming training the reception of information regarding speed in real-time is important. This is especially true when we want to acquire a proper training stimulus (Wilmore et al. 2008). Achieving better training effects is associated with the search for newer resources and training methods. The use of visual information is an example of this and one of many ways to optimize training. Swimming with the speed imposed by a moving beam of light makes it possible to maintain the established speed at a given intensity. Determination of individual speed, which should be controlled and maintained during training, increases the possibility of a more rapid adaptation to the exercise. This applies in particular to a swimmer’s adaptation to lactate production (Pérez et al. 2009; Scruton et al. 2015). For example, if the goal of training is swimming at a speed corresponding to the anaerobic threshold, the use of visual information helps the swimmer to perform the work within a given intensity. On the other hand, failure to control speed can cause the intensity of the exercise to be incompatible with the goal of training.

Speed control is also important from the point of view of the improved economization of motion by stabilizing the speed of swimming. Stabilization of the swimming speed is associated with a reduction in the physiological cost of the exercise (Costill et al. 1985; Barbosa et al. 2005).

Speed control is also related to an improved swimming technique with the increasing intensity of an exercise, and the optimization of the kinematic parameters of the swimmer, i.e. stroke length and stroke rate. By improving these parameters,
for example, the appropriate stroke rate and stroke length at a given distance can be executed by controlling the swimming speed through visual information, resulting in a reduction in the physiological costs of the exercise (Hay 2002; Costill et al. 1991; Scruton et al. 2015).

As shown, the ability to control swimming speed is very important. In particular, for the purposes of the tasks of training, an improved ability to adapt to an exercise, in order to reduce the cost of physiological effort and improve swimming technique at increasing intensity levels so as to optimize the kinematic motion of the swimmer. Hence, the method of controlling swimming speed through the transmission of concurrent visual information is the most valuable means by which it can be applied.

CONCLUSIONS

The use of concurrent visual information increases control over swimming speed. Obtaining more control over swimming speed will result in times closer to the designated test times, which indicates an improved accuracy of the training exercise. Increased accuracy of the training tasks results in improved physiological adaptation.

Greater control over swimming speed will also lead to improved swimming technique at higher intensity levels.

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CHAPTER II

EDUCATION IN SWIMMING
The Whole is Greater than the Sum of the Parts

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ABSTRACT

A drowning scenario is an holistic occurrence. A victim is threatened by a challenge to several or even many competencies, sometimes at the same time, sometimes serially, one after another. When the latter happens, there may be a chain of events, one leading to another. A pattern may emerge in which these events escalate in severity. Yet there also remains a sense of randomness as the scenario unfolds. When examining the reports of drowning survivors, and considering the recently presented competencies considered essential for teaching, we cannot ignore the sense that each of the factors named is intimately related to the others. There is a relationship between them which seems to have its own identity. This relationship is a kind of “critical mass”. What is this critical mass? In what way does it have an identity of its own? What might happen if this critical mass is somehow lost? If we wish to act preemptively to avoid such occurrences, what must we do? Logic suggests that our preemptive efforts must aim at a more holistic form of teaching than that which is traditionally offered. The intervention must be as holistic as that which we are trying to avoid. We need to teach – to the threat. There is always more than one contributing factor to a drowning episode! BUT! It always comes down to a single deciding, final factor. “I cannot breathe” (Lanoue 1963).

Key words: critical mass, the parts, relationships, holistic teaching.

INTRODUCTION

When neuropsychologists and neurologists discuss the workings of the human brain, they often cite “pattern recognition” as one example of what the brain does better than any computer. We can recognize a face in a crowd in milliseconds. A voice on the phone is immediately recognizable. We can learn a language or a piece of music as no computer can. Dean Buonomano, neurobiologist, describes pattern recognition as “understanding the whole by making sense of the relationship between the parts” (2011, pg. 9).

We wish to better understand the whole (the drowning episode). We have identified many of the parts (both the missing factors named by drowning survivors, and the competencies proposed as essential in teaching for drowning prevention). We have a need for greater understanding of the pattern formed by the relationships between these “parts”, precisely to better understand the whole. In this paper, I wish to discuss these relationships between the various elements (parts) of a drowning
scenario. I will present a speculative, conceptual model. Though yet to be proven, I believe these ideas have use in analyzing drowning episodes and in designing water safety educational interventions. Regarding teaching, good teachers have always instinctively done what is proposed. Inexperienced teachers have not done so.

**THE WHOLE**

A drowning scenario is described above as a “whole”, a holistic occurrence. The intention here is to focus on the fact that the emergency episode challenges several if not many competencies. In our experience, drowning survivors never name a single missing or weak competency as the only problem which led to their “incompetence” to solve the emergency issue. Which competencies are challenged, is related to the circumstances; the environment, the person involved, and the challenge(s) to be overcome.

The first step in the model presented here, is the recognition that the elements (missing competencies) in this holistic drowning episode a) have unique relationships with one another, b) that they combine, specifically because of the relationships between them, to “attempt to deliver a fatal blow to the victim”, and c) that these elements not only “conspire” with each other, but cannot be separated.

Not only can these various elements not be separated, but their relationships exist as somehow outside of the elements themselves, as a unique, identifiable entity. These relationships are the “glue” which holds the elements together. A simple example might be that breath control is intimately related to buoyancy control (or the lack thereof). How much we breathe in and out determines our buoyancy. Getting a breath quickly is often necessary. Being able to hold the breath (however much we have been able to take in) is a necessary part of regaining the surface after an involuntary submersion. Complete exhalation underwater is the necessary preparation for easily inhaling as the mouth and nose break the surface. If we have taken in enough to give “floatability”, (density < 1.0), this buoyancy alone may be enough to bring us back to the surface (Lanoue 1963). All of these and more, are interrelated and inseparable.

We can no more separate breath control from buoyancy control than we can separate the parts of an atom. In over-simplified terms, when we “split” the atom, driving the parts from one another, we destroy the atom. In the diagram below, you will see a graphic presentation of missing or weak breath control and buoyancy.
control, and more, within a drowning episode. Within the dotted box, you will also see the arrows representing the relationships named above. The varying size of the other elements suggests that they may have varying importance. The two circles in white and the arrows within the dotted box suggest that these are three unique entities but which are intrinsically related.

They cannot be separated without destroying some or all of the critical mass. Tearing out one of these circles, as a “part”, overextends the arrows and destroys them. They all contribute, together with some or all of the other missing competencies (and their interrelationships), to the emergency. I have previously (2008) described identifying the skills “missing or weak”, as reported by drowning survivors, as helping us to identify that which should be taught. In a currently ongoing study also reported here at The 8th Swimming Science Conference, we have begun to understand more about the relationships between these elements and their unique aspect. This led to the conclusion that the competencies recommended not only have such unique relationships, but also that when missing or weak, these relationships themselves also contribute to an aquatic emergency episode.

So if we cannot separate these elements within the drowning scenario, how do we compensate when teaching? How do we alter the traditional method of teaching the competencies one at a time?
THE PARTS

You will immediately see that the diagram below is identical to Fig. 2 above, but with a change in title. The intention here is to suggest that the way to compensate for the inseparability of the elements of a drowning scenario – its holistic nature, is to adopt the same approach in teaching.

There is a long tradition in the teaching of swimming/water competence, that the various competencies are usually addressed one at a time. The proposition above, that the elements in a drowning episode are inseparable, can also be adopted in teaching (Langendorfer and Bruya 1995). If we attempt to separate the elements for teaching purposes, the “critical mass”, i.e. the unique entity of the relationships between the competencies may disappear. Again, adapting the reference of Buonomano (2011) to brain neurons, to this discussion, these relationships can grow. When the various competencies which we wish to transmit to learners, are combined (in one way or another), they naturally beget these intimate relationships. Breath control, when combined with buoyancy control, sprouts new buds, gives birth to new relationships. Already in the 1940’s T. K. Cureton Jr. (1949) showed us that when combining any elements in a swimming teaching progression, final success is always better predicted. It may sometimes be useful to introduce one element at a time, but as the learner reaches a comfort zone, they should be combined, or recombined. In other words, mastering both A and B, separately, is not the same as mastering A + B (when combined). And remember that in a drowning scenario they are always combined. The critical mass is there. It must also be there in the teaching arena. So whenever possible, teach in wholes or combinations. We are teaching – to the threat.

Junge et al. (1986, 2010) showed that when assessing ten-year-old children who had previously been tested with a spurious test criterion, the critical mass discussed here was missing. In that study, among children able to swim 25 meters and who had been declared “competent swimmers”, only five percent (5%) were able to stop and rest underway (they were also weak in other aspects). Propulsion combined with stopping to rest, had never been taught. Oliveira et al (2013) staged an unannounced capsize of a RIB (in a pool under carefully controlled conditions). Among children who had mastered all of a given set of essential competencies, one third were judged under video analysis, to have been at risk. It would appear again here that the criti-
cal mass was missing. The relationships between the competencies taught were apparently missing. They may have never been taught together/combined.

THE CASCADE EFFECT

As a river cascades down its bed, it grows in volume. One might say, it’s critical mass increases. Along the way, new water (the critical mass) is added from other sources. A river cascade is normally thought of as repeated drops by steps, in a stepwise vertically dropping landscape. A salmon ladder is a man-made example. It occurs also in nature. The steps can be compared to the steps in any teaching progression. Even if we only introduce the steps one or two at a time, there is still a strategy which answers the needs discussed above.

The strategy recommended here is, as mentioned above, that which good teachers have always used. They have recognized the cumulative effect and interrelationships of the competencies as the learner progresses. They have recognized the need to systematically combine every new step with all of the preceding steps. They do NOT simply collect bits and pieces along the way, ticking them off as they, each on their own, are mastered. Consider the vertical lines in the figure below as steps in a teaching/learning progression. The inexperienced teacher often presents these one at a time and ticks off as the learner shows mastery of each. They assume that having mastered e.g. the first three steps, one at a time, that they are now ready for number four. This is usually not the case.

They have left the first three behind. The necessary maturing process, the consolidation of each step has not had a chance to develop. The advancement, improvement of each step, has not had the opportunity to take place. The cumulative effect of combining these first three has not taken place. The relationships between the steps, have not developed. This will not take place on its own.

As you examine Figure 5, note that at Step 1 something new has been introduced. On the horizontal, over time, Step 1 is consolidated and improved. By the time we get to Step 2, Step 1 is no longer as it was when first mastered, it is a new and improved model, it is now (1 +). Now we introduce Step 2, perhaps on its own, perhaps already combined with Step 1. The cumulative effect is taking place.

FIGURE 5. The “Cascade” effect
When combining Steps 1 & 2, we have a larger entity than when simply mastering 1 & 2 separately. Not only has Step 1 grown to a larger whole, but during the consolidation process, after Step 2 is added, new relationships develop between Steps 1 & 2. Neither 1 nor 2 are now as they were. And critical mass has been added (the X in the figure, their relationship).

An example for steps 1& 2 will help. For the sake of discussion, let’s say that Step 1 is to submerge the head and hold the breath for 10 seconds. Step 2 is to float motionlessly (one might very well adopt a different progression – here I wish to illustrate a specific point). You will see that during/after Step 1, a period of time elapses as depicted on the horizontal. Step 1 will be consolidated and improved during this time period (1 +). By the time we are ready to add Step 2, our learner should be holding the breath for 15–20 seconds. This will make the learning of Step 2 even easier. Had an inexperienced teacher simply jumped from 1 to 2, leaving breath holding behind, that consolidation process probably would not have occurred. When adopting a floating position, we also challenge breath holding. These two combine into a larger whole and allow us to float plus hold the breath for 15–20 seconds. By now, relationships are sprouting between Steps 1 & 2. A new element, this relationship (X), might e.g. be that – floating while holding the breath even longer (15–20 sec) – the learner feels the effect of floating even better, or they may discover that their posture can change, or they may find that it gets easier to stand after floating, or perhaps they open their eyes. These relationships grow because these two steps have been combined. By the time we are ready for Step 3, we have 1 + 2 + X. A cumulative effect has taken place. Steps 1 & 2 have continued to grow. And new critical mass has been added (X). As the water “cascades” down the mountain, it increases in volume.

As every new step is added, it is added to the growing list of the previous steps, all the way back to the beginning. This package continues to grow. Again comparing to brain neurons, it is as if this critical mass has the capacity to learn. Every time a new element is added to the package, this critical mass changes. It seems to learn. Thus, Step 1 e.g. continues to grow and to learn, for every new step along the way. The possibility of this package answering the needs of an emergency episode is greater than it would have been without this life preserving cumulative effect, this “cascade effect”, this new growth of relationships. The whole is greater than the sum of the parts.

Once again Buonomano (2011) comes to our aid. He gives the example that we may forget the numbers of our PIN code at the bank if asked to write them down (declarative memory). However, if we mock typing them in we “remember” because they have been stored as motor patterns in our non-declarative memory. As these patterns are repeated in the above described “cascade effect”, the neural messages are strengthened, strengthening (consolidating) the neuro-motor memory. In other words, once the learner has repeated these patterns often enough, strengthening synaptic bonds, it is more difficult to forget. In fact, such patterns often become reflexive or automated.
SWEETER THAN WINE

You have seen that consolidation of the steps, the cumulative effect and the development of relationships, take time (the horizontal aspect of each step; see Fig. 5). Permit an analogy. To today’s date, attempts to hasten the fermentation of wine chemically, have failed. There is no substitute for time in the fermentation process. That sweetest of wines has Father Time to thank. So too does the development of water competence. The mark of the seasoned teacher is that they have considerable patience, they are in no hurry to get to some magical end goal (arms & legs?). They see the “way” (the Zen) as more important than the goal (the goal often being misunderstood anyway). A well-known Zen proverb says that “He who sees only the goal, does not see the way.” The way is that path which allows consolidation, repetition, inclusion in games, combination with other elements, the growth of relationships – a maturing process which cannot be rushed.

In fact, the very experienced teacher envisions each development in the learner’s progress as the counterpart to the matching possible “missing competency” in the drowning scenario. This teacher “sees, feels, hears” what might be missing in some future possible emergency episode. “When she jumps to me from the side, can she immediately float? Can she turn? Can she exit?” Could she do that in an emergency? When she is floating, can she get a breath from time to time so as to continue floating (survival floating)? Could that happen? OK – let’s put it all together. This is a “package which might happen”. Here is another package (the reverse) to counteract the possible negative episode. For every possible element in a drowning scenario, there is a matching counterpart which is the positive, pedagogical strategy. See Fig. 4.

CONCLUSION

If we accept the idea that an emergency episode is an holistic occurrence, and that the elements are tightly bound together, we understand that they may not be torn apart from one another. We also see that the best way to compensate for these “relationships” and their interconnectedness may be to approach teaching in the same way. The competencies that we now believe are essential can also be taught in an holistic way, as described above. We can choreograph the teaching process to cater to these connections, these growing relationships, the accumulation of competencies in an ever growing package, and to benefit from these very relationships which grow because of the cumulative effect. We will appreciate the unique identity of these relationships, and the fact that they are a kind of “critical mass” which on the one hand can contribute to a drowning but on the other hand, can contribute to learning the competencies which help us to avoid drowning in the first place. The critical mass is added to the sum of the parts, thus “The whole is greater than the sum of the parts”.

R.K. Stallman

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Dominance profile and the speed of motor learning in 10-year-old children

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ABSTRACT

During the motor learning process the most important priority is to find various individual solutions to a given motor task. Every human being has a characteristic “educational superlink”, a way of processing information (Linksman 2001, Hannaford 2003). Recognising our personal learning strategy and using it will make the learning process more effective. The objective of this study was to identify the personal dominance profiles of the subjects and determine their impact on the speed of acquiring motor skills. The study comprised a group of 10-year-old pupils. The methods included a diagnostic survey aimed at determining their dominance profiles and a pedagogical experiment focused on diagnosis and analysis of motors skills in the context of the subjects’ ability to swim. The diagnostic survey revealed that the left brain hemisphere was the dominant hemisphere in over 73% of the subjects. The most common Profile was Profile A. Nearly 80% of the subjects mastered the motor skill taught to them to the highest degree; among them 59% were Profile A learners, 22% Profile B learners and 7% Profile C learners. Defining the dominance profile and adapting the course of the lesson to the diagnosed profile influences the speed of motor learning.

Key words: learning strategy, dominance profile, motor learning, swimming

INTRODUCTION

Learning as the basic activity among didactic activities is defined in the literature in a various ways. Learning can be defined as a “conscious, intentional and active process, occurring through direct or indirect exploration of reality, through experiences and exercises, as a result of which the learning subject acquires knowledge, habits and skills. The learning outcome consists of knowledge, the acquisition of which requires trained abilities needed to manage that knowledge” (Kojs 1987).

The process is intended to bring about changes which are manifested in individual experience. These changes are possible thanks to the existence of memory and the ability to store traces of experiences (Ledzińska 2004). During the motor learning process the most important priority is to look for various solutions to a given motor task. This search focuses on finding a solution irrespective of whether it is effective or not. Motor learning, which uses the process of discovery, is the domain of exercises similar to the target action, i.e. one facilitating adaptation to the available sources of information. When people are active in the learning process, they can focus their attention on using potentially important sources of informa-
tion. This makes it possible to look at the learning process for a given motor activity more broadly, not only with regard to fulfilling the requirements posed by the coach or teacher (Davids et al. 2003).

It is important to take into consideration the variety of acquired sensory-motor habits. They often have different objectives; they differ in terms of form of movement, tasks, speed, rhythm, level of difficulty or the significance of external and internal stimuli. Understanding all of the above is key to realising that we should not use only one way of teaching and developing sensory-motor habits. When it comes to the learning process in the case of various motor habits, it is worth taking into account the frequently varying levels of exercise and coordination capacity. Moreover, we should pay attention to the entire spectrum of psychomotor processes. This applies to those processes associated with movement (perception, attention, action choices or motor responses). In addition, it is invaluable when selecting the teaching method as well as the method for improving motor habits to consider the link between movement characteristics in competition and in training (Czajkowski 2002).

The teaching of motor skills is an exchange of information between the teacher and the learner, which leads to relatively permanent changes in the learner’s motor behaviour (Czabański 2003). Thus teaching is a didactic process during which the teacher transmits a predefined set of information to the subject, i.e. the learner.

The rate of learning in swimming depends on a number of factors. According to Bartkowiak, the most important factors influencing speed of learning in swimming are:

– motor talent
– level of physical development
– knowledge of the person conducting classes (expertise)
– feeling for the water
– buoyancy
– fear or lack thereof
– motivation to learn (Bartkowiak 2009).

Other elements that might, to some extent, affect the speed of learning in swimming are factors associated with the location of the lessons, equipment at the swimming pool and characteristics of the swimmers’ group. In addition, the ability of the teacher himself or herself may generate positive feelings in the learners and a greater desire to get to know the new environment. Learning to swim requires motor talent, which has a huge impact on the effectiveness of swimming lessons. Motor talent is genetically determined.

Of crucial importance in the teaching of swimming is choosing the right methods and means in order to achieve more effective and lasting results. The teaching of any new motor skill is a multi-factor process. That is why in the light of the information given above, it is worth considering where we should place the knowledge of diagnosing and using information about the learners on the basis of their dominance profiles. N.B. Quicker is not always better!

The concept of dominance profile has been defined by Carla Hannaford. It encompasses the dominant sensory channel: the dominant eye, ear, hand or leg. The dominance profile determines the capacity and frequency of channel utilisation as well as how the brain hemispheres are connected to the dominant hand, eye, ear and leg (Hannaford 2003; Borowy et al. 2011).
Each brain hemisphere controls the opposite side of the body. The left hemisphere controls the right ear, right eye, right upper limb and right lower limb. The right hemisphere controls the left ear, left eye, left upper limb and left lower limb. Either of the brain hemispheres can be the dominant one and the same applies to the ear, eye, upper limb and lower limb. Based on this information, it is possible to distinguish 32 dominance profiles (Hannaford 2003; Plewka and Taraszkiewicz 2010).

The notion of dominance profile is inextricably linked to the notion of lateral dominance. This phenomenon determines the brain’s capacity of preferring one of the sides of the body. Lateral dominance is innate and determines the so-called base (innate) profile. The base profile is what describes how and by means of which senses we assimilate information. Thus lateral dominance characterises the pattern according to which a human being processes information. Every time we learn something new, even when we are under stress, we draw on our base profile (Borowy et al. 2011).

Lateral dominance influences our body and our brain in the way information is transmitted. If we want to understand children’s behaviour, especially in the context of school learning, we should become familiar with and aware of the existence of these base (innate) dominance profiles. This understanding also concerns adults. These patterns may explain the behaviour of mature individuals in stressful situations. We should bear in mind that the innate dominance profile is always present, from the moment it emerges, influencing an individual’s behaviour. In order to overcome the limitations stemming from the base dominance profile, it is important to know how certain learning techniques and strategies are best adapted to each individual dominance profile. The well-chosen strategy will facilitate the learning process (Hannaford 2003).

The learning style is one of the components making effective and rapid learning possible. People learn in a variety of ways, a fact confirmed by numerous studies (Linksman 2005). They gather information about the external world, using all of the senses. It turns out that over time many people begin to prefer one sense over the others. Such brain activity enables them to learn new material, using their preferred sensory system. This is also why we choose a specific learning style. If we want to learn something very quickly, we need to take into account the way the material in question is “presented” – it should reach our brain in the most effective and simplest manner. That is why it is worth identifying which of the four main learning styles each individual prefers: visual, auditory, tactile or kinaesthetic (Linksman 2005).

The first step towards a better understanding of the learning style should be to define the individual’s dominance profile. By finding this individual dominance profile, we can prepare more detailed instructions as to how to present content in the teaching process. Therefore, it is worth focusing on diagnosing the dominant upper limb, lower limb, eye and ear (Boyd 2012).

Determining the dominant upper limb and the dominant lower limb is probably the easiest task. Most of us are able to indicate the dominant side without hesitation on the basis of daily activities. As a rule, the dominant upper limb is used to write or throw a ball. The dominant lower limb is used to kick the ball. If an individual uses both limbs to a nearly equal degree, a more specific test is needed to determine the degree of dominance. In such a case the dominant upper limb can be identified, if we put an object in front of the tested individual, at hip height, in the midline, and ask the individual to pick the object up. The upper limb used for the purpose...
will usually be the dominant one. In the case of the dominant lower limb, we can determine it by watching which leg is the first when the person in question climbs stairs or steps onto a chair. It could be assumed that the dominant upper limb and dominant lower limb are on the same side of the body. In most cases this is indeed true, but we should avoid generalising this link (Boyd 2012).

Diagnosing the dominant eye is more difficult, especially in adults who have adapted their eyes to binocular vision. A simple method for determining the dominant eye is to hold the right arm outstretched in front of the body and point the right thumb up. Next, we should find a vertical surface we will “aim” at (e.g. door frame, window). We focus our eyes on the thumb and try to “line up” the left edge of the thumb with the vertical surface. At this point we shut one eye and “aim”. The open eye with which it is easier for us to accomplish the task (the left edge of the thumb lined up with the vertical surface) is the dominant eye. During the test it is important to maintain visual focus on the thumb and not the vertical surface (Boyd 2012).

The dominant ear is easy to diagnose. It is the ear we usually use when we want to hear something better, more clearly. In order to determine the dominant ear, we should try to hear voices through a wall. Characteristically, we will use one ear for this purpose. That ear will be the dominant ear (Boyd 2012).

In her research Carla Hannaford has come up with 32 different dominance profiles. For the purpose of the present study, the authors have chosen and described here only those that were recognised in the tested children.

Profile A: the dominant brain hemisphere is the left, the so-called logical hemisphere. It also has all sensory-motor modalities. Individuals with such a profile learn better when they focus on details, which is why they prefer a structured pattern of knowledge transmission – from the particular to the general. They can capture information both from the visual and auditory channel. They treat the spoken language and the written language as important elements of knowledge consolidation.

Profile B: the dominant hemisphere is the left, logical hemisphere. The more dexterous hand and leg are on the opposite side from this hemisphere, while the dominant eye and ear are to be found on the same side as the dominant hemisphere. Individuals with Profile B focus best on visual details: it is through vision that they derive most benefit in acquiring new knowledge. In order to understand something, they need to observe it. They prefer a structured system of information transmission. They are limited acoustically under stress and, as a result, can experience problems with memory, mathematical skills and writing. The biggest problem for them is analysing information – they process it linearly, bit by bit.

Profile C: the dominant brain hemisphere is the left, logical hemisphere. The dominant ear, hand and leg are on the opposite side from this hemisphere, while they dominant eye is to be found on the same side as the dominant hemisphere. Individuals with such a profile focus better on auditory instructions. They process information through analysis, writing and verbalisation. In order to acquire knowledge, they need to listen to and process what they are learning both in writing and verbally. When under stress, they may have problems with reading; they may mix up letters or numbers, or may struggle with reading visual information. The biggest problem for them is analysing information – they process it linearly, bit by bit.
Profile EE: the dominant hemisphere is the left, logical hemisphere. The dominant ear, eye and leg are on the same side as the dominant hemisphere, while the dominant hand is on the opposite side. People with such a profile learn best through speaking, reading and analysing, and by focusing on information details. This enables them to memorise the content they are supposed to learn. When under stress, they are limited in terms of movement, hearing and sight. They may have problems with reading or writing; they process information linearly.

Profile HH: the dominant hemisphere in people with such a profile is the left hemisphere. Their dominant eye, ear, hand and leg are on the same side as the more active hemisphere. Such people learn most effectively by internal transformation, without external stimulation of the senses, in calm conditions and being on their own. They have a tendency to plan their movements. When under stress, access to all sensory-motor channels is limited in their case.

Profile K: the dominant hemisphere in people with such a profile is the gestalt (right) hemisphere. This is also the side of the more dexterous hand, leg, ear and eye. People with such a profile find it easier to assimilate information through movement; they focus more on the whole picture with emotional details. When they are not under stress, they are calm and no external stimuli influence them; they can hear and better communicate details and elements of information, both verbally and in writing. Under stress their hearing, communication and movement are limited, but the biggest problem is being able to distinguish detailed pieces of information and combine them into a coherent whole.

Profile L: is characteristic of people who use the right hemisphere more than the left one, and whose better eye, ear, hand and leg are on the same side. Such people learn better through movement; they even need it in order to analyse information. They imagine the whole picture of the task they are to perform; thus their learning proceeds from the general to the particular. When they are relaxed, they find it easier to assimilate both verbal and written data. Their movements are spontaneous and controlled; when under stress, they move timidly and awkwardly. When solving problems they use metaphors, associations and examples. They do not like to follow instructions and often tend to imagine the entire exercise in front of them; in such situations they instinctively do what seems right to them. They are sensitive to external stimuli and cannot cope with stress. When they are under pressure, they feel uncomfortable. The dominant hemisphere becomes inaccessible to the senses, but when such individuals are put in conditions in which they are able to relax, this may facilitate access to the left brain hemisphere, more so than in the case of people with different dominance profiles.

Profile LL: the dominant hemisphere is the right one; the dominant eye, ear and hand are on the same side, while the better leg is on the opposite side. People with such a profile assimilate and transform information best through movement. They focus on the whole picture. When under stress, their sight and hearing are limited, and communication processes are disrupted.

Profile PP: the dominant hemisphere is the gestalt hemisphere, the more dexterous hand is on the opposite side, while the dominant eye, ear and leg are to be found on the same side as the dominant hemisphere. Kinaesthetic communication functions well. When they acquire new information they subconsciously involve their hands. Stress causes their vision and hearing to become limited.
Such a diagnosis makes it possible to determine each individual learning profile and, more importantly, adapt the way content is presented and organise the learning situation directly for every learner. The first practical guidelines concerning ways of conducting educational activities were formulated by Taraszkiewicz and Rose (2006). Her research resulted in the observations characterised below.

Individuals with a visual learning style like order, are focused and rather calm, quiet. They tend to present things in terms of images and are not good at recalling instructions. When learning they need images, they like reading on their own rather than listening. Their writing is neat, correct, they see images of words. They have no problems with reading. They prefer to make notes and their concentration is disturbed by disorder and movement. When they are bored, they find something to watch, they look into the distance or draw. Their preferred mode of learning is through looking, reading, observing or demonstrating. They speak in a high-pitched voice, in a rapid, rhythmical and slightly chaotic manner (Taraszkiewicz and Rose 2006).

Audiles are people who easily lose their concentration, speak to themselves and move their lips while reading. They speak well and rhythmically, they like music. They learn through listening and like taking part in discussions. They write as they hear, which is why they may have problems with spelling. They read slowly, because they speak to themselves as they read. Such individuals are more predisposed to speaking than to writing. They prefer to repeat words aloud and easily lose concentration because of noise. They often hum and speak to themselves or to others. Their preferred mode of learning is through listening – to themselves or to others. Their speech is even, mellifluous and linear. They have melodious voices (Taraszkiewicz and Rose 2006).

Kinaesthetic, tactile learners are characterised by a high level of physical activity; they like touch and seek contact. Their gesticulation is rich and their reaction emotionally strong. The easiest way for them to learn is through action. They transform letters into movements, they need to write down a word many times in order to memorise it. They are not very fond of reading and prefer descriptions with some action. Their handwriting is specific or not very clear. They remember best what they have performed or done; in order to concentrate, they have to be on the move. They fidget, change position, find something to hold, tap and turn. Their preferred mode of learning is through action and direct engagement: experience and experiment. They speak slowly, sometimes with difficulty, and have a low-pitched voice (Taraszkiewicz and Rose 2006).

The aim of the present study was to determine the impact of the individual dominance profile of each learner on the speed of motor learning. The researchers formulated the following research questions:

1. Which of the dominance profiles is the most common in the analysed group?
2. Does adapting the course of the lesson to the diagnosed profile influence the speed of motor learning?

**MATERIAL AND METHODS**

The experiment featured 3rd grade children from Primary School No. 45 in Wrocław. There were 70 subjects in total (50 girls and 20 boys). The researchers excluded
pupils who were absent during any of the stages of the experiment (diagnostic survey, diagnosis of swimming skills, evaluation of acquired swimming skills). As a result a group of 38 subjects was eventually selected (Tab.1). Their results were subsequently analysed.

The experiment was conducted between September and November 2014. It was divided into two parts: diagnostic survey and pedagogical experiment. The diagnostic survey was conducted in the Wrocław school and its objective was to determine the dominance profile of every pupil. The pedagogical experiment consisted of 40-minute swimming classes at the University School of Physical Education indoor swimming pool in Wrocław. The classes were held once a week for five consecutive weeks in the presence of two PE teachers with swimming instructor qualifications. The classes were part of physical education classes.

The experimenters analysed the rate of motor learning in swimming with regard to the dominance profile preferred by each pupil. Selected motor activities were adapted to each group taking part in the experiment on the basis of the pupils' different swimming abilities. The experiment was preceded by a diagnosis of the subjects' swimming skills.

Before the start of classes in the swimming pool, the experimenters conducted two consecutive tests, using a diagnostic survey method. The tests took place at school, in the presence of the pupils’ form teacher. The tests made it possible to determine each pupil’s dominance profile.

The first test enabled the experimenters to identify the dominant brain hemisphere. The instrument was prepared for younger school children. It consisted of 32 questions and had three possible answers: a, b or ab. The subjects were to mark answers which they intuitively felt were those they liked the most. The questions were read out loudly and clearly by the teacher; whenever a pupil had problems with understanding the question, the teacher would modify it so that the pupil could understand it and mark the preferred answer.

The same type of answers were added up and on this basis the experimenters determined the dominant brain hemisphere. With the highest number of answers in category A, the subjects tended to be better at using the logical (left) hemisphere. With the highest number of answers in category B, the subjects tended to be better at using the gestalt (right) hemisphere. With the highest number of answers in category AB, the subjects tended to use both hemispheres in an integrated manner.

Next, the subjects performed simple exercises which made it possible to establish their dominant eye, ear, upper limb and lower limb. Each of the subjects received a dominance template on which he or she marked the dominant part of the body:

– upper limb – the subjects answered which hand they wrote with;
– eye – the subjects were to roll up an A4 sheet of paper and then to look at any point with one eye through the rolled up paper;

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>boys</td>
</tr>
<tr>
<td>38</td>
<td>12</td>
</tr>
</tbody>
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TABLE 1. Characteristics of the analysed group
lower limb – the subjects were to step onto a chair standing in front of them. The limb used first was marked as the dominant one;

– ear – the subjects were to mimic a phone conversation with the parents and put the phone to the ear, which indicated their dominant ear.

The results of the dominance profile test were compared with the answer key from Carla Hannaford’s book *The Dominance Factor – Knowing Your Dominant Eye, Ear, Brain Hemisphere, Hand and Foot*.

After analysing the results of tests conducted at school, the experimenters diagnosed the subjects’ swimming skills. The diagnosis made it possible to determine the subjects’ initial level of swimming ability. The analysis was carried out during two physical education classes in an indoor swimming pool. On each occasion it was preceded by a 10-minute warm-up. The diagnosis of swimming skills encompassed elements associated with the ability to swim backstroke, front crawl and breaststroke.

Owing to the poor results obtained during the swimming ability diagnosis, the subjects from form IIIA followed a training curriculum adapted to their swimming abilities. The training curriculum encompassed:

Lesson 1. Learning to glide in the prone position
Lesson 2. Perfecting gliding in the prone position
Lesson 3. Learning to glide on the back
Lesson 4. Perfecting gliding on the back
Lesson 5. Learning the basic propelling moves in the prone position and on the back.

The subjects from form IIIM and IIIB followed a training curriculum encompassing the following elements:

Lesson 1. Learning to kick in breaststroke.
Lesson 2. Learning to kick in breaststroke.
Lesson 3. Perfecting breaststroke kick
Lesson 4. Perfecting breaststroke kick
Lesson 5. Perfecting breaststroke kick

**RESULTS**

The research tools used by the experimenters showed that the dominant hemisphere in 9 subjects was the right brain hemisphere and in 25 subjects – the left hemisphere (Fig. 1). Four pupils diagnosed in the experiment tended to use both hemispheres in an integrated manner. However, these pupils were excluded later on from the analyses.

Regarding dominance profiles, the most common profile in the group was Profile A – 18 subjects; Profile L was diagnosed in 6 subjects; Profiles HH, B and C was demonstrated in 2 subjects each, while Profiles EE, K, LL and PP were found in 1 subject each (Fig. 2).

Analysis of the data has produced the following results. After 5 lessons 27 individuals (about 79% of the entire group) achieved 100% mastery of the motor skills taught. Two subjects (about 6% of the group) achieved 40% mastery, 1 subject (1% of the group) – 20% mastery, and 4 subjects (about 12% of the group) failed to master the skills taught (Fig. 3).
FIGURE 1. Distribution of brain hemisphere dominance in the group

FIGURE 2. Distribution of dominance profiles in the group

FIGURE 3. Level of motor skill mastery in the group

FIGURE 4. Distribution of dominance profiles among subjects with 100% mastery of the skill taught
The experimenters isolated those subjects who achieved 100% mastery of the skills taught (27 individuals). Within this group, 59% of the subjects had Dominance Profile A, also the dominant profile for the entire group. Twenty two (22%) had Profile L. Seven percent (7%) of the pupils had Profile C, while Profiles B, EE and LL could be attributed to 4% of the subjects each (Fig. 4).

DISCUSSION

In her book *The Dominance Factor – Knowing Your Dominant Eye, Ear, Brain Hemisphere, Hand and Foot*, Hannaford claims that knowledge of dominance profiles can have a significant impact on the effectiveness of learning. Teachers using this valuable knowledge in their work can increase the quality and effectiveness of communicating with their students, for example, by successfully adapting information transmission tools to make information reception as effective as possible, and- consequently- to help the students learn more effectively. In her research comparing the dominant profiles in students with labels used by schools to classify them, the author has demonstrated that individuals with the dominant logical hemisphere are more talented than students with the dominant gestalt hemisphere.

In *How to Learn Anything Quickly* Linksman distinguishes four main learning profiles: visual, auditory, tactile and kinaesthetic. She attributes each of these profiles to the dominant brain hemisphere, thus distinguishing eight superlinks which make rapid learning possible. In her book the author quotes instructors from the Michael Jordan Golf Company, who use their knowledge of learning styles in the teaching of golf. Today they are able to modify the content taught to the learners, choosing an individual approach to each learner and their respective learning style. The instructors explain that a golf lesson may involve watching videos, in-depth conversations, practical learning of new moves or simple training with short instructions. Linksman believes that all learners should find their optimal learning styles and thus will find it easier to assimilate new information. On the other hand, teachers, knowing their students’ superlink, can reach them more effectively and transmit teaching material to them more effectively.

Gardner, the author of *Multiple Intelligences*, has identified seven types of intelligence: linguistic, mathematical and logical, visual and spatial, musical, intrapersonal, interpersonal and kinaesthetic. In his view, every human being is born with all of these kinds of intelligence, some of which, however, develop more rapidly, others more slowly, and some that do not develop at all. The author presents the role of the teacher as someone whose task is to access each of these intelligences. The teacher can then create conditions in which all intelligences are stimulated for each student and each will develop more evenly, i.e. more effectively.

In her research Goddard-Blythe tries to draw attention to primitive reflexes characteristic of infancy. She believes that these reflexes should be integrated, because they will have a considerable impact on the speed with which the children will learn in the future. Visual and auditory perception, learning and remembering are the basis of correct development of all motor skills. According to Goddard-Blythe, the author of *Reflexes, Learning and Behaviour*, in order to achieve optimal results at school, the child must be able to sit still, use writing instruments, control the
numerous eye movements necessary to follow the printed word without jumping or getting lost on the page. These are physical abilities associated with development and motor maturity as well as postural control.

What all of these studies have in common is that they point to the significant role of the teacher, who must first of all show interest and acquire certain skills as well as knowledge of the way students learn. They must be able to make the material clear and understandable to students in a professional manner.

The present research demonstrates that by identifying the dominance profile and adapting the information transmission tools used in lessons to the dominant profile within the group, we may influence the rate and effectiveness of motor learning. The small size of this study group does not make it possible to draw unequivocal conclusions and therefore it can only be a starting point for further research. The authors’ intention is to present the possibility of raising the quality of the teacher’s work, of the teaching process and thus its effectiveness.

The key result of the present study is its demonstration of the significance of identifying the dominance profile in motor learning (human motor behaviour). Based on the results obtained in the course of this research process, it is possible to assume that the teacher’s knowledge of which dominance profile the learners represent enables the teacher to prepare and present the material in such a way that the material will reach the learners in the most precise manner possible, will be more effectively assimilated by the learners and will be stored in their memory.

CONCLUSIONS

The diagnostic survey revealed that the left brain hemisphere was the dominant hemisphere in over 73% of the subjects.

The most common profile in the group was Profile A.

Nearly 80% of the subjects mastered the motor skill taught to the highest degree; among them 59% were Profile A learners, 22% Profile B learners and 7% Profile C learners.

Defining the dominance profile and adapting the course of the lesson to the diagnosed profile influences the rate and effectiveness of motor learning.

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CHAPTER III

AQUATIC ACTIVITY
Effects of aqua aerobics on functional ability in elderly women

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ABSTRACT
The aim of this study was to verify the effects of a 24-week water-based aerobic exercise on flexibility of the lower back and hamstring muscles, and the lower extremity muscle strength level of elderly women. The study included 37 women at an average age of 67.2 ± 4.8 years who attended the Lukáš Senior Club in Prague 13. Participants were divided into the experimental and control group. The experimental group (n = 21) completed an organized water-based group exercise program. The control group (n = 16) did not participate in the physical program. The level of joint mobility was assessed by the trunk forward flexion test in a sitting position (Sit and Reach Test). The lower extremity muscle strength level was measured by the 30-Second Chair Stand Test. This study discovered that upon completing the intervention program in the water, the experimental group achieved improvement in the results of the sit-and-reach test by 1.8 cm (i.e. by 8.49 %, p < 0.05). The control group achieved smaller improvement – by 1.7 cm (i.e. by 7.46 %), yet this improvement is not statistically significant. Upon completing the physical program in the water, the muscle strength of both groups increased. There weren’t statistically significant differences between the groups, yet a better result was observed in the experimental group than in the control group. The experimental group exhibited the improvement by 24.1 %, while the control group by 20.67 % (p < 0.01). The physical program in the water seems to be a safe and effective way of increasing the functional condition of musculoskeletal system during activities of daily living (ADL) of elderly women.

Key words: aged, exercise in water, performance, women

INTRODUCTION
A general characteristic of aging is atrophy, which affects all organs and tissues in the body (Kalvach et al. 2004). At elderly age, the musculoskeletal system experiences significant changes on the level of bones, joints, ligaments, muscles and nerves. The elderly also experience loss of bone mass and disruption of bone structure and bone thinning – osteoporosis. Bones are more fragile and more likely to experience fractures which are caused by falls or excessive strain. Degenerative changes occur due to wear of joints – osteoarthritis which causes a gradual reduction of joint range (Valešová and Valeš 2010).
Aging of muscles may be characterized by a reduction in volume, a decrease in strength, endurance, flexibility and speed of contractions – all these aspects significantly increase the risk of falling. The loss of muscle is partly covered by multiplication of fat tissue. Histologically, myocyte atrophy is detected together with a selective loss of type II fibers, an increase in connective tissue and deposition of lipofuscin; however, there is no detail clarification of processes associated with the so-called myocyte apoptosis (Marzetti et al. 2010). There are also discussions on the relationship of dynapenia and sarcopenia – whether the limitation of movement is primary, followed by impairment of muscles, or vice versa (Clark and Manini 2010).

Due to the deterioration of balance, the lack of joint range and muscle strength lead to disturbances in posture, impairment of functional ability, increased risk of falling, decrease in walking speed and impaired performance in activities of daily living. From this perspective, the care of the muscular system represents a significant controllable factor of inspecting the quality of life of elderly people (Evans and Rosenberg 1991). Several studies have documented the positive effects of physical activity of senior population with different health conditions, even of very fragile individuals. Regular physical activity may lead to improvement in mobility, performance in activities of daily living, walking speed, decrease in risk of falling, increase in bone mass and improved personal comfort (Province et al. 1995; Daley and Spinks 2000). The increased level of regular physical activity in elderly people plays an important role in the prevention of muscle atrophy and emergence of sarcopenia which is accentuated with age and leads immobility (Cheetham et al. 2002). Regular physical intervention, adequate to the current state of an elderly person, represents a significant prerequisite for maintaining overall physical fitness and also for the preservation of muscle mass. Furthermore, physical intervention in the form of group exercise gives the elderly people an opportunity of communication, social integration and enjoyment.

Reduced mobility and fear of falling in the elderly may become the reason for not including physical activities into the daily routine. Physical programs carried out in the water environment may minimize these obstacles (Skelton and Dinan 1999; Hauer et al. 2002). These programs take advantage of a specific effect of water environment on the human organism; they comprise swimming skills and swimming as well as other locomotion in the water and in a wide range of gymnastic exercises. Swimming and specific equipment, such as gloves, water dumbbells, water “noodles”, are used to strengthen the muscles. Motion programs in the water are often carried out with musical accompaniment which creates a pleasant atmosphere, determines the rhythm of movement and respects the possibilities of carrying out movement in their entirety.

The physical properties of water may prevent falls of people with balance disorders. It is believed that the viscosity and buoyancy of water can improve the equilibrium functions (Suomi and Koceja 2000) thanks to stimulations of proprioceptor (Tokuno et al. 2008) and deep muscles (Kaneda et al. 2008) in the water. In their study, Katsura et al. (2010) demonstrated significant improvements in dynamic balance (measured by the Timed Up and Go test) of seniors over 65 years of age after an eight-week intervention in the water at a frequency of 90 minutes three times a week.
Stevenson et al. (1988) concluded that physical intervention in the water positively affects the cardiovascular and neuromuscular function of elderly people, similarly as aerobic exercise on dry land. Physical activity programs in the water provide benefits for seniors with increased risk of falls or impaired mobility and those suffering from arthritis (Simmons and Hansen 1996). Physical activities in the water are often easier and less painful than on dry land. Thanks to hydrostatic buoyancy of water, the joints are less loaded and patients suffering from arthritis are able to perform movements with less effort and greater extent (Konlian 1999). There are studies which indicate improvement of aerobic fitness and mobility of seniors with rheumatoid arthritis after the intervention in the water (Harkcom et al. 1985; Minor et al. 1989). Similar results were also recorded by other authors who established improvement in aerobic and muscular fitness in people over 60 years after 8 to 12 weeks of physical interventions in the water (Taunton et al. 1996; Takeshima et al. 2002). Wang et al. (2007) further demonstrated significant improvement in knee and hip joint flexibility in patients with osteoarthritis after 12-week intervention program in the water, at a frequency of 50 minutes 3 times a week.

Aquatic training programs use resistance and bouncing exercises. A study which followed the recreationally active younger individuals discovered that a motoric program in the water, including dynamic exercise (e.g. bouncing exercises), leads to a significant improvement in the area of functional mobility, muscle strength and speed of movements. In a recent study, Kieffer et al. (2012) addressed the influence of physical program in the water on the functional condition of the musculoskeletal system of the elderly. It was a randomized trial which involved 26 seniors (15 women and 11 men) at an average age of 76.3 ± 5.6 years. The experimental group of seniors (n = 15) completed a physical program in the water which included aerobic, fitness and bouncing (plyometric) exercises. The control group (n = 11) completed the exercise program on dry land under the supervision of an instructor, which included walking, low aerobics (without jumping), dancing and strength training exercises were intentionally omitted by this group. Both mobility programs were carried out in 8-week period at a frequency of 30–40 minutes twice a week. The functional condition of the musculoskeletal system of seniors was assessed through the following motoric tests: sit and get up from the chair in 30 seconds (30-Second Chair Stand Test), flexion at the elbow with a barbell (Arm Curl Test) and stand up, walk 2.44 meters and sit (8 Foot Up and Go Test). The results of this study showed that a short-term exercise program in the water, dynamic motion activities, increases functional fitness (muscular fitness, mobility) of seniors more significantly than the exercise program on dry land. The group that completed the motion program in the water experienced improvements in all evaluated motoric tests. The control group improved only in the 30-Second Chair Stand Test. Furthermore, it is interesting that the group exercising in the water showed a significant improvement in the Arm Curl Test. The authors thus suggest that the dynamic exercise program in the water not only increases the strength of the lower extremities, but also the strength of the upper extremities. Performing activities of daily living, such as rising from a chair or walking up the stairs is closely associated with the level of muscular strength and its production. The dynamic motion programs in the water may be used to maintain and develop physical fitness of seniors. Some of the strengthening exercises on dry land may not be suitable for seniors because of impacts and over-
loading of joints. The effect of the exercise program in shallow water (the water level reaches the level of the chest) on joint mobility and strength of lower extremities of elderly women was examined by Sanders et al. (2013). The quasi-experimental study included 66 women (age ranged between 60 and 89 years), who were divided into two groups. The first group \((n = 48)\) underwent an organized 4-month motion program in the water (3 exercise units of 45 minutes per week), the other group \((n = 18)\) did not engage in any regular physical activity. The level of joint mobility was evaluated by the Sit and Reach Test and the level of muscular strength in the lower extremities was assessed by the 30-Second Chair Stand Test. In comparison with the control group, the exercising group experienced significant improvements in the flexibility of lower back and hamstrings – by 8% \((\text{before} = 25.59 \pm 6.47 \text{ cm}; \text{after} = 27.66 \pm 6.9 \text{ cm})\), and significant enhancement of muscular strength of lower extremities – by 30.5% \((\text{before} = 10.77 \pm 3.06 \text{ full stands}; \text{after} = 14.06 \pm 3.95 \text{ full stands})\). The authors conclude that exercise in the water seems to be a safe and effective way of improving the functioning during activities of daily living (ADL – “Activities of Daily Living”) of elderly women.

The physical programs in the water depend on the quality and accuracy of performing given exercises or swimming locomotion. From our own experience, we may provide a few examples of negative effects of physical activities in the water on the musculoskeletal system. For instance, swimming breaststroke with the head constantly above water level may damage the cervical spine. The entire body of the swimmer is levitated by the water except for the head which is the only body part which is not levitated. Therefore, a rather long swimming with the head above the water level harms the extensors mainly in the cervical spine area (Čechovská et al. 2003). We often come across asymmetry in the breaststroke kick. These undesirable repetitive motion structures may cause injuries in the lumbar spine area. During physical programs in the water in a vertical position in contact with the bottom, movements based on hopping may lead to muscle cramps in the area of lower extremities and the Achilles tendon may become overloaded. This happens due to the absence of complete clamping down of the foot. Moreover, the risk of getting cold is increased when the physical activities are not performed with sufficient intensity. These injuries may be prevented by performing the exercise and swimming locomotion through appropriate technique and intensity.

It has already been established that trichloramine (a byproduct of chlorine) and other aerosols containing chlorine oxidants used for disinfection of water in swimming pools may cause changes in the epithelium of the airways and on the skin, and this contribute to triggering and development of allergic diseases (eczema, asthma) in genetically susceptible individuals. However, if the relevant standards for disinfection are followed, the concentration of the trichloramine shall be safe (Jacobs et al. 2007). The pool environment may cause gynecological problems in susceptible women. The starting torque may be chlorine which disrupts the natural vaginal microflora by destroying part of the bacteria which are responsible for vaginal balance (Calda 2011). Also the risk of fungal diseases is associated with the hygiene of the environment. The primary source of fungal diseases are humans. Transmission through water has never been proved, and the infection is transmitted by direct contact or through jointly used objects and areas (towels, floors, seats), usually by stepping on infected skin scales falling off the feet of affected
The aim of this study was to verify the effects of a 24-week water-based aerobic exercise on flexibility of the lower back and hamstring muscles and the lower extremity muscle strength level of elderly women.

**MATERIAL AND METHODS**

The study was a single factor intergroup and intragroup quasi-experiment with a pretest and posttest design.

A sample of 37 women at an average age of 67.2 ± 4.8 years, who attended the Lukáš Senior Club in Prague 13, participated in the study. All participants met the following inclusion criteria: age over 60 years, adherence to a physical program in the water, examination of monitored indicators, the absence of any organized water-based exercise program in the previous 6 months. The exclusion criteria were: immobility, incontinence of urine or feces, cognitive disorders (dementia) and inability to perform the tests proposed. Participants were divided in a non-randomized way into two groups: the experimental group and the control group. The experimental group (n = 21) completed an organized water-based group exercise program once a week (one exercise unit lasted 60 minutes and there were 24 lessons in total). The control group (n = 16) did not participate in any physical program – neither in the water, nor on dry land. The general characteristics of subjects are shown in Table 1. There were no significant differences between the groups.

**TABLE 1. General characteristics of subjects**

<table>
<thead>
<tr>
<th></th>
<th>Exercise group (n = 21)</th>
<th>Control group (n = 16)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>67.2 ± 5.1</td>
<td>67.1 ± 4.6</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>70.9 ± 10.2</td>
<td>71.5 ± 11.6</td>
<td>0.866</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>159 ± 4.2</td>
<td>161.3 ± 6.4</td>
<td>0.220</td>
</tr>
<tr>
<td>BMI [kg · m⁻²]</td>
<td>28.1 ± 4.1</td>
<td>27.4 ± 4</td>
<td>0.771</td>
</tr>
</tbody>
</table>

Values are presented as mean and standard deviation (±). No differences were detected between the two groups with respect to general characteristics; p < 0.05

BMI: Body Mass Index

The participants underwent a six-month supervised exercise program in shallow water (the water level reached the level of chest) once a week (60 min/session). The intervention program in the water was carried out on the premises of the Elementary School of Prague 5, between November 2013 and April 2014. The dimensions of the pool were 25 m × 10 m. The water temperature was around 29°C. Each exercise session began with a 10 minute warm-up including basic locomotor movement such as water running, hopping, jumping, galloping, and leaping done in multiple directions. The conditioning phase of the aquatic session included 40 minutes of aerobic conditioning, resistance exercise, and flexibility training. The
The aerobic exercise component consisted of advanced moves, choreography and patterns (jumping jack, cross country ski, kicks, hamstring curls, pendulum, rocking horse, twist). Muscular strengthening component consisted of leg, arm and trunk movements using aquatic noodles. The leg exercises were done in standing, alternating sides and included hip flexion and extension with knee flexed and with knee extended, hip abduction and adduction with knee extended, heel raises, and hip rotation. Upper extremity exercises were also done in standing position and included pushing a noodle under the water using shoulder extensor and triceps bilaterally and shoulder abduction and adduction. For trunk strengthening, participants worked sitting on a noodle. The cool-down component of the program consisted of slow movement activities and stretching. For example, see figures 1 and 2.

The participants underwent basic anthropometric testing (body height, body weight). To assess the level of their joint mobility, the test of the depth of a forward
bend in a sitting position (Sit and Reach Test) was conducted in order to assess the range of mobility in the lumbar spine areas, hip joint and the flexibility of lower back and hamstring muscles. Measuring of the flexibility by the Sit and Reach Test is a traditional part of testing batteries of health-related fitness (Kabešová 2011). The test was conducted according to the methodology of the Eurofit testing battery for adults (Oja, Tuxworth 1995). The tested person is sitting on the floor, her legs are stretched out and she attempts to reach forward with both of her arms as far as possible. The measuring is performed by a special measuring device. The participants have to warm up before the testing, e.g. by a few deep bends conducted without maximum effort. The test is performed without shoes. The test is properly demonstrated to the participant in advance. The participant then conducts two attempts with maximum effort. During the attempts, it is necessary to keep checking that both legs are stretched out all the time. The depth (length) of the reach of both hands is measured on a centimeter scale. The longest reach of the fingers of both hands is crucial for recording the result, whereas the maximal bend should be performed slowly, with an exhalation and then it should be maintained for 2–3 seconds. Of the two attempts, the better one was recorded – the one which provided a higher value (under the measuring accuracy of 1 cm).

The lower extremity muscle strength level was measured by the 30-Second Chair Stand Test. Sitting on a chair with her feet shoulder-width apart and her arms crossed over her chest, the tested person is instructed not to lean back in her chair during the test. She repeats rising from the chair as quickly as possible for the period of 30 seconds. The test is carried out once and the total number of repetitions of rising from the chair into the upright stand in 30 seconds is recorded (Rikli and Jones 1999). According to many authors, this method represents high reliability $r = 0.79–0.93$ (Jones et al. 1999). Good reliability of this method was also reported by Boneth et al. (2012).

The results of the measuring before and after the intervention program were statistically processed using the Wilcoxon non-parametric paired-sample test and to compare the results between the experimental and control group, the Mann-Whitney U Test was used. The classification of effect sizes was determined by calculating point-biserial correlation ($r$). Cohen’s guidelines for $r$ are that a large effect is 0.5, a medium effect is 0.3, and a small effect is 0.1 (Coolican 2009). The significance level was set at $p < 0.05$. The SPSS 21.0 software was used for calculations and data processing.

RESULTS

Figure 3 presents the measured average values of the Sit and Reach Test. No significant difference between the experimental and control groups was found before the intervention program was introduced (21.2 ± 6.2 cm vs. 22.8 ± 7.2 cm). Yet after the intervention program in the water, the experimental group experienced an improvement in the trunk flexion test up to 23 ± 6.2 cm (i.e. by 8.49 %). The experimental group experienced a statistically significant difference ($p < 0.05$); while the difference in the measured values of the control group were not statistically significant.
At the beginning of the study, measuring of lower extremity muscle strength did not demonstrate any statistically significant difference between the experimental and control groups (16.6 ± 2.4 stands vs. 17.9 ± 3.4 stands). Figure 4 shows the average difference between the values before and after the intervention. Upon completion of the physical program in the water, the experimental group experienced a significant improvement in the lower extremity muscle strength to 20.6 ± 3.9 stands (p < 0.01). The control group has also experienced an improvement in the level of muscle strength of lower extremities. The performance increased to 21.6 ± 4.4 stands (p < 0.01). The difference between the values of the 30-Second Chair Stand Test before the physical program in the water and after it was statistically significant in both groups, yet the experimental one experienced more significant improvement in comparison to the control group (i.e. by 24.1 % vs. 20.67 %).
Table 2 presents results of the functional performance tests and the percentage difference between the performance before and after the intervention program in the water. By attending the group exercise in the water regularly, the experimental group experienced improvement by the end of the study – in the depth of trunk flexion while sitting on average by 1.8 cm (i.e. by 8.49 %, p < 0.05). The control group achieved smaller improvement by 1.7 cm (i.e. by 7.46 %), yet this improvement is not statistically significant. Upon completion of the physical program in the water, the muscle strength of both groups increased. There were no statistically significant differences between the groups, yet a better result was observed in the experimental group than in the control group. The experimental group exhibited the improvement by 24.1 %, while the control group by 20.67 % (p < 0.01).

### TABLE 2. Change in functional performance tests before and after intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise group (n = 21)</th>
<th>Control group (n = 16)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>before</td>
<td>after</td>
<td>%</td>
</tr>
<tr>
<td>Sit and Reach Test (cm)</td>
<td>21.2 ± 6.2</td>
<td>23 ± 6.2*</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>before</td>
<td>after</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>22.8 ± 7.2</td>
<td>24.5 ± 6.4</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>0.018</td>
<td>0.492</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.386]</td>
<td>[0.003]</td>
<td></td>
</tr>
<tr>
<td>30-Second Chair Stand Test (numb.)</td>
<td>16.6 ± 2.4</td>
<td>20.6 ± 3.9**</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>before</td>
<td>after</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>17.9 ± 3.4</td>
<td>21.6 ± 4.4**</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.829</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.859]</td>
<td>[0.035]</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean and standard deviation (±). Figures in brackets are effect sizes. * p < 0.05; ** p < 0.01

### DISCUSSION

Performing activities of daily living, such as rising from a chair or walking up the stairs is closely associated with the level of muscular strength and its production. Dynamic physical programs in the water may be used to maintain and develop physical fitness of seniors. Certain strengthening exercises performed on dry land may not be suitable for seniors because of impacts and overloading of joints (Kieffer et al., 2012). The aim of physical programs in the water (e.g. fitness swimming, aqua-jogging, aqua-aerobic and other) should mostly be the positive influence on the overall physical fitness, from mild incentives to supporting the health, from maintaining the current level of physical fitness up to the stimulation of further development of physical fitness (Houdová and Čechovská 2012).

Our results have demonstrated a positive effect of the physical program in the water on functional condition of the musculoskeletal system of elderly women. Upon completion of the intervention program in the water, the experimental group experienced more significant improvement in the Sit and Reach Test (cm) in comparison to the control group (8.49 % vs. 7.46 %). Improvement in the level of flexibility in the lower body upon applying the physical program in the water is in accordance with other studies (Alves et al. 2004; Tsourlou et al. 2006; Sanders et al. 2013). The authors state that this effect is related to the physical characteristics of the water environment which enables people to conduct movements in the joints (e.g. forward and side kicks) in a much larger range than when performing
them on dry land. The unlimited mobility of the lower body (especially in the hip joints) and the muscle symmetry of the lower extremities muscles is necessary for ensuring the correct posture, preventing muscle injuries and functional spine pain, and reducing the risk of falling (Rikli and Jones 2001).

Our study also demonstrated the positive effect of the physical program in the water on the level of muscle strength of lower extremities. Upon application of the physical program in the water, the level of muscle strength of lower extremities increased by 24.1%. The 30-Second Chair Stand Test was used in order to assess the level of muscle strength of lower extremities (number). Our results correspond to results of a few authors. Kieffer et al. (2012) recorded the improvement in the level of muscle strength of lower extremities by 29.36%, while Sanders et al. (2013) showed the improvement by 30.55%. Aging is associated with progressive decrease in muscle mass and decreased production of muscle strength. Physical activities in the water environment may help to maintain the mobility and to increase the level of the functional condition of the musculoskeletal system (Takeshima et al. 2002). The mobility represents the ability to move around unassisted, which is crucial for maintaining self-sufficiency and managing locomotive activities (walking the distance of 400 m, walking up the stairs, raising from a chair) (Reid, Fielding 2012). Many studies show that the muscle strength (speed of the performed movement) may more efficiently predict the performance in activities of daily living (Reid, Fielding 2012). The measurements of performances in motoric tests, such as sitting down on the chair and rising from it, remaining standing, walking speed, are used in objectification methods of diagnosing activities of daily living (ADL) which require muscle power (Reid, Fielding 2012).

CONCLUSION

Based on the results obtained during this study, the significant contribution of regular physical interventions with aspects of aqua-aerobics for elderly women were confirmed. It has been demonstrated that regular group exercise in the water under the guidance of a trainer significantly improved the mobility of the spine, flexibility of the lower back and hamstring muscles and the lower extremity muscle strength level of elderly women in the performance of the activities of daily living (ADL). The physical program in the water seems to be a safe and effective way of increasing the functional condition of the musculoskeletal system during activities of daily living (ADL) of elderly women.

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Participation in aqua aerobics classes –
a need or a necessity?

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ABSTRACT

Broadly defined swimming serves a number of important roles in the life of an individual, from health-related, through compensatory and corrective, to recreational. All these aspects are reflected in aqua aerobics. Results of various studies on exercise motivation point out to an evolution in the value of physical culture coinciding with social, technological, economic and ideological changes taking place today. This means that the traditional reasons behind taking up exercise – based on sports rivalry, with clearly defined rules and training monitoring – are being replaced by new forms of exercise and experiencing exercise, characterised primarily by inner satisfaction from engaging in physical activity. The objective of the study was to determine what motivated women of various age groups to regularly take part in organised exercise classes in water (aqua aerobics). The assumption was that the most frequent motives behind the women’s participation in physical activity in water changed with age. The study included 100 women aged between 20 and 70 and regularly (at least twice a week) attending water aerobics classes. The method chosen in the study was diagnostic survey. Taking into account the division of the respondents into age groups, it can clearly be seen that in every age group the most important motives for choosing physical activity in water are a desire to improve one’s fitness level and care for one’s health.

Key words: aqua aerobics, music, motivation, swimming

INTRODUCTION

Over the last few years people have become increasingly interested in physical fitness and activities promoting a healthy lifestyle. It has become clear that physical activity in water can significantly improve the functioning of the entire human body and the quality of life (Haffor et al. 1991; Meyer and Bucking 2004). Today physical activity in water is not limited solely to covering specific distances in the shortest possible time. Broadly defined swimming serves a number of important roles in the life of an individual, from health-related, through compensatory and corrective, to recreational. All these aspects are reflected in aqua aerobics. This form of movement, which has its roots in rehabilitation in water, has been acknowledged by scientists, physicians as well as ordinary people. It combines gymnastic, strength, aerobic or dance exercises transferred to and adapted to water. This integration has produced water aerobics. Other commonly used names are: aqua fitness, aqua aerobics, hydrobics, water gymnastics. “This form of physical activity is training
in water, which strengthens muscles and makes them more flexible, makes the body slimmer, improves circulation and breathing, as well as fitness, prevents stress, delays exhaustion, improves mood and gives tremendous satisfaction. This form of physical activity is addressed to people of various age groups, physical fitness level and swimming abilities.” (Pietrusik 2005).

The constant evolution of aqua aerobics and versatility of its use has led to the emergence of its many varieties. Here is one possible division:

1. Equipment used: aqua ball, aqua disc, aqua noodle, aqua spinning, aqua step.
2. Target group: aqua senior, aqua for pregnant women.
3. Type of training method followed: aqua fatburner, aqua interval, aqua circuit training.
5. Arrangement of classes and its style, with music being the basic determinant: aqua afro dance, aqua Irish dance, aqua ballet, aqua musical, aqua fun.
6. Use of other techniques involving body movement: aqua fight kick, aqua yoga, aqua Pilates, aqua jogging, aqua walking, (Stasikowska and Konieczna 2011).

All aerobic exercises increasing the body’s demand for oxygen and improving physical fitness and circulation are performed in water and in the non-weight-bearing mode. When the body is immersed in water its weight decreases by even as much as 90%, as a result of which exercises are not strenuous for the joints and almost completely reduce the risk of injury. In addition, they involve all large muscle groups, which improves body shape and increases fat burning. During an hour-long aqua aerobics class, it is possible to burn from 350 kcal up to even 790 kcal. Thanks to the resistance provided by water, it is possible to increase muscle strength and flexibility to an extent comparable to that achieved at the gym. Exercises in water are more efficient. When working out in water, we are not exhausted as much as we are in a gym and the heart is not put under so much strain. The force of gravity is much weaker than on land, which is why moving in water is more beneficial to joints. In addition, constant water pressure acting on the body immersed in water helps to decrease swelling around joints. (Pietrusik 2005; Zysiak-Christ et al. 2010; Huey and Foster 1993).

Drawing on their research, Nicholl and associates found that physical activity in water brought with it a limited risk of injury (Nicholl et al. 1991). Off-loading provided by water causes the muscles to relax, which facilitates the assumption on the correct posture and enables the exercisers to move more easily than on land (Pasek et al. 2008). In addition, while moving in water, the body is affected by alternative thermal, physical, chemical and mechanical stimuli which activate centres in the brain other than those activated on land. Those that are active on land can rest. That is why people coming out of the water feel reinvigorated, relaxed and well rested (Łubkowska 2015).

All human activity, people’s actions or choices, has its roots in human psyche. Any activity, including physical activity, is inextricably connected with motivation. Generally speaking, motivation can be defined as a process causing, directing and sustaining a certain kind of behaviour whose objective is to achieve a goal set in advance. What is characteristic of motivation is its direction and intensity. The direction of motivation means simply defining the goal we want to achieve. Intensity,
on the other hand, is slightly more complex and stems directly from force (the degree to which a motive determines our behaviour), size (the higher the goal, the higher the motivation to achieve it) and intensity (degree to which the body is aroused to achieve the goal) of the motivational process. In order for this to emerge, some determinants must occur. One must feel a need, a desire, and at the same time it must be possible for them to act to satisfy their needs. In addition, the result of such action must be beneficial to the individual. Finally, one must be convinced that a task can be performed (a need satisfied) to a degree that satisfies them. The components of the process include motives (everything that prompts people to act, sustains that action or hinders it) (Maslow 1990; Strelau 2006).

Motivation has been studied extensively with regard to physical activity and sports, because it is regarded as an important determinant of engagement (Iso-Ahola and St. Clair 2000). The results of various studies concerning exercise motivation (Derry 2002; García Ferrando 2006; Hellin et al. 2004) point to an evolution in the value of physical culture coinciding with social, technological, economic and ideological changes taking place today. This means that the traditional reasons behind taking up exercise – based on sports rivalry, with clearly defined rules and training monitoring – are being replaced by new forms of sports activity and new ways of experiencing exercise, characterised primarily by inner satisfaction from engaging in physical activity. This non-traditional way of viewing sport and physical activity is in line with new societal values aimed at improving our quality of life, caring for physical and mental health, meeting individual needs of play and motivation. Such attitudes and interests, together with the fact that health professionals have acknowledged activity in water as being very beneficial to the body, have led to the emergence of various forms of such activity. That is also why in recent years more and more people have been willing to take up exercise in water (García Ferrando 2006; Sowa 1998).

Numerous studies pointing to a favourable effect of aqua aerobics on fitness and functioning have inspired the authors of the present study to define the most frequent motives prompting women of various age groups to take up this form of physical activity.

The objective of the study was to determine what motivated women of various age groups to regularly take part in organised exercise classes in water (aqua aerobics). The assumption was that the most frequent motives behind the women’s participation in physical activity in water changed with age.

The following research questions were formulated to verify the hypothesis:

1. Are women from different age groups prompted by the same motives to take up physical activity in water?
2. How does the assessment of the perception of the motives among women change depending on age?
3. Which motives are the most frequent and which are the least among women irrespective of their age?
MATERIAL AND METHODS

The study included a hundred women aged between 20 and 70 and regularly (at least twice a week) attending water aerobics classes. The respondents answered the questions – which were to check the motivation behind their participation in aqua aerobics classes – anonymously. Questionnaire forms were handed out after the end of the classes. The participation of the investigator was limited to handing out questionnaires and explaining how they should be filled in, and then collecting and verifying them. Each respondent replied independently to the same questions. In addition, the respondents had to fill in boxes in the questionnaire concerning their age and number of hours they spent weekly doing aqua aerobics. Thanks to this, the results are reliable and can be standardised.

The women taking part in the survey were divided into four age groups (by decades). The last group comprised women aged between 50 and 69 owing to a small number of respondents in the group if divided by decade. The most numerous were women aged between 30 and 39 (33%) and between 20 and 29 (31%). Groups of women aged 40–49 (17%) and 50–69 (19%) were similar in size.

The method chosen in the study was diagnostic survey. The investigators used a questionnaire comprising sixteen closed-ended questions with cafeteria answers according to the five-level Likert scale. In every question the respondents would indicate whether it well reflected their thoughts and feelings about the issue. Answers could be chosen from among five categories: definitely yes, generally yes, hard to say, generally no, definitely no (Wasilewska 2008). The age of the respondents was determined as well.

The classes were conducted by a team of highly qualified instructors in four indoor swimming pools in Wrocław (at Hotel GEM, Wrocław University of Environmental and Life Sciences, Primary School no. 18, and Military Academy of Land Forces. The exercises were done at the shallow (90 cm) and deep end (1.20–2.30 m) of the pool for about 50 minutes. The average water temperature was about 31 degrees centigrade for shallow and about 28 degrees centigrade for deep pools. These were mostly TBC (total body condition) classes aimed at strengthening and modelling the whole body.

The results of the survey were collected, sorted out and underwent a statistical and descriptive analysis. All the data are presented in percentage and numerical values in the figures below.

RESULTS

Seventy percent of the respondents claim they attend aqua aerobics classes twice a week. Only 1% take part in organised water exercise classes five times a week. The remaining 29% choose this type of activity three times a week. The data come from the questionnaire in which the respondents wrote the number of hours they devoted to aqua aerobics.

At each figure below from the left: definitely yes, generally yes, hard to say, generally no, definitely no.
Participation in Aquatic Classes – a Need or a Necessity?

The figure 1 shows that in all age groups women decide to enrol in water exercise classes in order to improve their physical fitness (answers in the affirmative constitute about 80% of all the answers). It is a very positive sign that staying very fit is so important to most women surveyed in the study. Answers in the negative or lack of definite opinions are few and far between – only between 2 and 4% of the respondents opted for them in all age groups.

Answers in the affirmative in the various groups are distributed according to a pattern similar to that in the first question (Figure 2). It is a very positive sign that in the second (30–39 years of age) and fourth (50–69 years of age) groups there were no answers in the negative. This may mean that the respondents are aware that caring for one’s health is very important. In the first group (20–29 years of age) none of the respondents chose the “hard to say” answer, unlike the respondents in the second group, five of whom – 15% – chose it and the respondents in the fourth group, 21% of whom opted for it.

Significantly, in the first group (20–29 years of age) the number of answers in the negative, nearly 46% (14 answers) is only slightly higher than the number of answers in the affirmative (13 answers), when it comes to the question about going to water aerobics classes for social reasons (Fig. 3). The situation is similar in the second group (30–39 years of age), but here answers in the affirmative are slightly more numerous than answers in the negative. It can be said that groups two, three and four are characterised by a similar distribution of answers in the negative and in the affirmative (which predominate).

As we analyse the figure 4 for the first (20–29 years of age) and second group (30–39 years of age), we will see easily that answers in the affirmative dominate.
over answers in the negative, when it comes to choosing aqua aerobics as a way to improve one's appearance (86% of answers in the first group and 81% of answers in the second group). In the third group (40–49 years of age) 52% of the respondents chose answers in the affirmative, 23% had no opinion and 22% chose answers in the negative. In the fourth group (50–69 years of age) only one respondent answered in the negative, 21% were neutral, while 72% replied in the affirmative.

Significantly, aqua aerobics improves the mood of most women in all age groups (over 80% of the respondents in every age group) (Fig. 5). A few respondents in the 20–29 and 40–49 groups replied that a desire to improve the way they felt was not their motive for choosing aqua aerobics (about 3% in group one and about 10% in group three).
When analysing the figure 6 featuring the answers to the sixth question, concerning going to aqua aerobics classes following a doctor’s recommendation, we note that in both group one and group two answers in the negative account for about 70% of all answers. A similar pattern of answers can be found in the 40–49 age group, in which answers in the negative were chosen by about 58% of the respondents. In the fourth group answers in the affirmative are more numerous than answers in the negative by just 5%.

It is a good sign that a large majority of the respondents, nearly 80% of answers in the affirmative in groups one and two, and over 50% in groups three and four, choose aqua aerobics, because they like to spend their free time actively (Fig. 7). When it comes to undecided respondents, their number is the highest in the oldest group (about 15%); there are fewer of them in groups two and three (about 3%) and no undecided respondents in the youngest group.

Figure 8 shows that women aged 20–29 do not decide to take up aqua aerobics because they have been encouraged to do so by their friends (only 35% of the respondents). In the 30–39 age group, 48% of the women say that a friend has encouraged them to take up aqua aerobics, while 45% say that they took that decision without their friends’ help. Over half (52%) of the respondents from group three answered in the affirmative, while 41% answered in the negative. Nearly half (46%) of the women aged 50–60 answered in the negative, while 36% answered in the affirmative.
Only 18% of women aged 20–29 confirm that they go to aqua aerobics classes because this sort of activity is trendy (Fig. 9). Over 73% of the respondents from this group answered in the negative. Among the thirty-somethings, 33% answered in the affirmative, 15% chose the “hard to say” answer, while 51% decided to answer “no”. The distribution of affirmative, negative and neutral answers in the 40–49 age group was almost even (about 35% each). Women aged 50–69 clearly are not guided by latest fitness trends when choosing aerobics classes – only 26% of them answered in the affirmative in this case.

For a majority of the respondents aqua aerobics is a form of escape from everyday life, irrespective of their age group (Fig. 10). When coming to water aerobics classes, they can relax and forget about the problems at work and in their private life. Most respondents in the first three groups chose the “definitely yes” answer (66% in group one, 63% in group two, 52% in group three). In the oldest age group only 5% of the respondents answered in the negative, with 60% answering in the affirmative.

In groups one and three it matters to the respondents how they are perceived by others (Fig. 11). As many as 63% of the twenty-somethings and 64% of the forty-somethings admit they attend aqua aerobics classes to impress their friends. Few respondents (12%) in the 30–39 age group and 21% of the respondents in the 50–69 age group have no opinion about the matter. The highest number of answers in the negative come from the 30–39 group – 45% of all answers.

It is satisfying to note that in each age group (about 70% of the respondents in groups one and two, and about 60% in groups three and four) the personality and skills of the instructor matter greatly when choosing classes (Fig. 12). Only 6% of
Participation in aqua aerobic classes – a need or a necessity?

The twenty-somethings do not take into account the instructor’s attitude. In group two, few respondents (12%) answered in the negative. In the case of the thirtysomethings, 11% answered in the negative, and so did 10% of the forty-somethings. The highest number of answers in the negative came from the 50–69 group – 15% of all answers.

As the figure 13 suggests, regardless of their age, the respondents see exercises in water as less embarrassing than those on land. The women do not experience the unpleasant consequences of exhaustion like sweating. Nor are they at risk of being peeped at by non-exercisers on land. This is most evident in the 30–39 age group.
(66% of answers in the affirmative) and the 40–49 age group (75% of answers in the affirmative). In the oldest group 15% of the respondents did not feel lesser discomfort in water than on land, while for 67% of the women lesser discomfort during classes in water was an important reason for choosing aqua aerobics.

When looking at Figure 14 for the 50–69 age group, we see that thanks to aqua aerobics the respondents feel better in water than during traditional swimming (62% of the respondents). Not having to dive under water during classes lowers the fear of water. Using buoy belts gives the exercisers better control over their bodies. The distribution of answers among the women in the 40–49 age group was even. As many as 63% of the women from group three answered in the affirmative, while no fewer than 30% were not able to decide. In the 20–29% age group, 57% of the respondents answered in the affirmative to question 14, while only 25% in the negative.

In groups two (75%), three (73%) and four (72%), for most women it is important to set a good example for their family and friends (Fig. 15). The “definitely yes” and “hard to say” answers were chosen by 29% of the women. Nearly one-fourth (22%) chose the “generally yes” answer, while 18% answered in the negative.

When analysing Figure 16, we noticed that the twenty-somethings did not feel markedly younger thanks aqua aerobics classes, which is quite understandable. In the 30–39 age group, no fewer than 26% of the women had no opinion about question 16, while only 6% answered in the negative. More than half (57%) of women from that group feel younger thanks to water aerobics. Both in the 40–49 and
Participation in Aquatic Exercise Classes – a Need or a Necessity?

50–69 age groups, over half of the respondents (about 60%) have the impression that they feel younger thanks to aqua aerobics. Exercises in water slow down involuntary processes and help people to keep their bodies in good health longer.

**DISCUSSION**

Aqua aerobics, one of many types of physical activity, is becoming increasingly popular among women regardless of their age. Exercises in water are among those that mature women like to choose (Król and Maszorek-Szymala 2009). Regular exercise can improve mobility, efficiency in the performance of daily activities, walking speed, can lower the risk of falls, increase bone mass and private comfort, especially among the elderly (Province et al. 1995; Daley and Spinks 2000). Exercises in water and swimming are recommended particularly for the obese. The basic advantage of water consists in diminishing the person’s weight and using water resistance during exercises. In addition, exercises in water engage many muscle groups at the same time, lower the pain or discomfort associated with the exercises and are the preferred form of physical activity for the obese (van Baak and Saris 1999).

The dynamic growth of this phenomenon made many researcher and scientists more and more interested in it. Initially, they focused on the health-related aspects of water aerobics. They studied the impact of such exercises on the human body in terms of physiology, biomechanics or health. Exercise should be viewed from a multidimensional perspective and not focus only on the human physique. That is why psychologists study this form of activity in water.
The results of numerous studies on women participating in aqua aerobics classes indicate that exercise in water can improve the women’s mood in mid-adulthood. It significantly reduces anxiety and negative mood of the women doing aqua aerobics in comparison with the initial values. The biggest benefits in the emotional sphere come with endurance, rhythmical and coordinated exercises as well as medium intensity exercises without an element of rivalry (Piotrowska-Całka 2007).

Research shows that aqua aerobics owes its unquestionable success to water, which enables people to perform all types of exercises. There are no limitations associated with the age and gender of the exercisers or their fitness level. It has been demonstrated that aqua aerobics improves the mood and self-esteem of the exercisers, and increases their energy level (Baily et al. 1997).

Research into the benefits of aqua aerobics was also carried out by Eider. The study shows that most women (nearly 46%) take part in the classes to generally improve their health. They have developed the so-called hypokinesia, i.e. decreased physical activity associated, for example, with the nature of their work. After three months of attending classes 87.5% of the exercisers saw their physical fitness level increase (Eider 2003).

Poliszczuk and Mosakowska (2007) studied the motivation of women taking up water aerobics. Their study featured 100 women aged between 17 and 62, living in Warsaw or near it, and regularly going to aqua aerobics classes two or three times a week. Given their age, women from the youngest group (17–35) were motivated by their desire to change their appearance. The respondents from the 36–48 and 49–62 age groups listed as the most important motives for taking up exercise in water their desire to improve their level of physical fitness and prevent joint diseases. The authors have demonstrated that the motivation for choosing aqua aerobics classes changes with age (Poliszczuk and Mosakowska 2007).

Many researchers studying the motivation for choosing all types of aerobics classes, both on land and in water, have demonstrated that women are guided mainly by aesthetic values. By choosing this form of exercise, they want to model their bodies and lower their weight. Another important factor is a desire to improve their level of physical fitness. What is also satisfying is the fact that the respondents very often are guided by their desire to care for their health (Majchrzak et al. 2009; Aljeziak 2011).

In other studies researchers point to health-related values as the most important motive for choosing exercise in water for most women (52%). These are followed by aesthetic values – 39% and social values – 25%. To a lesser extent, women are guided by emotional motives – 16%, hedonistic motives – 12% and utilitarian motives – 8%. No fewer than 75% of women admit that the most important effect for them is mood improvement and general improvement of their health – 70%, as well as physical fitness and ability – 63%. Improvement in the way their bodies look is less important – 45%. Other effects listed by researchers include a feeling of being relaxed – 35%, having new friends – 34%, other (more energy, optimism, inspiration, unforgettable experiences) – 12% (Łubkowska 2015).

The present study, just as those indicated above, shows that women are guided by various motives when taking up physical activity in water. The most important motive for the respondents was health and desire to improve their fitness level as well as mood. Given the changing motivation depending on the age of the wom-
en, the researchers have noted that despite being guided by a variety of motives, all women are focused on health-related spheres (caring for their health and seeking to improve the level of their physical fitness). Significantly, among the thirty-somethings the most important motive is a desire to feel better.

**CONCLUSIONS**

After analysing the survey results, the following observations can be made:

The most frequent motives why women decide to take up aqua aerobics are a desire to improve their fitness level and their health status. In addition, the respondents cited their need to feel better. This is very satisfying because it indicates that people are increasingly aware of the health-related aspects of aqua aerobics when it comes to both the physical and psychological sphere.

The least common motive chosen by all the respondents, regardless of their age, was their doctor’s recommendation. This may suggest that women choose healthy activities without being prompted to do so by their doctors.

Taking into account the division of the respondents into age groups, it can clearly be seen that in every age group the most important motives for choosing physical activity in water are a desire to improve one’s fitness level and care for one’s health. Only among the thirty-somethings, a desire to feel better is the most important motive. This demonstrates that the primary motives do not change much with the age of the respondents.

When it comes to the secondary motives for choosing aqua aerobics, we can see clear differences depending on the age of the women. The twenty-somethings choose water aerobics to model their bodies and reduce their weight. Thus aesthetic considerations predominate. The thirty-somethings have decided that their health status is their second most important motive. Among the forty-somethings an important stimulus is a desire to influence those around them by setting an example.

The least important motive for the twenty-somethings and thirty-somethings is their doctor’s recommendation and fashion for aqua aerobics. The forty-somethings are the least likely to be guided by a desire to feel better. The women in the 50–69 age group firmly deny choosing aerobics in water because it is fashionable. As can clearly be seen, the least important motives are common for most respondents.

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Variability of skin parameters during swimming training

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ABSTRACT

Swimmers are less prone to injuries caused by direct contact with dangerous surfaces, an opponent or a large object. However, the aquatic environment in which they spend a lot of time, often more than 4 hours per day, can become a threat to the skin’s health. The hydrolipid film covering the stratum corneum is essential to maintain the permeability of the skin barrier, not only in terms of protection. Exogenous factors such as detergents, the use of cosmetic products, or chlorinated water can significantly affect the performance of the skin. These factors play a role in the pathogenesis of skin diseases, such as irritant contact dermatitis, atopic dermatitis, ichthyosis, acne and infections caused by Candida albicans, and Malassezia dermatis. The study included 32 elite swimmers and synchronized swimmers, members of the National Team and Staff Macro-region Lower Silesia. We studied 32 subjects, aged 15–26 years (mean age 21 ± 1). During the experiment, skin parameters such as hydration, lubrication and skin pH at the back (around the left shoulder) were measured. The scanning of parameters took place before the start of training in the water and after 120 minutes. The measurement tools used included the Corneometer, Sebumeter and Skin-pH-Meter® PH 905 Courage Khazaka (probe parameters and certification of medical measuring with an accuracy of 0.001). During the study, the swimmers and synchronized swimmers were in the pool and performed standard workouts. Skin parameters changed regardless of gender during the two-hour training period in relation to the physiological state. At the end of the workout, hydration and lubrication change to the detriment of the swimmer and their skin pH values become more alkaline. We suggest applying specialized skin preparations the elite athlete’s body in order to reduce fluctuations in the skin parameters and restore its homeostasis.

Key words: competitive sport, swimming, hydro-lipid film, skin pH

INTRODUCTION

The study of elite sportsmen provides a lot of interdisciplinary information about a sport discipline, its growth rate and direction of its development as well as the biomechanics and biophysics of movement. Also, the new findings enable us to look ahead into the future and develop new trends (Kuder et al. 2005). Elite athletes are exposed to a variety of environmental factors and many others elements during their training. Swimmers are less exposed to injuries caused by direct contact with
dangerous surfaces, other competitors, or large objects than other athletes. However, they are constantly exposed to the effects of swimming pool water and substances contained therein.

Li and colleagues studied the direct influence of chlorinated water on the body of swimmers. Interestingly, they discovered that the eyes and skin, which are directly exposed to such water, are less irritated than the lungs (Li et al. 2015). Among all internal organs of the human body, the liver, spleen, lungs, and kidneys are the most probable targets of disinfection by-products (DBPs). Long skin exposure to the reactions between organic and inorganic matter occurring in the water with chemical treatment agents used for the water disinfection process may cause various skin problems.

Skin is the largest organ of the human body. It has a complex structure and consists of three layers: epidermis, dermis, and subcutaneous tissue. The skin performs many functions, but for an athlete who stays in the water for several hours daily, the protective function is vital. The skin plays the role of a barrier and protects against infection caused by bacteria, fungi, and viruses; as well as mechanical, physical, and chemical factors, and light radiation. The skin also provides constant conditions for the internal environment of the human organism (homeostasis).

The hydrolipid film composed of a mixture of sebum, sweat and lipids takes the form of a water-in-oil (W/O) emulsion and creates the uppermost protective layer of the epidermis. It reduces transepidermal water loss (TEWL) and protects against water loss from deeper layers of the skin. The proper quantitative and qualitative composition of the protective layer defends the body against fluctuations in temperature, the penetration of potentially harmful substances, and the colonization of pathological bacteria. Additionally, the condition of the epidermal barrier (hydrolipid film) guarantees a healthy appearance of the skin and its proper functioning.

Sebum is a natural secretion produced to lubricate the skin and hair, secreted by the sebaceous gland in most mammals. It is a mixture of epithelial lipids. Sebum is composed of free fatty acids (5%), glycerides (50%), wax (20%), squalene (10%), other hydrocarbons (5%), cholesterol esters (4%), other sterols (1%), and other substances (4%).

Skin parameters are measured by precise devices which are certified for medical use and give results with an accuracy of 2 or 3 decimal places. The most frequently examined skin parameters are skin color (Mexameter), hydration (Corneometer, Tewameter), pH (pH meter), sebum level (Sebumeter), and elasticity and flexibility (Cutometer). These parameters and their variability due to various physical and chemical factors, drugs, and combined therapies have become an important element of new trends in creating drugs, cosmetics, perfumes, and household chemical compounds.

The importance of the acidic character of the skin was discovered by Heussa in 1892. As late as 1928, Schade and Marchionini published their report on skin pH, describing precisely all of the biophysical methods used during their studies. The
acidic nature of skin pH was interpreted as being due to impregnation of the horny layer with acidic constituents or components of eccrine sweat. Potentiometric measurements revealed skin pH values between 4.2 and 5.6. Since the beginning of the 1950s, for skin pH measurements, the flat glass electrode which enabled precise and non-invasive readings during examinations was used. (Schmid-Wendtner and Korting 2006) Today, pH is defined as the negative logarithm of the concentration of free hydrogen ions in aqueous solution. The neutral point is set at 7 and the maximum values of the acidic and alkaline solution ranges are 0–7 and 7–14, respectively.

Both passive and active factors are thought to be based on the proton pump. Recently, many studies on changes of pH in the deeper layers of the stratum corneum of the skin as well as the influence of physiological pumps and exogenous factors pathologically affecting human organism have been published. Accordingly, new interpretations for the planning and management of the treatment of dermatologic diseases have been created.

The TEWL measurement aims to assess hydration of the human skin, or more precisely, the state of the barrier protecting the skin against water loss. The advantage of TEWL measurement is the reproducibility of results – i.e. we can expect similar results in various people having similar skin condition. This method allows for non-invasive examination of the hydrolipid barrier and its level of permeability in terms of water evaporation (semi-permeability). The result is presented in a numerical form.

The aim of the present study was to evaluate the effect of the long-term contact of swimmers’ skin with swimming pool water. An additional goal was to assess whether changes of these skin parameters caused by exposure to swimming pool water are dependent on sex due to differences in skin structure between men and women. Selected skin parameters such as skin pH, sebum level, and TEWL were assessed. When altered, this may lead to impairment of human body homeostasis.

**MATERIAL AND METHODS**

The study included 32 swimmers and synchronized swimmers aged from 15 to 26 (mean age 21 ± 1). All swimmers were members of the National Team and Lower Silesian Macro Region Team. During the experiment, skin parameters such as hydration, sebum level, and skin pH were measured on the back, in the area of the left shoulder blade. The measurements were taken at baseline before training (physiological condition) and after 120-minute standard training in swimming pool water. The measurement tools used included the Korneometr, Tewameter® Sebumeter, and Skin-pH-Meter® PH 905 (Courage Khazaka, Cologne, Germany).

The pH meter Skin-pH-Meter® allows measurement of the pH level of the skin surface. The examination must be carried out in controlled conditions to ensure reliability and clinical application. The temperature and humidity in the examination room were kept constant (fluctuations < 1.5°C). The relative air humidity was 30%. Before measurement, the subjects remained in the same room for about half an hour to stabilize the superficial temperature of the body and humidity level.

The Sebumeter® measures the sebum content of the skin. The method of measurement is based on grease spot photometry. The sensing element is a special tape that becomes transparent after contact with sebum. The photometric method measu-
asures the degree of the tape’s transparency. A special foil Sebu-Fix® absorbs greasy substances from the skin. Dedicated software calculates the level of sebum and displays the results as a percentage. The range from 0 to 20% indicates dry skin with a tendency towards oily skin; ca. 25% constitutes a normal value; from 30 to 100% indicates a tendency to oily skin and oily skin.

Hydration is an important element of the condition of the skin. TEWL measurement indicates the amount of evaporated water in grams from one square meter of the skin surface area in one hour. The unit of measurement is g*m²*h. Measurement of TEWL allows for assessment of the barrier protecting deeper layers of the skin from the water loss. No direct evaluation method of skin condition exists; therefore, it can be estimated by measuring water evaporation from the skin. A healthy epidermis transmits only small amounts of water resulting in smaller values of the TEWL than those observed in the case of dry skin or skin affected by certain diseases. In healthy skin, evaporation ranges usually from 5 to 50 [g*m²*h]. Significant sweating influences the result of measurement, therefore a rest before and after measurement must be provided. Additionally, prolonged examination also promotes sweating. The maximal time of measurement should not exceed 10 minutes.

Statistical analysis was based on calculation of means and standard deviation. The differences between results were regarded as significant in the cases where p was lower than 0.05. Statistical analysis was conducted with the R Project for Statistical Computing v. 3.2.2.

RESULTS

The results showed that the level of baseline physiological pH of the skin differed by 0.48 units between the sexes, while after 120-minute training, the difference diminished and was only 0.18.

TABLE 1. Comparison of skin pH, sebum level, TEWL between men and women (Student’s t-test for independent samples)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women (mean)</th>
<th>Men (mean)</th>
<th>P value</th>
<th>Women (standard deviation)</th>
<th>Men (standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline pH</td>
<td>5.64</td>
<td>5.16</td>
<td>0.00*</td>
<td>0.30</td>
<td>0.41</td>
</tr>
<tr>
<td>pH after 120-min training</td>
<td>6.61</td>
<td>6.42</td>
<td>0.14</td>
<td>0.27</td>
<td>0.41</td>
</tr>
<tr>
<td>Baseline sebum level</td>
<td>18.16</td>
<td>17.77</td>
<td>0.63</td>
<td>2.27</td>
<td>2.09</td>
</tr>
<tr>
<td>Sebum level after 120-min training</td>
<td>17.26</td>
<td>17.15</td>
<td>0.86</td>
<td>1.79</td>
<td>1.72</td>
</tr>
<tr>
<td>TEWL</td>
<td>10.08</td>
<td>8.69</td>
<td>0.01*</td>
<td>1.06</td>
<td>1.64</td>
</tr>
<tr>
<td>TEWL after 120-min training</td>
<td>14.33</td>
<td>14.51</td>
<td>0.58</td>
<td>0.96</td>
<td>0.81</td>
</tr>
</tbody>
</table>

* statistically significant differences between parameters before and after the training at a significance level lower than 0.05
Significant differences in TEWL between baseline and after-training values were observed in both women (4.24) and men (5.82). There was also a significant difference between men and women at the baseline. This discrepancy can be explained by differences in the skin structure between men and women. (Burgdorf et al. 2011).

**TABLE 2. Comparison of skin pH, sebum level, TEWL before and after the training in women (Student’s t-test for dependent samples)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Number</th>
<th>Difference</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline pH</td>
<td>5.64</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH after 120-min training</td>
<td>6.61</td>
<td>0.27</td>
<td>19</td>
<td>−0.97</td>
<td>0.00*</td>
</tr>
<tr>
<td>Baseline sebum level</td>
<td>18.16</td>
<td>2.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sebum level after 120-min training</td>
<td>17.26</td>
<td>1.79</td>
<td>19</td>
<td>0.89</td>
<td>0.00*</td>
</tr>
<tr>
<td>Baseline TEWL</td>
<td>10.08</td>
<td>1.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEWL after 120-min training</td>
<td>14.33</td>
<td>0.96</td>
<td>19</td>
<td>−4.25</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

* statistically significant differences between parameters before and after the training at a significance level lower than 0.05

The results indicate statistically significant changes in all examined parameters for the women, before and after training in the swimming pool.

**TABLE 3. Comparison of skin pH, sebum level, TEWL before and after training in men (Student’s t-test for dependent samples)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Number</th>
<th>Difference</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline pH</td>
<td>5.16</td>
<td>0.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH after 120-min training</td>
<td>6.42</td>
<td>0.41</td>
<td>13</td>
<td>−1.27</td>
<td>0.00*</td>
</tr>
<tr>
<td>Baseline sebum level</td>
<td>17.77</td>
<td>2.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sebum level after 120-min training</td>
<td>17.15</td>
<td>1.72</td>
<td>13</td>
<td>0.62</td>
<td>0.01*</td>
</tr>
<tr>
<td>Baseline TEWL</td>
<td>8.69</td>
<td>1.64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEWL after 120-min training</td>
<td>14.51</td>
<td>0.81</td>
<td>13</td>
<td>−5.82</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

* statistically significant differences between parameters before and after the training at a significance level lower than 0.05

The condition of the skin changed for all parameters during the two-hour training period compared to physiological conditions regardless of sex. At the end of the training, sebum level changed to the detriment of the athlete and pH of his skin becomes more alkaline than at baseline.
Values of pH in women and men differed significantly before training. They increased significantly after 120-minute training for both men and women, but differences between women and men after training were not statistically significant.

The differences in sebum level between women and men were insignificant before training. The sebum level decreased significantly for both men and women after training. Sex did not differentiate the level of sebum.
The TEWL values were different in women and men before training. After the 120-minute training, the TEWL values increased indicating transepidermal water loss resulting in secondary dehydration, and the differences between the sexes disappeared.

**DISCUSSION**

A characteristic feature of all forms of competitive sport is their potential to produce pathologic changes in various organs, including the skin (Rodney et al. 2000). Studies of the factors affecting the variability of skin parameters revealed that from birth, the skin is subjected to the process of adaptation and maturation. On the other hand, there is a group of irritants (chlorinated water therein), which may permanently affect the condition of the skin and contribute to the development of skin diseases (Jungersted et al. 2010).

Formation of the epidermal barrier involves several pH-dependent enzymes, especially with respect to its lipophilic components. These hydrolyzing enzymes include glucocerebrosidase, sphingomyelinase, phosphatases, and phospholipases. An environment with a pH of 5.6 creates the best conditions for the synthesis of ceramides; on the surface of the stratum granulosum, there is a release of acid hydrolases into the extracellular space by differentiated keratinocytes. (Schmid-Wendtner and Korting 2006).

The role of an acidic environment as a regulating factor in the stratum corneum homeostasis was studied by Schmid-Wendtner and Korting. They proved that this acidic milieu is crucial for the integrity of the barrier function, from normal maturation of the stratum corneum through to desquamation. The increased (alkaline) pH of the skin may affect the level of lipid enzymatic processes, and in turn, impaired lipid metabolism might contribute to atopic dermatitis. Moreover, changes in the skin pH create a favorable environment for the growth of pathogenic bacteria, especially *Staphylococcus aureus*. (Schmid-Wendtner and Korting 2006).

The author of this paper would like to draw attention to the diminishing differences in the level of the skin pH between women and men after the 120-minute training period in chlorinated water. This change is unnatural because the acidic

![FIGURE 3. Comparison of TEWL before and after training in both sexes](image-url)
environment becomes alkaline. It is therefore necessary to use soaps and body-care preparations with the appropriate pH level in order to decrease altered skin pH after training in the swimming pool, even by subjects having healthy skin. Proper skin care helps to prevent fungal infections or even infection with rotavirus. (Baran et al. 1992)

The sensation of itching and skin tightness are very common discomforts appearing in people practicing swimming in chlorinated, swimming pool water. Gardinier and colleagues examined a group of volunteers who swam for one hour daily. Researchers examined their skin parameters such as skin elasticity, TEWL, skin temperature, skin pH, and sebum level. After one-hour training in swimming pool water, biophysical values showed significant changes for all tested skin parameters: skin pH and TEWL increased, while elasticity and sebum level decreased. The biophysical parameters returned to baseline physiological values after 24 hours following the training in the water. Researchers emphasized the importance of their outcomes indicating that even recreational swimming for an hour daily leads to significant changes in the skin surface of healthy volunteers (Gardinier et al. 2009). The results of Gardinier’s and his colleagues’ study are in line with the results presented here. This author comes to a similar conclusion.

Skin structure differs between men and women and the outcomes obtained here reflect those differences. The skin in women has a thinner epidermis, which consists of 14–20 layers, while in men the epidermis is considerably thicker – about 30 layers. Men have a more vascularized dermis, especially in the area of the cheek bones. Male sebaceous glands responsible for the production of sebum are larger, more active, and more numerous than those in women. The present study showed that differences in skin parameters (skin pH, TEWL, and sebum level) between the sexes diminish after the 120-minute training period in the swimming pool water. Unfortunately, there is no explanation of this phenomenon in the literature.

After having examined the parameters of the skin in swimmers, attention should be paid to the very important aspect of psychodermatology. As discussed above, changes in skin parameters such as skin pH, sebum level, and TEWL lead to impairment of human homeostasis. Long-term exposure to harmful factors (including swimming pool water) provokes development of various dermatoses, fungal infections, and even secondary bacterial superinfections. Pathological conditions and skin defects on the exposed parts of the body such as the face, neck, cleavage, back, and limbs create an esthetic problem. “There is no doubt that there is a link between dermatologic diseases and the psyche. This phenomenon of mutual interaction requires that modern medicine must offer holistic treatment for humans” (Lipczyński 2015)

When studying competitive swimming, attention should also be paid to the aesthetic appearance of the body of the athlete.

CONCLUSIONS

All examined skin parameters changed to the detriment of the athlete. Skin pH increased towards more alkaline, sebum level decreased, and TEWL increased.

The biophysical parameters of the skin differed between the sexes.
After the 120-minute training period in the swimming pool water, differences in skin parameters between men and women diminished.

Application of specialized body-care preparations in order to reduce fluctuations in these skin parameters may accelerate the return to homeostasis in competitive swimmers.

The study conducted does not explain clearly whether the difference in outcomes between the baseline and after the 120-minute training period in the water results from the aggressive environment, the physical effort, or the interaction of these two factors.

REFERENCES


The influence of ageing on the activity of the autonomic nervous system in swimmers

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³ Department of Sports Medicine and Human Nutrition, University School of Physical Education in Cracow, Poland

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ABSTRACT

Introduction: Regular endurance-type physical exercise exerts a positive effect on the capacity and endurance of the body and the activity of the autonomic nervous system (ANS). In contrast, the exercise loads used in professional sports for extended periods of time may lead to significant functional impairment of all tissues and organs, including ANS. The study comprised of a group of 27 swimmers, divided into two sub-groups: A and B. The first group of swimmers contained 9 young men aged 19–24 (age 21.4 ± 1.9 years). Into the second group 18 swimmers were qualified. The mean age of those swimmers was 42.7 ± 8.9 years. Moreover, in the control group 28 healthy men who lead a normal life were qualified. We have observed that the R-R intervals (mean duration of cardiac cycle) in swimmers were longer than in healthy volunteers. In healthy volunteers we have observed a reduction in the R-R interval, accelerated HR, which also occurred with age. In swimmers we have observed that the R-R interval was slightly shorter with age. The results of our study indicate that long-term physical training is reflected in greater heart rate variability.

Key words: autonomic nervous system, physical exercise, heart rate variability, swimmers

INTRODUCTION

It is commonly believed that moderate and regular endurance-type physical exercise exerts a positive impact on the capacity and endurance of the body, as well as on the activity of the autonomous nervous system (ANS). A standard ANS reaction to moderate physical exercise is a decrease in tension of the vagus nerve, a component of the parasympathetic nervous system, and consequently, an increase in activity of the sympathetic component. After prolonged or intense physical effort is reduced, the activity of the parasympathetic nervous system is rapidly resumed and regains its initial state of stable balance. The occurrence of this autonomous reaction was observed both as a reaction to one-time endurance-type physical exercise and in studies involving many months of endurance-type physical exercise (Daniłowicz-Szymanowicz et al. 2011; Raczac et al. 2005; Vinet et al. 2005).
Alterations in the ANS activity in the ageing process have been described in the professional literature. Numerous studies indicate a decrease in the activity of both the sympathetic and parasympathetic nervous systems (Raczak et al. 2005). A preponderance of tension in the sympathetic nervous system is observed in individuals over 50, which is indicated by LF ratios (low frequency power) exceeding HF ratios (high frequency power) (Piotrowicz 1995). However, ANS functioning in elderly individuals who have practiced endurance–type sports for many years has not been explored in detail.

Training load in competitive sports which demand efforts of increased duration and intensity can lead to significant disorders in functioning of all tissues and organs, and particularly to disorders of the ANS (Raczak et al. 2003). It has been proved that extremely intensive and long physical exercise performed by athletes leads to a permanent shift of the activity of the autonomic nervous system, from the dominance of the parasympathetic system to the dominance of the sympathetic system. These changes have been shown to be harmful to the organism (Leti and Bricout 2013). This phenomenon is observed in the course of the “overtraining syndrome”, which is often observed in professional athletes, but still frequently ignored by their coaches. Among other symptoms, this syndrome manifests itself by a loss of form and depressive mental changes, which are reflected by poorer results during a competition (Gawroński and Szyguła 2005; Foster and Lehman 2002; Sartor et al. 2013). Studies also show the changes in the values of HRV variables and the risk of infections in swimmers (Hellard et al. 2011).

The aim of each athlete is to reach the level of body adaptation to specific exercises enabling him/her to achieve optimal results. These objectives can be met by proper planning and execution of training, with the effectiveness of the latter being determined by the volume, intensity, and periodization of training stimulation as well as by the psychological profile of the athlete (Sartor et al. 2013, Rakowski 2008, Costas and Terry 2011).

Professional athletes, when achieving high-class championship results, are comprehensively monitored during their training process. The analysis includes the volume and structure of training load while the functional body capacity is controlled on an ongoing basis. This reduces the risk of unfavorable fatigue or overtraining that would impair the process of preparation for competition. However, as most previously published papers dealing with the problem only included master class athletes (Iellamo et al. 2002), studies involving sportspersons characterized by lower achievements are relatively scarce.

The number of athletes who compete at levels lower than master class is higher, which hinders their comprehensive observation. Usually, such athletes are subjected to standard medical examination twice a year, and the physiological and medical control of their training effects is limited. Consequently, the evaluation of the real status of their body systems at various stages of training cycle, including examination of the ANS and cardiovascular system, is incomplete.

This study is an attempt to demonstrate the influence of the endurance–type physical exercise regime held over the course of many years on the activity of the cardiac ANS. The measurement of HRV–heart rate variability was used to evaluate the cardiac ANS (Vinet et al. 2005).

The purpose of the study was to evaluate the impact of the swimming practice regime upheld over the course of many years on the HRV–heart rate variability.
MATERIAL AND METHODS

The analysis was conducted in a group consisting of males actively engaged in swimming. Twenty seven men aged between 19 and 63 were subjected to tests (mean age was 35.6 ± 12.3) and divided into two groups. Group A consisted of 9 athletes aged between 19 and 24 (mean age was 21.4 ± 1.9) who were competitive university level swimmers. Group B comprised 18 men aged between 34 and 63 (mean age was 42.7 ± 8.9) who practice swimming on a Masters team.

In both groups, no cases of arterial hypertension were diagnosed. In group A, the duration of the swimming training experience was between 8 and 13 years (average period: 10.5 ± 1.5), whereas in group B the duration of the swimming regime ranged between 10 and 30 years (average period: 19.6 ± 6.5).

The control group was made up of 28 healthy males leading regular lifestyle. They were divided into two subgroups of individuals whose age corresponded to the age of the athletes participating in the study. One subgroup consisted of 10 individuals aged from 22 to 24 (mean age was 22.4 ± 0.8), whereas the other subgroup comprised 18 individuals aged from 35 to 55 (mean age was 41 ± 5.8).

The examination was conducted during the morning hours, at least 12 hours after the last training session. The tests were carried out by a single researcher. The participating subjects consumed their last meal (light breakfast) at least 2 hours before the tests. A ten-minute electrocardiogram was recorded which measured the resting heart rate in all athletes subject to the study.

The measurement was preceded by twenty-minute relaxation in a supine position, the purpose of which was to stabilize the activity of the cardiovascular system and ANS. Resting electrocardiograms and those obtained during the DBT (deep breathing test) were recorded with a three-channel digital recorder AsPEKT 700, registering electrocardiographic signaling without compression on PCMCIA semiconductor memory cards.

Temporal and spectral analyses were conducted using the fast Fourier transformation algorithm. Temporal analysis indices were compared (mean value and standard deviation of the average R-R intervals [ms], as well as spectral analysis (spectral power [ms²] with regards to low [0.05–0.15 Hz] frequencies and high [0.15–0.4 Hz] frequencies.

Student’s t-test was used to analyze the data. The significance level was assumed p < 0.05. The protocol of the study was approved by the Local Bioethical Committee of the Jagiellonian University, Approval No KBET/26/B/2012. The subjects who qualified for the study received detailed information regarding the details and objectives of the study, and gave their informed written consent to participate in the study.

RESULTS

A comparison between the lengths of the R-R intervals in swimmers and the controls proved that they were markedly longer in individuals who engage in endurance-type physical training (p < 0.05). This regularity was observed in both age categories. In healthy individuals who do not participate regularly in sports, a shortened R-R interval was observed, i.e. an acceleration of the sinus rhythm.
accompanying the ageing process. In swimmers a slight reduction in the R-R interval (p > 0.05), progressing with age, was observed. Analogous to the length of the R-R interval, HR values demonstrating the number of R waves in a time domain were markedly lower in individuals participating in sports than in controls (p ≤ 0.05).

Comparison of time domain HRV indices in professional swimmers and in controls is presented in Tables 1 and 2.

**TABLE 1. Values of time domain HRV indices in young athletes and in control group**

<table>
<thead>
<tr>
<th></th>
<th>Mean R-R interval [ms]</th>
<th>Mean HR [sk. · min⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>970.8 ± 155.6</td>
<td>53.2 ± 9.1</td>
</tr>
<tr>
<td>Control group</td>
<td>747 ± 74.4</td>
<td>68.4 ± 8.3</td>
</tr>
<tr>
<td>T Test</td>
<td>p = 0.000004</td>
<td>p = 0.00003</td>
</tr>
</tbody>
</table>

**TABLE 2. Values of time domain HRV indices in older athletes and in control group**

<table>
<thead>
<tr>
<th></th>
<th>Mean R-R interval [ms]</th>
<th>Mean HR [sk. · min⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>955.8 ± 114.2</td>
<td>61.0 ± 9.3</td>
</tr>
<tr>
<td>Control group</td>
<td>842.6 ± 85.5</td>
<td>67.2 ± 6.5</td>
</tr>
<tr>
<td>T Test</td>
<td>p = 0.007</td>
<td>p = 0.05</td>
</tr>
</tbody>
</table>

An evaluation of spectral analysis indices in athletes revealed there were differences in comparison to the control groups. In young healthy individuals not engaged in sports, a slight dominancy of the sympathetic nervous system activity was observed (LF/HF = 1 ± 0.3). In swimmers belonging to the comparative group, a pronounced prevalence of the parasympathetic nervous system activity was observed (LF/HF = 0.9 ± 0.2). The difference was not significant in statistical terms (p > 0.05). Moreover, this group demonstrated a lower LF value (p > 0.05) and a higher HF value (p > 0.05) than that represented by the control group.

In older individuals who do not practice any sports discipline, a slight dominancy of the sympathetic nervous system was observed (LF/HF = 1.13 ± 0.4). Furthermore, lower spectral analysis indices as compared to the young individuals were documented (p < 0.05). In group B, lower LF indices values (p > 0.05) and HF indices values (p < 0.05) as well as higher LF/HF ratios (p < 0.05) were documented than those in group A. A comparison of spectral analysis HRV indices in athletes and in control groups is presented in Tables 3 and 4.

**TABLE 3. Spectral analysis indices in young athletes and in control group.**

<table>
<thead>
<tr>
<th></th>
<th>LF [ms²]</th>
<th>HF [ms²]</th>
<th>LF/HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>614 ± 361.5</td>
<td>799.8 ± 641.7</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>Control group</td>
<td>454.2 ± 133.1</td>
<td>520.5 ± 270.1</td>
<td>1 ± 0.3</td>
</tr>
<tr>
<td>T Test</td>
<td>p = 0.47</td>
<td>p = 0.36</td>
<td>p = 0.37</td>
</tr>
</tbody>
</table>
TABLE 4. Spectral analysis indices in older athletes and in control group.

<table>
<thead>
<tr>
<th></th>
<th>LF [ms²]</th>
<th>HF [ms²]</th>
<th>LF/HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>515.2 ± 155.8</td>
<td>462.4 ± 214.1</td>
<td>1.22 ± 0.3</td>
</tr>
<tr>
<td>Control group</td>
<td>386.3 ± 196.1</td>
<td>395 ± 302</td>
<td>1.13 ± 0.4</td>
</tr>
<tr>
<td>T Test</td>
<td>p = 0.01</td>
<td>p = 0.13</td>
<td>p = 0.53</td>
</tr>
</tbody>
</table>

**DISCUSSION**

A slower sinus rhythm may frequently be observed in individuals engaged in physical activity (Banach et al. 2000). Bradycardia often occurs at rest, particularly during sleep. A twenty-four hour recording of the heart rate using a Holter monitor allows us to diagnose this condition. This phenomenon is widely discussed (Kiviniemi et al. 2014, Peçanha et al. 2014). Jansen-Urstad and co-authors (Jansen-Urstad et al. 1997) and Holly and co-authors (Holly et al. 1998) describe the occurrence of decreased frequency of heart rate to the value of fewer than 30 contractions per minute, and, at times, the appearance of atrioventricular blocks of the first and second degree. On the other hand, Szygula and co-authors (Szygula et al. 1997), based on the studies focusing on long distance runners, claim that the aforementioned disorders may be due to the heightened tension of the vagus nerve. Raczak (Raczak et al. 2005), Shin and co-authors (Shin et al. 1997) came to the same conclusions based on the research they conducted, which are in line with the studies conducted previously by Palak and co-authors (Palak et al. 2013) and with the present study. On the other hand, Dixon and co-authors (Dixon et al. 1992) describe an increase in HF index values in athletes participated in their studies, which indicates a heightened activity of the parasympathetic nervous system.

The occurrence of slower sinus rhythm in swimmers at rest were corroborated by the results of the trials conducted in this study. The tendency towards resting bradycardia was observed both in young swimmers (mean age 21.4 ± 1.9) and in older competitors (mean age 42.7 ± 8.9) who practice swimming actively. In both cases the differences between them and the corresponding control groups were statistically significant, although they were more pronounced in the younger individuals. The ageing process is characterized by the acceleration of the sinus rhythm and a consequent reduction in the R-R intervals. An analogous interdependency was observed in studies where the length of R-R intervals in athletes was compared and it was observed that, as their age progressed, the R-R intervals became reduced.

In our study, spectral analysis of HRV indices in swimmers included also indicated differences as compared to the control groups. In group A, we observed increased values of LF and HF indices as well as a reduction in the LF/HF ratio. The differences were not statistically significant. We observed decreased LF and HF values in elderly individuals who do not practice any sports discipline, as compared with young individuals. This is consistent with the results of previous research devoted to this topic, which quotes a physiological drop in the activity of the sympathetic nervous system in elderly individuals (Banach et al. 2000, Piotrowicz 1995).
In group B we observed higher LF (p < 0.05) and HF (p > 0.05) values in relation to the control group. However, these values were lower in comparison with younger swimmers (fig. 1) and did not indicate an increased activity of both ANS components due to many years of practicing sports. The statistically insignificant higher value of the LF/HF indicator does not directly indicate an increased activity of the sympathetic ANS component in elderly swimmers. With regards to the aforementioned findings, the results of the spectral analysis differ from the results obtained in identical measurements conducted a couple of years prior to this study, where the research group consisted of long–distance runners (Banach et al. 2000).

![Figure 1. HRV spectral analysis indices in younger (1) and older (2) swimmers](image)

**CONCLUSIONS**

The results obtained in this study confirm the assumption that the heart rate variability increases as a result of many years of participating in a physical training regime, because both the time domain indices and spectral analysis indices are higher in individuals who practice swimming as compared to individuals not engaged in sports. In our studies we observed that swimmers might be characterized by alterations in the autonomic nervous system activity, which consists mainly in increasing tension of the vagus nerves. Moreover, it has been shown that participation in the training regime for many years does not necessarily lead to an increased activity of the two components of the autonomic nervous system, which is characteristic of the specificity of the sport practiced by the persons subject to investigation. Therefore, the issues discussed in this paper require further research.

**REFERENCES**


